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Acute Effects of Exercise, Physically Active Video Game Play, and Inactive Video Game Play on Executive Functioning Skills in Children

A Dissertation submitted in partial satisfaction
of the requirements for the degree of

Doctor of Philosophy

in

Psychology

by

Rachel Marie Flynn

December 2013

Dissertation Committee:

Dr. Rebekah Richert, Chairperson
Dr. Chandra Reynolds
Dr. Tuppett Yates

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The Dissertation of Rachel Marie Flynn is approved:

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ABSTRACT OF THE DISSERTATION

Acute Effects of Exercise, Physically Active Video Game Play, and Inactive Video Game Play on Executive Functioning Skills in Children

by

Rachel Marie Flynn

Doctor of Philosophy, Graduate Program in Psychology
University of California, Riverside, December 2013
Dr. Rebekah Richert, Chairperson

Interactive media plays a central role in children's lives, however limited research has examined the impact of interactive media on children's cognitive development. Past research has suggested that exercise and video game play can improve executive functioning (EF) skills in both the short and long term. EF is a cluster of higher order cognitive skills, including selective attention and inhibition, which work together to coordinate higher order functioning. Interventions that improve EF are of interest based on the relationship between these skills and academic outcomes. Acute EF change in 155 7- to 12-year-olds was assessed after participation in a 20-minute activity session. The between-subjects design had four conditions: an exergame, sedentary video game, exercise and non-playing control. The varied level of physical activity and cognitive engagement were used to examine if it was the nature of the activity, such as physical movement, or cognitive engagement in an enjoyable activity that drove changes in EF.

An accelerometer and heart rate monitor were used to measure the intensity of energy expenditure, an expected mediator.

Three age-appropriate tasks (i.e. stroop, go/no-go and flanker) measured EF pre- and post-activity, however children had ceiling effects on both the stroop and go/no-go task. Children in all conditions improved from pre- to posttest on the flanker task as well as many of the sub trials on the flanker task; however, the exergame group improved more than the other three conditions from pre- to posttest on the two sub trials that required the highest level of inhibition skills. In addition, both the exergame and the sedentary video game groups had the largest changes from pre- to posttest on the block of the flanker task that required switching between rules. The findings revealed different patterns between accuracy and reaction times, which reflects differences in inhibitory processes. Energy expenditure was not a mediator of EF outcomes. Prior video game experience was related to EF change in that those with more video game experience were faster, but not necessarily more accurate. Gender differences reflected the same pattern where boys became faster, but not more accurate. Girls were more accurate, but not faster. Findings are discussed in terms implications for the relationship between exergame play and cognitive benefits for children.

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Chapter 1: Introduction

Overview

Interactive media has been rapidly changing as a technology since the invention of the first video game in the late 1970s (Green & Bavelier, 2007). These dynamic changes have made it difficult to study the impact of using these media, and there has been limited research with children (Blumberg, Altschuler, Almonte, & Mileaf, 2013; O'Keefe & Zehnder, 2004). Socio-cultural theories provide a foundation for understanding how children's cognitive development, specifically executive functioning (EF) skills, may benefit from interactive media, because these tools are integral to the social and cultural environment in which children learn (Gauvain, 2001).

Interactive media include video games, computer games, and handheld video games, as well as many Internet interactions. O'Keefe and Zehnder (2004) explained that in order to be considered interactive media, there must be a dialogue between the device and the user. Between the user and the medium, there must be a level of response, feedback and/or collaborative problem solving. Some researchers have suggested that scaffolding during an interactive media task comes from the interactivity of the game itself (Dipietro, Ferdig, Boyer, & Black, 2007). The user receives instant feedback and consequences during goal-directed behavior (Greenfield, 1996). The game, therefore, supports the learning experience in a way that allows children to perform at a level that challenges them, which can advance cognitive skills (Gauvain, 2001; Vygotsky, 1978). The goal of the dissertation research was to examine the relationship between EF and interactive media for children ages 7 to 12.

The interactive nature of these media leads to differences in the way children engage with the technology when compared to traditional toys or television. Video games are becoming more complex in both the players' ability to change the perspective and the interactivity of the device itself (O'Keefe & Zehnder, 2004). For example, many games are seen from the player's point-of-view; and Nintendo's motion-sensing Wii and Microsoft's Kinect map a player's physical actions onto the screen. O'Keefe and Zehnder argued games with 3-D points-of-view are changing the way children view and understand the world through differences of horizon, changes to navigational references, and self-representation visualization. These changes in the technology fit better with human perceptual systems than traditional 2-D points-of-view video games in which the user was an observer (Feng, Spence, & Pratt, 2007).

Interactive games require memory, attention, knowledge, and problem-solving, therefore they may be influencing the developmental trajectory for these cognitive functions (Greenfield, 1996). Because using interactive media requires visual perception, fine motor skills, and selective attention, the use of these cultural tools influences children's development of these cognitive skills (Gauvain, 2001; Vygotsky, 1978). Research has found that playing video games may improve cognitive strategy skills, cognitive flexibility, spatial relations, reasoning, and visual attention (Blumberg et al., 2013; Feng et al., 2007; Green & Bavelier, 2007; Powers, Brooks, Aldrich, Palladino & Alfieri, 2013), however most research has been conducted with adults and undergraduates.

The focus of the dissertation research is on understanding how engagement with different interactive media platforms impacts children's cognitive development, specifically their EF skills. Interventions that improve EF are of interest based on the relationship between these skills and academic outcomes (Best, Miller, & Jones, 2009). Previous research has found that exercise and video game play can improve cognitive skills in both the short and long term (See Review by Best, 2011). However, it is unclear if it is the nature of the activity or merely cognitive engagement that is driving the improvement (Anderson-Hanley et al., 2012; Best, 2011). In a review of research into exercise and EF, Best (2011) explained that research on exergames, physically active video games, might be the key to untangling the effects of exercise from general cognitive engagement, which regular video games provide.

This dissertation will first provide background information on children's use of interactive media, EF, and the relevant research on improving EF through exercise and video game play. Then the current study's methods, results and discussion are presented.

Trends in Interactive Media

Media use has become a central part of children's environment. According to Rideout, Foehr, and Roberts (2010), over 60% of children aged 8 to 18 play video games, whether console or handheld, each day. According to statistics published in 2010, 8- to 18–year-old children used media for an average of 5.5 hours daily, an hour more than in 2005 (Rideout et al., 2010). On average, children used the computer for 1.3 hours and played video games for 1.13 hours a day. In addition, mobile media has dramatically increased since 2005, such that 66% of youth have a cell phone and 76% have an iPod or

MP3 player. Children 8 to 18 years old spend an average of 17 minutes daily playing games on a cell phone, iPod or handheld game device. Rideout et al. (2010) found that 93% of households have a computer and 87% of households have a video game console. Video game play has increased significantly from 26 minutes in 1999 to 49 minutes in 2004 to 1.13 hours a day in 2009. Sixty-four percent of children ages 8 to 18 have used the computer daily for recreational purposes. This time is spent mostly on social networking sites (22 minutes), playing games (17 minutes), visiting video websites (15 minutes) or instant messaging (11 minutes).

In Rideout et al.'s (2010) findings, Black and Hispanic youth consumed media at a higher rate (13 hours daily) than their Caucasian peers (8.5 hours daily), even after controlling for age, parental education, and single family homes. Black and Hispanic youth spend 4 more hours watching television and 30 more minutes playing video games daily when compared to Caucasian youth. Very little research has examined if interactive media can be beneficial even though this activity is taking up much of children's lives. The current research investigated the ways exergames may be cognitively beneficial.

Executive Functioning Skills

Executive functioning as a construct. Executive functioning skills are a set of cognitive skills that include attention, inhibition, memory, rule use, and regulation of mental activity (Zelazo, Carter, Reznick, & Frye, 1997). Executive functioning skills work together to achieve higher-order functions, such as problem solving, strategy selection, goal-directed behavior, and planning (Best & Miller, 2010; Zelazo et. al, 1997). Executive functioning is typically understood as domain-general (Zelazo et al.,

1997; Zelazo & Frye, 1998), however according to Best and Miller the main challenge when researching EF is the lack of agreement on whether EF is one construct or a set of independent skills.

Zelazo, Qu, and Muller (2005) suggested EF is a hierarchial structure (i.e. construct) that organizes processes around a behavioral outcome, namely problem-solving, planning, and goal directed behavior. Executive functioning has been proposed to have four major components (Zoelch, Seitz, & Schumann-Hengsteler, 2005). The first component is selective attention and inhibition, which is the voluntary or involuntary control of a response verbal or physical. Best and Miller (2010) and Miyake et al. (2000) described inhibition as the foundation of executive functioning. Inhibition also includes directed forgetting and emotion control (Best et al., 2009). The second component is managing concurrent tasks and switching between tasks (i.e. task switching). Task switching is different from inhibition in that it requires coordinating between a set of rules or tasks, as opposed to a single response (Best & Miller, 2010). The third component is encoding and retrieving strategies for working memory, in other words manipulating information in short periods of time. The fourth component is the manipulation of information stored in long-term memory.

Measuring executive functioning. Zoelch et al. (2005) attempted to operationalize the development of these four components to explore if EF is a unitary construct or consists of nonunitary components. In order to isolate the EF processes used to perform specific tasks, the researchers tested children in five age groups on seven tasks that measured one or more EF processes. Each task and the components measured is

described below as much of the research reviewed uses these standard measures. There are several other widely-used EF tasks that Zoelch et al. did not use in their cross-sectional research. These tasks will also be reviewed below.

Tasks that measure encoding and retrieval strategies. Tasks that measure encoding and retrieval strategies also often require selective attention, inhibition, and task switching. The *Random Generation* task requires participants to generate a series of responses in a random order from the given set. The set may be numbers (e.g. 1-10), letters (e.g. A-H), or hand movements (e.g. tapping intervals) (Zoelch et al., 2005). Random generation has two testing components. First, responses become less random and more stereotyped (e.g. 1, 2, 3) the more possible responses there are. Second, the responses become less random as the speed of response expectation increases. This task requires short and long-term retrieval strategies, and on a lesser basis, selective attention and inhibition.

Another set of tasks that Zolech et al. (2005) compared were *Span Tasks,* which require increasingly challenging working memory while processing information. Span tasks have a variety of configurations, such as presenting an increasing number of items and asking the participant to remember a specified series. For example, participants are presented sentences and asked to recall the last word of the sentence; or participants are presented a random series of numbers or colors and asked to recall the series backwards. Simple versions of these tasks measure encoding of information and retrieval of stored information. Selective attention and inhibition may also be required.

The more complex span tasks also require task switching. *Mental Fusion,* another task adapted by Zoelch et al. (2005), measures long-term memory storage and manipulation. Participants are shown two different shapes for two seconds and ask to mentally fuse the shapes together to make a picture. *Trail Making* is a test of retrieval strategies and task switching typically used for pre-adolescents and older though adaptable for younger children. An example "trail" is to connect all the letters of the alphabet in order as quickly as possible.

Tasks that measure selective attention and inhibition. Some tasks only measure selective attention and inhibition, which makes it easier to isolate the reasons for errors. However, there are few tasks that only measure inhibition (Best & Miller, 2010). Zoelch et al. (2005) adapted the *Stroop Task* for use across various ages. The stroop task measures selective attention and inhibition. The standard version of this task has colored words written in congruent and incongruent colors. The goal is to read the color the word is written in but not the name of the color. For example, the word red may be written in the color blue and the participant's goal is say "blue." This task involves selectively attending to naming the color of the words and inhibiting naming the words.

The *Decision-Making Task,* also called *Go/No-Go,* requires selective attention and inhibition to a stimulus. Participants are given criterion to react to, such as children wearing blue shirts. Every time a picture of a child in a blue shirt is shown, participants react by saying "yes" or pushing the "go" key. When the child in the picture is wearing any other color shirt, children are to say "no" or not push a button. In some versions as the task progresses, increasing numbers of criteria are required.

The *Flanker Task* is a test of selective attention and inhibitory control that is easily modified for children (Hillman, Buck, Themanson, Pontifex, & Castelli, 2009). In this task, participants are presented with five congruent items (e.g. arrows all facing the same direction or the same letter) or five incongruent items (e.g. arrows facing opposite directions or different letters). Participants are asked to focus on the center item and press a button that matches. Both types of trials require selective attention of the center item, but the incongruent trial also requires inhibition of the periphery items. Children are faster and more accurate on congruent trials than incongruent trials (Hillman et al., 2009; Rueda, Fan, McCandliss, Halparin, et al, 2004). Diamond, Barnett, Thomas, and Munro (2007) adapted the flanker task to have both center focus trials as well as "reverse" trials where the participant focused on the outside items. These reverse focus trials add another element of cognition, in that children must switch between the center and outside focus rules. Rueda et al. (2004) found linear improvement for children ages 6 to 10 on accuracy and response time on the flanker task.

The *Dimensional Change Card Sort* (DCCS) is a response inhibition task typically used with preschool children (Best & Miller, 2010). Children are shown cards that have two different dimensions, color (red or blue) and shape (rabbit or boat). Children are asked to sort the card based on one dimension and then asked to switch to the other dimension. For example, the child must sort cards into two different piles by color and then is asked to switch rules to sort the cards by shape.

Tasks that require multiple processes. Many of the standard EF measurements are complex tasks that require all of the EF processes. The *Wisconsin Card Sorting Task*

(WCST) is a widely used EF task (Zelazo et al., 2005). The WCST requires several EF processes including encoding, selective attention, and working-memory retrieval strategies. The WCST measures rule use, problem representation, planning and problem-solving (Zelazo et al., 2005).

In this task, participants are given four reference cards. Participants are then shown a series of target cards which they are to sort into one of three categories: color of the card (red, blue, yellow or green), number on the card (1, 2, 3, 4), or shape on the card (circle, cross, square, triangle) (Miyake et al., 2000). Only one of these categories is correct for the target card, and the sorting criterion changes throughout the task. For example, children might first be asked to sort by color and then be asked to sort by number. Tasks that measure different aspects of EF can present challenges in interpreting errors (Best & Miller, 2010) as it is unclear if a certain aspect of EF or the entire construct that driving the result. These tasks can also be too challenging for young children to accomplish (Zelazo et al., 2005).

Development of executive functioning skills. Although EF skills begin to develop in infancy, children typically meet many of the developmental milestones related to EF during preschool. Performance on complex EF tasks has a linear trend from age 5 through adolescents (Zoelch et al., 2005). Executive functioning skills are thought to have an extended development because they are non-automatic complex processes that involve coordinating lower-level cognition (Best et al., 2009). Even though these skills continue to develop through childhood and adolescence, most research has focused on preschool children (Best & Miller, 2010; Zelazo et. al, 1997). In a recent review on the

development of EF, Best and Miller (2010) acknowledged that little is known about the mechanisms of change for each process throughout middle childhood, adolescence, or even adulthood.

Some researchers have suggested that the linear developmental trend is due to both increases in processing efficiency and attentional resources (Zoelch et al., 2005). Information-processing theory provides a framework for understanding this developmental trend in EF skills. According to information-processing theory, as children develop their cognitive resources increase through experience (Miller, 2002). The increased cognitive resources allow children to attend, acquire, and use information more efficiently (Miller, 2002). Through this increased efficiency, children develop a set of strategies for problem solving (Miller, 2002).

Zelazo and Frye (1998) presented a model for the development of EF skills, the Cognitive Complexity and Control (CCC) theory. According to the CCC theory, age-related development of EF is based on children's increased cognitive ability to reflect on rules, which then allows them to use more complex rules for problem-solving and planning. During the preschool years, children tend to make errors of perseveration on rule-based EF tasks (Zelazo et al., 1997). Perseveration errors take place after a rule switch, when children continue to respond based on the previous rule.

Very few cross-sectional research studies have been conducted on EF beyond the age of 5. In one cross-sectional study, Zelazo, Craik and Booth (2004) created two deductive rule tasks that were similar to the WCST and the DCCS. The new tasks reduced the complicated interpretation of the WCST while creating a task that was

suitable across a wide range of ages. The *Visually Cued Color-Shape Task* has participants sort cards based on four target cards, and the *Auditorily Cued Number-Numeral Task* has participants respond to auditory cues. The researchers found that 8- and 9-year-old children and elderly adults made more perseverative errors than young adults on the visual sort task (Zelazo et al., 2004). On the auditory sort task, the 8- and 9-year-old children made more perseverative errors than both adult groups. The two tasks were highly correlated for both adult groups, but not for the child group. This means that different processes were being used for the two tasks even though the researchers were attempting to equalize the tasks. Zelazo et al. (2004) postulated that children might have a hard time attending to auditory cues because these skills continue to develop until age 10.

Zoelch et al. (2005) conducted a cross-sectional study by adapting seven standard EF tasks to be easy enough for 5-year-olds to complete while challenging enough for older ages. This research compared 5-year-olds, 6-year-olds, 8-year-olds, 10-year-olds and young adults. There was an age effect for the random generation task, which requires retrieval strategies, attention, and inhibition. The largest increase occured between the 5-year-old group and all other age groups. However, the developmental trend was weak after 8-years-old. The youngest children had the most stereotyped responses attributed to their inability to inhibit these types of responses and, perhaps, limitations with remembering previously generated numbers (Zoelch et al., 2005).

A strong developmental trend was found for the adapted stroop task (Zoelch et al., 2005). The outcome on the stroop task was the time it took to name the incongruent-

colored objects. Five-year-olds took about 118 seconds, 6-year-olds took about 70 seconds, 8-year-olds took about 40 seconds, 10-year-olds took about 30 seconds, and adults took about 20 seconds (Zoelch et al., 2005). Simple and complex span tasks, as well as trailmaking and mental fusion tasks also had a general linear trend, but with significant gaps between 5- and 6-year-olds and 10-year-olds and adults (Zoelch et al., 2005). Task switching on the span tasks and trail-making task accounted for the difficulties 5-year-old children had with the tasks. Zoelch et al. speculated that the age differences on the mental fusion task were due to increased efficiency accessing long-term memory. Finally, in the decision-making task, 5-year-olds differed greatly from all other ages, which may mean the components of selective attention and inhibiton develop between 5 and 6 years of age.

Zoelch et al. (2005) analyzed the effect sizes of age-related differences across the tasks, however the magnitude of the effect varied by task. The researchers found that there were significant age gaps between 5-year-olds and all other groups, and 10-year-olds and adults. For example, both span tasks and the mental fusion task had a very large gap between children and adults, suggesting the development of the processes needed for these tasks continues through adolescence. The stroop task, trail-making task and decision-making task had a different developmental trend. These tasks had a trend that was much closer to linear, but with a large gap between the 5- and 6-year-old groups. The researchers speculated a developmental shift in inhibition between these two ages (Zoelch et al., 2005).

Other research has found that the flanker task, which measures selective attention and inhibition, has a linear trend up until 8 or 10-years-old when it reaches its adult-level performance (Hillman et al., 2009; Rueda et al., 2004). This research demonstrated that different components of EF had varying developmental trends as measured by different tasks that use multiple processes. This means that careful consideration of which components are of interest is required when selecting EF tasks to be measured across ages. In addition, research beyond the preschool years contributes to increased comprehension of the development of EF.

Challenges of measuring executive functioning. A limited number of studies have measured EF across age ranges (Zelazo et al., 2004). One of the challenges of measuring EF across ages is that different components take different developmental trajectories (Best & Miller, 2010; Zelazo et al., 2004). The research by Zoelch et al. (2005) comparing seven EF tasks elucidated the relationship between complexity and age trends. Five-year-old children do much worse on tasks that require multiple processes. There are several theories that may account for this effect. First, it may be that the different processes are not yet well coordinated for 5 year olds (Zelazo et al., 2004). Another theory is that one process might not be fully developed, which affects performance on the whole task (Zoelch et al., 2005). Finally, cognitive overload may occur when there are multiple processes involved (Zelazo & Frye, 1998). In addition, some tasks show performance increases all the way through adolescence into adulthood; but others are mostly accomplished by age 6 or 8 (Zelazo et al., 2004; Zoelch et al., 2005).

Another challenge of measuring EF across age ranges is that many tasks use multiple EF processes, which can make the tasks challenging and make interpretation of errors complicated. Some researchers believe that there are no standardized EF tasks that measure just one component (Zoelch et al., 2005). Research with older children, adolescents and adults often has used more complex tasks that measure multiple EF processes, such as the WCST (Best & Miller, 2010). Because older children can accomplish many of the simpler tasks, ceiling effects can blur interpretation (Zelazo et al., 2004). However, because complex tasks require multiple processes, errors may occur for a variety of reasons such as perseverance on the old rule, not attending or acting upon the new rule, or not having a cognitive capacity for the task demands (Zelazo et al., 2004; Zoelch et al., 2005).

Younger children are able to accomplish a wide range of EF tasks, however Zelazo et al. (2004) and Zoelch et al. (2005) recommended simplifying the working memory aspects of complex tasks. For example, it is better to use tasks with simple working memory aspects or no working memory aspects in conjunction with other EF processes (Zoelch et al., 2005). The goal is to reduce the cognitive load allowing the child to perform the task (Zelazo & Frye, 1998). Some researchers have been successful using the simpler DCCS with younger children, where errors are interpreted simply as perseverance on the old rule (Zelazo et al., 1997; Zelazo et al., 2004). As demonstrated by both Zoelch et al. (2005) and Zelazo et al. (2004), adapting complex tasks that use multiple processes for use with younger children was a successful way to demonstrate linear trends through adolescence.

A National Institutes of Health task force recently created a cognitive battery toolbox in order to address some of these developmental challenges (Weintraub, et al., 2013). The toolbox was designed to provide publically-available computerized measures that were appropriate for ages 3 to 85. Zelazo, Anderson, Richler, Wallner-Allen, Beaumont and Weintraub (2013) selected the DCCS and the flanker task as the measurement tools for EF. The validation study of 208 children showed a linear trend from ages 3 to 15, however the relationship with the EF measures and age was stronger for 3- to 6-year-olds than 8- to 15-year-olds. These tools had strong convergent validity with tools that measure the same constructs (i.e. Wechsler Preschool and Primary Scale of Intelligence, 3rd Edition, Delis–Kaplan Executive Function Scales Color-Word Interference Inhibition).

Outcomes of executive functioning. Executive functioning and potential influences of EF are of particular interest because of research that has linked EF skills with improved academic outcomes (Best et al., 2009). Blair and Razza (2007) found that higher EF skills were related to early math and reading abilities even after controlling for general intelligence. Bull, Espy and Weibe (2008) found that better EF skills in preschool predicted general learning at age 7. Executive functioning skills have also been linked to classroom behavior as they help students focus attention, follow directions and self-regulate (Riggs, Blair, & Greenberg, 2004). The relationship between school achievement and EF has been found at least through age 11 (Best et al., 2009).

Some researchers believe the relationship between EF and school-outcomes may be a direct effect, because working memory, inhibition and shifting are directly related to

remembering and learning academic subjects (Best et al., 2009). Others believe the relationship may be due to classroom behavior (Riggs et al., 2004). In this case, children with impaired EF are unable to behave in a non-disruptive way, which in turn interferes with their ability to learn in a classroom setting. School can also facilitate the development of EF because it is an environment that requires behavior inhibition and presents structured activities that require goal-directed planning (Best et al., 2009; Diamond & Lee, 2011). Because EF develops throughout childhood, these skills can be influenced by a wide range of experiences and are linked to a range of developmental outcomes. Therefore, interventions that improve EF skills have the potential to also improve academic outcomes. Diamond and Lee (2011) reviewed interventions that improved EF for children. A wide range of activities improved EF: computerized training, aerobic exercise, martial arts and mindfulness training, and classroom curriculum (Diamond & Lee, 2011). The researchers also found that children whose EF skills were lowest at baseline gained the most and that the most variability between intervention groups and control groups existed when the EF task was the most difficult (Diamond & Lee, 2011). Diamond (2012) stated that in order for EF interventions to be successful they must increase in difficulty and be activities in which children are motivated to participate.

Executive Functioning Skills and Exercise

Physical activity and exercise have been found to facilitate EF development or at least temporarily enhance the use of EF skills (Best, 2011). Physical activity is defined as being engaged in movement higher than normal physical demands (Chaddock,

Pontifex, Hillman, & Kramer, 2006). In contrast, exercise is planned and structured movements with the goal of physical fitness (Tomporowski, Lambourne, & Okumura, 2011). Researchers hypothesized that participation in physical activity, exercise and sports requires complex and flexible cognitive skills (Best, 2011). For example, when playing a sport or game children must work with their teammates toward a common goal while using strategies and rules. Even aerobic exercise requires adapting and modifying physical movements in a goal-directed manner. EF skills are required for this type of task planning and monitoring (Best, 2011).

Research has found a relationship between exercise and many aspects of cognition during childhood, including EF and academic performance (Hillman, Erickson, & Kramer, 2008). Researchers typically have measured the level of physical activity and exercise using accelerometers, pedometers, and exercise journals (Chaddock et al., 2011). According to a meta-analysis of 44 studies totaling 125 effect sizes, physical activity was related to improvements in cognition, including perceptual skills and academic outcomes, for children and adolescents ranging from 4 to 18 years old (Sibley & Etnier, 2003). Correlational research on large samples found that children ages 7 to 12 years old with higher aerobic fitness had better selective attention, response inhibition, working memory and effortful control when compared to their peers (Buck, Hillman & Castelli, 2008; Hillman, Castelli & Buck, 2005; Tomporowski, Lambourne, & Okumura, 2011). Previous empirical research has found that aerobic activity interventions improve EF skills for 7- to 11-year-olds both immediately after a 10- to 40-minute session of physical

activity (Ellemberg & St-Louis-Deschênes, 2010; Hillman et al., 2009) and after several weeks of physical activity (Davis, et al., 2007).

Many of the experimental studies have tested the acute effect of exercise on EF. In this case, cognitive skills are pretested and then measured again immediately upon completing different types of exercise (Best, 2011). Tomporowski (2003) reviewed 40 research studies since the 1970s on the acute effect of exercise on a wide range of adult cognitive functioning (e.g. perceptual skills, memory tasks, decision-making tasks, and inhibition tasks). The researcher explained that improvements in cognition, especially speed of processing, occur after acute bouts (20 to 60 minutes) of exercise of moderate intensity. Tomporowski, Davis, Miller and Naglieri (2008) reviewed studies examining exercise and cognition research with children. The researchers stated that type of exercise in the interventions made a difference for cognitive outcomes, such that multi-task aerobic-based interventions had more of an impact than solitary exercise, like running or cycling. Tomporowski et al. (2008) hypothesized that aerobic exercise requires more selective attention, inhibition and planning skills than non-aerobic exercise.

Recent research has also supported the benefits of short amounts of physical activity on cognitive functioning with children. In terms of EF, research has found children improve these skills after exercise interventions ranging from 10 minutes to 40 minutes (Best, 2011). Two relevant studies are reviewed that measured EF immediately before and after short bouts of exercise.

Using a within-subjects design with 9- and 10-year-old children, Hillman et al. (2009) found that after 20 minutes of walking on a treadmill, children improved on an

EF task more than after a resting session. Twenty children were pre- and posttested on a modified flanker task, which is a test of selective attention and inhibitory control. The procedure took place in a laboratory over two days with one 20-minute resting session and one 20-minute workout session. The order of the sessions was counterbalanced to control for order-effects. Participants wore a heart-rate monitor, and measurements were taken at baseline, during the session and after the session. During the resting session, children sat with their caregiver and were asked to have minimal conversation. The workout session was 20 minutes on a treadmill at 60% of their maximum heart rate. The researchers found that children significantly improved their response time on incongruent trials of the flanker task after the exercise session, but not after the resting session (Hillman et al., 2009). This means that participants improved from pre- to posttest on inhibitory skills after exercise regardless of if they participated in the exercise or resting session first.

Ellemberg and St. Louis-Deschênes (2010) used a between-subjects design to examine the effects of exercise on EF. Seven- to 10-year-old boys participated either in an exercise condition or sedentary condition. In the exercise condition, the participants cycled on a stationary bike at moderate intensity for 30 minutes. In the sedentary condition, the participants sat motionless on the bike. Participants in both conditions watched the same age-appropriate television show while they were on the bike. The participants in the exercise condition had a faster response time in a decision-making posttest when compared to the participants in the non-exercise condition (Ellemberg & Louis-Deschênes, 2010).

Davis et al. (2007) conducted a study over 15 weeks with 7- to 11-year-old overweight children to examine changes in EF skills. Participants were split into three conditions: control, low-duration exercise, and high-duration exercise. The low-duration exercise group participated in 20 minutes of physical activity five days a week. The high-duration exercise group participated in 40 minutes of the same physical activity, which included aerobics, running, active games, and sports. Children were pretested and posttested on the four scales of the Cognitive Assessment System (CAS), which has three subtests (Davis et al., 2007). There are four scales within the CAS. The first scale measures planning and is considered the EF task because it requires strategy processes, self-regulation and the manipulation of information. The second scale is attention, which requires selective attention and distraction elimination. The third scale is called simultaneous, which is a series of verbal and nonverbal content that requires solving spatial and logical questions. The fourth scale is successive, which requires the recall and order of visual and auditory information. The significant differences on this measure were found on the planning scale between the high-duration exercise group and the low-duration group and control group (Davis et al., 2007). There were no significant differences between the low-duration and control groups on any of the scales. These results support the idea that the nature of the exercise may link to planning skills as opposed to general cognition, though other studies have found a relationship with exercise and attention (Davis et al., 2007; Hillman et al., 2009).

There were several major differences between the Davis et al. (2007) study and the studies by Ellemberg and St. Louis-Deschênes (2010) and Hillman et al. (2009).

First, in the Davis et al. (2007) study the children were overweight. Second, the research took place in an applied setting with multiple children exercising at the same time. Both of these factors may play a role when considering the impact of duration of exercise. Childhood obesity has been linked with lower scores on intelligence tests and measures of visuospatial relations (Tomporowski et al., 2011), therefore it may take a longer duration of exercise to see improvements.

In summary, exercise is an experience that can facilitate cognition generally, and EF specifically. There are several factors across research studies that have led to an exercise intervention condition improving more on EF measures than the non-exercise control. First, the type of physical activity matters. Interventions that use aerobic-based exercise have a larger impact than solitary exercises such as running. Second, the duration and intensity of the exercise makes a difference. Although some research found that even 10 minutes of intense exercise increased cognitive outcomes from pre- to posttest, most successful studies used a minimum of 20 minutes for their intervention at a 60% maximum heart-rate intensity. Third, the EF task used pre - and posttest mattered. Research that used tasks that measured selective attention and inhibition have more consistent results across a variety of studies than other tasks (Tomporowski et al., 2008).

Although these studies have shown that exercise can improve EF skills, it is not clear if it is the gross motor skills or the cognitive engagement that is causing the change. The effect may not be due to the energy exertion, but instead may be due to participation in a goal-directed activity that requires selective attention, inhibition, and planning.

Therefore, any activity that engages children in this manner may show similar improvements.

Executive Functioning Skills and Interactive Media

Video games place demands on cognition by requiring flexibility, decision-making and goal-directed behavior in a novel environment (Greenfield, 1996). This level of engagement and immersion in interactive media warrants more research on the impact of video games and cognition (Greenfield, 1996). Using interactive media requires visual perception, fine motor skills, and attention (Green & Bavelier, 2007). Research with adults has found that playing video games may improve cognitive strategy skills, cognitive flexibility, reasoning, task switching, and visual attention (Feng et al., 2007; Green & Bavelier, 2007). Nouchi et al. (2013) conducted a video game training study with 32 adults for five weeks (5 days/week for 15 minutes/day). Participants improved from pre- to posttest on EF, working memory, and speed of processing tasks (Nouchi et al., 2013). In addition, Anguera et al. (2013) found that targeted video game training over four weeks improved cognitive control for older adults, 60 to 85 years old. These older adults outperformed untrained 20-year-old participants on all the cognitive tasks. In addition, the researchers found these improvements lasted over six months (Anguera et al., 2013). These findings support the use of video games as a tool to support cognition, specifically EF.

Greenfield (1996) explained children could learn a variety of cognitive skills from playing interactive video or computer games. For example, processing quickly-moving images requires attentional skills. Studies have found that children ages 8 to 11 can

develop visual attention, spatial relations, and mental rotation from playing video and computer games (Bottino, Ferlino, Ott, & Tavella, 2007; De Lisi & Wolford, 2002; Subrahmanyam & Greenfield, 1994). However, limited research has examined the links between video game play and EF (Blumberg et al., 2013).

De Lisi and Wolford (2002) examined the effects of computer video game play on 8- and 9-year-olds. The goal was to see if playing a game that promoted mental rotation would improve accuracy of mental rotation on a posttest paper version. Participants in the experimental condition played a game that required mental rotation (*Tetris*), whereas participants in the control condition played a game that did not require mental rotation (*Where in the USA Is Carmen Sandiego*). Children in the experimental group scored significantly higher on the mental rotation posttest than children in the control group, but the groups were not significantly different on the pretest. Boys outperformed girls on the pretest but not on the posttest. Children whose initial mental rotation performance was low improved after playing computer games that entailed mental rotation skills.

A similar study by Subrahmanyam and Greenfield (1994) found that fifth graders who played a game that required spatial skills outperformed control groups on posttest. In addition, children whose spatial skills were weakest in pretest showed the most improvement. Overall, boys performed better than girls though more girls began with low spatial skills.

Taken together this research shows children generally improve in spatial relations and mental rotations after an interactive media task, however there may be ceiling effects for children already high in spatial relations or mental rotations. These skills are related

to the research on EF because children who develop their spatial abilities are more apt to use alternative solution strategies, thereby improving their overall problem-solving skills (De Lisi & Wolford, 2002).

Computerized training studies using games designed specifically to improve EF skills for children have been effective in both short and long term (Best, 2011; Thorell, Lindqvist, Nutley, Bohlin, & Klingberg, 2009). Although these games are very controlled, they include some of the basic elements of all video games, such as the need to selectively attend to information, inhibit responses and make decisions in a fast-paced, changing environment. Thorell et al. (2009) conducted a training study with 65 4- to 5-year-olds. Four conditions were used: a working memory training group, an inhibition-training group, an active control that played non-training computer games, and a non-playing control group. The intervention took place daily for 15 minutes over 5 weeks. The training games had similar features to regular computer games in giving feedback and rewards, and adjusting difficulty based on performance.

Children were pre- and posttested on an adapted stroop task, a go/no-go task, the span scale of the WAIS, a word span task, an auditory task, and a block design task (Thorell et al., 2009). The working memory-training group outperformed all other conditions on the working memory tasks (i.e. span tasks). In addition, the working memory-training group had less omission errors on the auditory and a go/no-go task. The inhibition-training group did not improve significantly more than any condition on any measure. The researchers gave several explanations for the lack of effect in the inhibition training (Thorell et al., 2009). The lack of effect for the inhibition training group may

have occurred because inhibition was not the only process needed for the inhibition training tasks as working memory was also required. Second, children were trained on three different inhibition tasks; therefore children might not have spent enough time practicing inhibition. Limited research has been conducted on EF training programs, and little is known about the mechanisms that promote these skills or their transfer to other outcomes (Diamond, 2012; Thorell et al., 2009).

It is unclear if the improvements in cognition post-video game play are due to the nature of the video game or the fact that the player is cognitively engaged in an activity he or she enjoys (Green & Bavelier, 2007). The nature of the game may place specific cognitive demands, such as selective attention or inhibition, which engage EF skills. Very little research has examined the relationship between video game play and EF skills during childhood, when EF is still developing (Blumberg et al., 2013; Green & Bavelier, 2007).

Executive Functioning Skills and Exergames

Exergames, physically active video games, may have the most potential to impact EF skills based on the combination of exercise and video game play. Exergames include any video game that involves gross motor skills. There is a wide range of interactivity within the genre ranging from arm and hand movements (i.e. Wii Sports games such as boxing, bowling and tennis) to full body movements (i.e. Wii Fit, Wii Active, Microsoft Kinect, and Dance Dance Revolution). A 2011 report of game sales showed that six exergames were in the top 20 best-selling games since 1995 (Walton & Mazel, 2011).

Wii Sports was at the top of the list with 47 million copies sold in the United States and 77 million copies sold worldwide.

Limited research has found that when children play these physically active video games they expend energy at a moderate rate, as measured by accelerometer, heart-rate monitor, and expired breath analyzer (Daley, 2009). Since Wii Sports was released in 2006, empirical studies with small sample sizes have found a link between exergaming and physical activity. Research has found that active video games that use the entire body, such as Wii Fit, have a much higher energy expediture than sedentary video games or even mildly active video games such as Wii Sports (Graves, Stratton, & Ridgers, 2008; Graves, Ridgers, & Stratton, 2008; Lanningham-Foster, et al., 2006; Lanningham-Foster, Foster, McCrady, Jensen, Mitre, & Levine, 2009). In a systematic review of 18 studies on children and exergaming, Biddis and Irwin (2010) found that exergaming was equivelant to light-to- moderate physical activity. Biddis and Irwin (2010) stated that the energy expended during exergame play was higher than sedentary video games, but not high enough to improve physical fitness. A recent systematic review of 52 studies including children 3 to 17 years old found that active video games increased light-to-moderate intensity physical activity acutely (LeBlanc, Chaput, McFarlane et al., 2013).

Several studies have found that energy expenditure while playing full exergames is equivalent to moderate physical activity. Graf, Pratt, Hester, and Short (2009) compared playing *Dance Dance Revolution* (DDR) on Level 2 and boxing and bowling in Wii Sports to walking moderately on a treadmill. Twenty-three 10- to 13-year-old children visited the laboratory two times. In the first visit, all children played DDR for

30 minutes. In the second visit, all children boxed for 15 minutes and bowled for 15 minutes using Wii Sports and walked on a treadmill for 6 minutes. The researchers found that children's heart rates and energy expenditure, as measured by an expired breath analyzer and accelerometer, were similar or higher during DDR and boxing than while walking on the treadmill (Graf et al., 2009). Heart rates and energy expenditure were lowest during Wii Sports bowling, a game that uses limited arm movements. Bailey and McInnis (2011) compared energy expenditure for 39 children 9 to 13 years old while playing six exergames, including DDR. Baily and McInnis (2011) found that children expended energy at a rate 5.4 times above rest while playing DRR on the easisest level, which is higher than previous studies and higher than walking on a treadmill at a pace of three miles per hour.

A 12-week intervention study by Mhurchu, Jiang, Jull, Prapavessis, and Rodger (2008) examined engagement with active video games in order to test the effects on children's Body Mass Index (BMI). The intervention included 20 children ages 10 to 14, who owned a Nintendo Playstation but did not play active video games. Participants in the intervention group were given an active video game package and asked to substitute non-active video game play with these games. Participants in the control group did not receive the exergame intervention and were asked to maintain regular daily activities. Both the control and intervention group wore a motion-sensored accelerometer and kept a daily activity journal for four days in a row during the first, sixth and twelfth week. Physical activity, as measured by the accelerometer, was higher in the intervention group (Mhurchu et al., 2008).

The research on exergames has shown that these physically active video games are a viable source of physical activity for children, which means these games can be compared to exercise when used with the goal of promoting fitness. This increased interactivity has two potential benefits. The first is the physical activity required during game play. The second is the cognitive benefits of combined gross motor skills and the cognitive engagement of video game play. Therefore, exergames may be uniquely suited to promote EF (Anderson-Hanley, Tureck, & Schneiderman, 2011; Anderson-Hanley et al., 2012; Best 2011; Best, 2012; Best, 2013).

There have been few studies examining the influence of exergames on EF skills. Anderson-Hanley et al. (2012) found that exergaming provided cognitive benefits beyond the benefits of exercise in a sample of 102 older adults, average age 75. Participants were randomized to either an exergame cyber-cycling condition or a traditional stationary bike for a three-month study and tested on a battery of cognitive skills at baseline, and post-intervention. The researchers found that the EF improved more from pre- to posttest for the cyber-cycling condition compared to the traditional stationary bike condition (Anderson-Hanley et al., 2012).

Gao and Mandryk (2012) found that 10 minutes of exergame play had an acute positive impact on EF for adults. In the within-subjects design, 24 young adult participants completed three activities: an exergame, a sedentary video game and exercise on a treadmill. Gao and Mandryk (2012) found that after playing the exergame participants improved more on the stroop task then they did after the sedentary video game, however there were no differences between the acute effects of exergame play and

exercise. In a follow-up study, Gao and Mandryk (2012) had participants play an active and sedentary version of the same video game. The researchers found that after the active condition participants improved overall and had faster response times on the cognitive tasks, however there was not a difference between the two conditions for accuracy.

O'Leary, Pontifex, Scudder, Brown and Hillman, (2011) conducted a within-subjects study with young adults to examine the relationships between exercise, exergames, and video game play. The 36 participants each participated in five 20-minute activities: a book-reading resting session, a treadmill exercise session, Wii Fit exercise session, and a seated video game session. O'Leary et al. (2011) used the flanker task to measure selective attention and inhibition. Energy expenditure was measured using a heart-rate monitor. During the Wii Fit session, participants played three aerobic games: Hula-Hoop, Aerobic Step, and Rhythm Boxing. The video game session used Nintendo's MarioKart, a racing game that involves navigating a vehicle around a racetrack by moving the Wiimote like a steering wheel. This game requires arm movements. Participants read the campus newspaper during the resting session. There was not a main effect by condition on response accuracy or response time on congruent or incongruent tasks even though it was hypothesized that the participants in the exercise conditions would have increased accuracy and decreased response times (O'Leary, 2010). However, event-related potentials (ERP) for attentional resources increased more after the treadmill session than the two video game sessions. There are several factors that make interpretation of results difficult. First, each session had a varying level of physical

activity; however all sessions were cognitively engaging, including the resting session. Second, walking on a treadmill is a very different physical activity then aerobic-exercise. Third, the video games used were very different from each other. Taken together, it is difficult to disentangle the roles of physical activity and cognitive engagement.

In one study on exergames and EF with youth, adolescents who played a competitive exergame improved EF more than control groups (Staiano, Abraham, & Calvert, 2012). In this research, 54 15- to 19-year-old African American adolescents participated in a 10-week fitness intervention program. The majority of the children were overweight or obese and from a low-income neighborhood. There were three conditions: a competitive exergame group, a cooperative exergame group, and a control group, which played a non-active video game. Although there were no baseline conditions or sex differences in EF skills, there was a significant main effect of condition. Participants in the competitive exergame condition improved more than the coopertaive condition and the control. There were no significant differences between the adolescents in the cooperative and control conditions.

Another study on exergame and youth by Anderson-Hanley et al. (2011) compared cognitive improvements for participants in a DDR condition to participants in a video-watching control condition. Children in the study were age 10 to 18 and diagnosed with an autism spectrum disorder (ASD). After several practice sessions for game familiarization, children played DDR for a 20-minute session. Children's performance on the digits backwards task, a measure of EF, improved more for children in the exergame condition than the video-watching condition (Anderson-Hanley et al., 2011). However,

response time on the stroop task improved more for the control condition then the DDR condition (Anderson-Hanley et al., 2011). These findings may reflect difficulties with the multiple processes needed for the stroop task.

In a within-subjects study, Best (2012) found that 6- to 10-year-old children's level of physical activity, but not cognitive engagement, while playing an exergame was related to increased ability to resolve interference from conflicting stimuli on the flanker task. Each child participated in a 20-minute activity on four different occasions: a video watching session, a sedentary video game session, a jogging exergame session, and an aerobic obstacle course exergame session. Children reported being more engaged while playing the sedentary video game and the obstacle course exergame than while watching the video and playing the jogging exergame (Best, 2012). In addition, while watching the video game and playing the jogging exergame, children verbalized more frustration and enjoyment than while participating in the other two sessions (Best, 2012). However, EF skills only improved immediately after play for the two exergame conditions, suggesting exercise may have a stronger influence on EF than engagement and enjoyment while doing an activity.

In sum, the research on exergaming provided evidence that these technologies are a viable source of physical activity as measured by heart-rate monitors, breath analyzers, and accelerometers. However, some research suggests that the level of intensity while exergaming may vary, and sometimes may not be enough to improve aerobic fitness. Limited research has examined the impact of exergames on EF. Studies examining

exergaming and EF have shown mixed results. The studies with children indicate that exergaming may have an acute impact on EF depending on the EF assessment.

A factor that was not discussed by the reviewed studies was that the type of video game played in the study could be a factor confounding results. The study by Gao and Mandryk (2012) was the only study that controlled the video game across active and sedentary conditions. Best (2012), O'Leary et al. (2011) and Staiano et al. (2012) compared different video games across platforms (exergame vs. sedentary game). This means that different games were used in the different conditions. Video games have varying levels of feedback, competition, and visual-spatial graphics. If each of these factors is different in each condition, it can make interpretation of cognitive results difficult. For example, if the sedentary video game has more competitive aspects or is faster paced than the exergame the two games may be equally cognitively engaging. Therefore, it is hard to know if change in EF, or lack of change, by condition is due to playing a video game with competition or playing a video game with gross motor skills or playing any video game at all. The second video game factor that impacts the change in EF from pre- to posttest is the cognitive measure used. It is important to consider if the games played use the same EF skills that are being tested (Green & Bavelier, 2007). For example, the findings by Anderson-Hanley et al. (2011) were opposite depending on the measurement tool. The DDR group improved more than the control group on the digit backwards task, but did worse than control group on the stroop task. Additional research that controls for both of these video game factors is needed to fully understand

the relationships between exercise, exergames, and video games on cognition (Best, 2011; O'Leary et al., 2011).

Research Questions and Hypotheses

Research question 1. Do participants in the exergame condition have a significantly higher mean EF score after the intervention when compared to participants in the non-playing control, exercise, or sedentary video game condition? The first research question examines if changes in EF skills are significantly different based on condition (non-playing control vs. exercise vs. exergame vs. sedentary video game). This will test a main effect of condition on EF.

Hypothesis 1. The hypothesis is that children in the exergame condition (DDR) will demonstrate the greatest improvement in EF skills when compared to the sedentary video game condition and the exercise-only condition.

Research question 2. Does the intensity of the exercise influence changes in EF? The second research question explores if the mean change in EF are significantly different based on the intensity of exercise as measured by heart rate and accelerometer during exercise.

Hypothesis 2. The hypothesis is that EF skills will change the most for children who exert the most energy during exercise.

Research question 3. Does gender influence changes in EF? The third research question has three parts. First, are the changes in mean EF significantly different by gender (i.e. do males have a different mean change in EF than females)? Second, are there patterns of differences between mean changes in EF for condition by gender?

Third, does the influence of gender on change in EF depend on condition and intensity of exercise?

Hypothesis 3. The overall hypothesis is that gender has a unique contribution to changes in EF. The first hypothesis is that gender will moderate the change in EF skills, such that males will show the largest gains. The second hypothesis is that there will be a condition by gender interaction, such that female participants in both video game conditions will have lower gains in EF scores than all males and females in exercise conditions. The third hypothesis is that boys will exert more energy in the exercise and exergame condition than girls, creating a pattern of differences between mean change in EF score by gender for some conditions based on the level of intensity.

Chapter 2: Design and Methods

Four conditions (non-playing control, exercise, exergame, and sedentary video game) were used to test the effects of varying levels of interactivity. There were two conditions of interactivity on the same video game, which allowed for testing the impact of the medium on EF. There was also an exercise group to explore the relationship between physical activity and cognitive engagement through video games. The current study examined differences in EF immediately after game play as measured by pre- and posttest. This design was based on the findings that EF skills improved after acute bouts of exercise (Ellemberg & St-Louis-Deschênes, 2010; Hillman et al., 2009).

Participants

Power analyses constraining alpha to 0.05 revealed that to detect a moderate significant effect with 80% power, 140 participants, 35 per condition, were need. In total, 155 children ages were recruited from southern California to the Child Cognition Lab. Families were recruited through direct mailings, referrals from participating families, flyers posted around the University of California, Riverside and local establishments, and Craigslist.org. Participation required that all participants spoke English as the primary language in the home. Participants were compensated $15 for their participation. University of California, Riverside's Human Research Review Board approved all procedures and materials.

Of the 155 children, 6 children were excluded due to non-compliance on the EF tasks and two children did not complete the EF task due to experimenter or software error. In the remaining sample of 147, children's age ranged from 6.8 to 12.9 (M = 9.05

years, *SD* = 1.5 years; 48% female). The average Body Mass Index (BMI) was 19.92 (*SD* = 4.6).

In terms of participants' ethnicity, 31% were Caucasian, 18% were African American, 23% were Hispanic, 2% were Asian, 25% were multi-ethnic or biracial participants and 1% declined to answer. Participants' parents reported their level of education: 2% did not complete High School; 14.4% had a High School diploma or GED; 43% had some college; 16.2% had an Associates degree; 14.4% had Bachelor's degrees; and 10% had advanced degrees. In addition, parents reported their employment status: 35% of parents worked full-time; 20% worked part-time; 43% were homemakers, retired, unemployed, students or disabled; and 2% declined to answer the question. Average parent-reported annual household income was $50,682 (*SD* = 40,808), however 30% of parents declined to answer.

Preliminary analysis explored differences in demographics by condition (see Table 1 for descriptive information). A small sample (5%) of children had parents report physical activity or exercise limitations. Five children had asthma symptoms, and two children were reported as being out of shape. Nine parents reported that their children (6%) had Attention Deficit Disorder (ADD), and six of these children took medication. A one-way ANOVA revealed that there were no differences in age or BMI by condition (see Table 1). Chi-square analyses revealed there were no significant differences in gender, ethnicity, limitations to physical activity, or parent-reported ADD by condition. One-way ANOVA's revealed that there were no differences in annual income across conditions or ethnicities.

Table 1. *Means (and Standard Deviations) for Demographics by Condition.*

	Overall	Control	Exercise	Exergame	Sedentary Video Game	Statistical Test
	N = 147	N = 41	N = 36	N = 35	N = 35	
% Female	48%	54%	44%	49%	46%	$\chi^2(3, N=146) = .78$
Age	M = 9.05 SD = 1.49	M = 8.75 SD = 1.38	M = 8.99 SD = 1.47	M = 9.15 SD = 1.54	M = 9.39 SD = 1.57	$F(3, 143) = 1.24$
BMI	M = 19.91 SD = 4.66	M = 19.38 SD = 4.65	M = 21.10 SD = 5.39	M = 19.63 SD = 4.42	M = 19.64 SD = 3.96	$F(3, 143) = 1.05$
White African American, Hispanic/Latino, Biracial/Other	31% 18% 23% 39%	24% 20% 22% 39%	22% 19% 36% 22%	40% 14% 14% 28%	37% 17% 20% 26%	$\chi^2(3, N=147) = 7.51$
Limitations to Physical Activity	N = 7	N = 3	N = 1	N = 2	N = 1	$\chi^2(3, N=147) = 1.25$
Attention Deficit Disorder	N = 9	N = 2	N = 2	N = 4	N = 1	$\chi^2(3, N=145) = 2.60$

Note: † < .10, *p < .05, ** p < .001, *** p < .001

Materials

Nintendo Wii console and Dance Dance Revolution mat. The study used Nintendo's Dance Dance Revolution (DDR) mat, Wii controllers, and traditional video game controllers, all of which were played through Nintendo's Wii console. DDR is a video game played in conjunction with a motion sensored mat. The game is an exercise-based dance game that is based on controlled stepping movements. Players follow visual direction cues on screen repeating the corresponding actions on the mat. This game was selected, as at the time of study design DDR was the only exergame that could be played both with full-body movements and while seated using a hand-held controller. Graf et al. (2009) found that children's heart rates and energy expenditure, as measured by an expired breath analyzer and accelerometer, while playing DDR was similar to walking moderately on a treadmill. In addition, DDR has been used in a variety of physical activity studies and children enjoy the experience (see Biddis & Irwin, 2010). In the traditional sedentary video game condition, children were seated, held the controller in their hand and pressed the directional arrows on either side of the controller in time with the on-screen arrows.

Nintendo games. In the exergame condition and the sedentary video game condition, children played the same Nintendo's Dance Dance Hottest Party 2 game, which was released in 2008. In the exergame condition, DDR was played using a mat with four brightly colored squares with arrows (up, down, left, and right). The goal of the game was to step on the mat (or press the directional arrows) in the same sequence as the on-screen symbols, which is done in time to music. The tempo of the music varied

depending on the song, ranging from 90 to 160 beats per minute. Children completed a playlist of 12 preselected songs that ranged in difficulty, number of steps, beats per minute, and length (see Appendix A for playlist). Players were given accuracy scores based on the number of correctly timed steps.

The game was set in training mode so that all children could complete each song without failing, even if it was too difficult for them. The first song the participant completed was a training song that gave directions and explained how the game worked at a slow pace. The game gave a feedback score based on the participants timing of their steps or button pushing with the arrow on the screen: *Perfect* (5), *Great* (4), *Good* (3), *Almost* (2), *Boo* (1) and *No Attempt* (0). A game performance variable was created for each song. First, the number of times the child received each feedback score was multiplied by the coded value to yield a weighted score. For example, 10 perfect scores would be multiplied by five to get a weighted perfect score of 50. The weighted scores for each type of score were then summed together for a total weighted score (i.e., 50 Perfect + 30 Good + 6 Almost = total weighted score 86).

Next, the total weighted score was divided by the number of possible perfect scores for each song to create a percent correct variable. The percent correct scores were averaged across the entire session to give the overall game performance variable used in analysis. This variable accounted for if children played different numbers of songs due to experimental error. Individual length of songs played ranged from 1 minute 32 seconds to 1 minute and 48 seconds. The playlist length was 21 minutes and 47 seconds, and the amount of time a child played ranged from 15:12 to 21:48 (M = 21:08; SD = 1:54).

Variations in time were due to errors in song order, technical difficulties, or children wanting to stop playing. All children played the game on beginner level. The game was rated "E" for everyone.

The advantage of using DDR was that the exact same game could be played using the DDR mat or a traditional video game controller. Using the same game reduced variability on competition, feedback, visual-spatial perception (i.e. pace of game and user-point-of-view), and player enjoyment. At the time the study was designed, there were no other exergames on the commercial market that had a compatible traditional controller version. In addition, research found that aerobic-based games have more impact on EF skills than solitary exercise games like running or cycling (Tomporowski et al., 2008). The other exergames that had slightly comparable traditional controller equivelants were running games.

Heart rate and accelerometer. Physical activity monitors that measured heart rate and energy expenditure were used during the activity session for all conditions. Participants wore two wireless non-invasive monitors. The first is a Polar RS800 heart rate monitor, which monitors heart rate, and calories. The system includes a watch and a Polar WearLink transmitter with a 2.4 GHz disturbance-free transmission. Participants wore the transmitter on a cloth strap that goes around their chest and fastened with Velcro. The heart rate monitor transmits data to a watch that the researcher wore on their wrist to monitor the child throughout the session. The heart rate monitor was programmed to beep when the participant's heart rate was below 60% of their maximum heart rate. Research has shown that exercise intensity mediated EF, therefore effort was

made to keep participants at a moderate to high intensity (Hillman et al., 2009). In addition, participants wore a small accelerometer by Fitbit clipped to their waistband. The system was lightweight (.28 ounces) and used a 3-axis accelerometer to detect body motion. The Fitbit monitored number of steps, distance traveled, speed, and calories burned. Heart rate and energy expenditure were recorded throughout the session and downloaded from the monitors at the end of the session wirelessly to a computer.

Measures

Demographic Questionnaire and Interactive Media Questionnaire. All parents completed a demographic questionnaire about their income, education level, ethnic background, and employment status. For statistical analysis the ethnic categories *Multiple/Biracial*, *Asian* and *Other* were combined into one category, while the responses "I don't know" and declined to answer were treated as missing data. In addition, parents completed medical information for their child. These questions included, "Does your child have any health conditions that make physical activity or exercise difficult?" "Does your child have any limitations or restrictions when it comes to physical activity or exercise?" "Does your child have asthma, allergies, diabetes or ADD/ADHD?" Parents could respond with *Yes* (1) or *No* (0). If they replied *Yes*, they were prompted to answer if their child took medication, what type of medication, and the schedule of medication.

Children and parents completed a short media questionnaire regarding their attitudes about and exposure to interactive media. This questionnaire was based on a media survey that examined media use for children (Rideout, et al., 2010). Parents received the paper questionnaire to complete in the lab, and children completed the

survey as a one-on-one interview with the researcher or undergraduate research assistant. Parents answered a series of questions about how much time their child does each of the following: Play physically active video games? Play video games? Play handheld video games? Play video games on a cell phone?" They also answered a series of questions about how much time their child plays each of the following type of video game: "How often does your child play strategic life simulation video games, like Sims? Sports video games, like Wii Sports? Racing video games, like Mario Kart? Puzzle video games, like Tetris? Adventure quest video games, like Fable or World of Warcraft? First person shooter video games, like Call of Duty?"

Parents responded to both types of questions first by writing down the number of days their child participated and then choosing the category of amount of time they play a day: *Less than 30 minutes* (1), *30 minutes to an hour* (2), *1 to 1.5 hours* (3), *1.5 to 2 hours* (4), *2 to 2.5 hours* (5), *2.5 to 3 hours* (6), *3 to 3.5 hours* (7), *3.5 to 4 hours* (8), *4 to 4.5 hours* (9), and *more than 4.5 hours* (10). *Don't Know* was an option for all questions and was treated as missing data[1]. Total amount of time for each type of game was calculated. First, time was converted from a categorical number to the highest number of minutes in the category. For example, *30 minutes to an hour* was recoded to be 60 minutes. Second, the number of days played was multiplied by the number of minutes played for a total weekly video game play variable, that could range from 0 to 2,100 minutes.

[1] All video game experience variables were examined. There was inaccuracy in reporting of time on all of the subcategories of video game play. Therefore, the only variable used in analyses was total amount of video game play in a week.

Level of enjoyment. Participant's level of enjoyment during the activity was measured at the end of each activity session. Participants were asked, "How much did you like the activity you just did?" Response categories were: *A lot* (2), *A little* (1), *Neutral* (0), *Didn't like a little* (-1), *Really didn't like* (-2). After they responded, participants were then asked what they did or did not like about the activity.

Executive functioning measures. Three EF tasks, *Stroop Tasks*, *Flanker Task* and a *Go/No-Go Task*, were conducted in pre- and posttest. The stroop tasks were counterbalanced to reduce order effects. The tasks had a fun game-like structure that children enjoyed during the pilot studies. The EF tasks took 15 to 20 minutes for the researcher to administer depending on the children's performance on the task.

Stroop task. Stroop-like tasks have been successfully used with children to measure attention and inhibition; they select attention on one aspect while inhibiting another aspect (Demetriou, Spanoudis, & Christou, 2002). During these tasks, the researcher presented different kinds of cards (i.e. verbal and symbolic) with congruent and incongruent information. For example, children were asked to say the color the word is written in instead of the word that is written on the card (see Appendix E). Stroop tasks have high reliability (.73 to .93) and validity (MacLeod, 1991). The outcomes on these tasks were accuracy and response time in milliseconds, as measured from videotape. In each of the stroop tasks, there was a practice trial then 10 test trials; five of each type of card were shown in the sequence that Kochanska, Aksan, Prisco, and Adams (2008) used. See Appendix E for example cards and Appendix B for full protocol.

The first sets of stroop tasks were the day/night task and snow/grass task. These two tasks were counterbalanced in pre- and posttest. In the snow/grass task, children were shown a green square and a white square. Children were asked to identify the color of "grass" and the color of "snow" by pointing to the correct card. If the child identified each correctly the researcher said, "Now we are going to play a game with these pictures. This is how the game works. When I say grass, you point to the white square. When I say snow, you point to the green square. Let's practice." The researcher then conducted a practice round reinforcing correct responses and correcting incorrect responses by reminding them to point to the correct square. After the practice trial the researcher administered 10 test trials.

In the day/night task, children were shown a black card with a moon and stars, and a white card with a sun. Children were asked to point to the "day" card when the experimenter said "night" and to point to "night" card when the experimenter said "day". If the child identified each correctly the researcher said, "Now we are going to play a game with these pictures. This is how the game works. When I say day, you point to the night sky. When I say night, you point to the day sky. Let's practice." The researcher then conducted a practice round reinforcing correct responses and correcting incorrect responses by reminding them to point to the correct square. After the practice trial, the researcher administered 10 test trials.

The next set of stroop tasks were the two-dimension tasks based on Demetriou et al.'s (2002) procedure. There was a color word task and a shape task, each given in pre- and posttest. The orders of the tasks were counterbalanced in pre- and posttest.

For the color cards, the dimension was the color of the words, in which a color word (red or blue) was written in a congruent or incongruent color (green). The instruction for the color task was to say the color the word was written in. Participants were shown each type of congruent and incongruent card and asked what each word said. If the child could not read the word, then the task was not continued. Children were then asked what color the word was written in. If the child could not state the color then the task was not continued. If the child identified both the word and the color of each card correctly the researcher said, "Now we are going to play a game with these pictures. This is how the game works. When I hold a card you say the color the word is written in. So, when I hold up this card (word red written in red) you say the color the word is written in, red. When I hold up this card (word red written in green) you say the color the word is written in, green. Let's practice." The researcher then conducted a practice round reinforcing correct responses and correcting incorrect responses by reminding them to say the color the word was written in. After the practice trial, the researcher administered 10 test trials.

For the shape card task, the dimension is smaller or larger; shapes are made up of either congruent or incongruent small shapes. The instructions for the shape cards are to say the shape that the shape on the card is made up of. Participants were shown each shape card and asked what shape the larger shape was and what shape it was made up of. If the child could not identify the shapes the task was not continued. If the child identified both the larger and smaller shape of each card correctly the researcher said, "Now, we are going to play a game with these pictures. This is how the game works.

When I hold a card you say the shape that the larger shape is made up of. So, when I hold up this card (compatible: circle made of circles) you say the shape it is made up of, circle. When I hold up this card (incompatible: circle made of triangles), you say the shape it is made up of, triangle. Let's practice."

The outcomes on these tasks are accuracy on ten test trials and response time in milliseconds. The accuracy codes for all stroop tasks were *no response* (0), *incorrect response* (1), *incorrect response, but self corrects* (2), *correct response* (3). Each trial was coded for accuracy and then summed to create an accuracy score for each type of stroop task. The response time for each trial was coded from video and then averaged to create a reaction time variable for each type of stroop task.

Flanker task. A computerized *Flanker Task* by Diamond et al. (2007) was used (see Appendix E for example). The flanker task was selected because it was one of the most frequently used tasks in the research on exercise and EF (Best, 2011; Hillman et al., 2009). The task was run on an IBM computer using the software "Presentation" by Neurobehavioral Systems. The same flanker task was given in pre- and posttest. All instructions for the flanker task were written on the computer screen and read out loud by the researcher. First, children completed a practice test in order for them to learn which keys to press. In this task, they were told that they would play some games with two buttons. The researcher then demonstrated pressing the control key with their left hand and the enter key with their right hand. Children were instructed that when they saw the smiley face on the screen to press the button on the same side as fast as they could. The child had two practice rounds where the researcher reinforced correct responses. If

children press the wrong button in practice they were reminded of the rules and practiced again. Children then completed eight trials. Upon completion of the practice rounds the researcher explained that now they would play another game using those two buttons, the flanker fish task. Children were presented with five fish and asked to focus on different items depending on the trial block.

Block 1 had a single focus such that all the fish were blue. In the blue fish trials, children were asked to focus on the middle fish and press in the direction the middle fish was facing. The child was to press the enter key with their right hand for center items facing right and the control (ctrl) key with their left hand for middle items facing left. There was then a practice round that reinforced correct responses. If the child made more than two errors the computer reminded them of the rule, "to press in the direction of the middle fish." They then had to complete another practice round. The first trial of each block was dropped from analyses as intended by Diamond et al. (2007). There were 16 total Block 1 trials, eight right facing, and eight left facing middle fish. There were 10 incongruent trials, in which the flanking fish faced in the opposite direction; two congruent trials, where the flanking fish faced in the same direction as the middle fish; two no distracter trials, where the middle fish was alone; and two neutral trials, where the flanking fish faced up or down.

Block 2 was a single focus reverse task where all the fish were pink. Children were asked to focus on the four flanking fish and press the direction that the outside fish were facing. The child pressed the enter key with their right hand for outside items facing right and the control (ctrl) key with their left hand for outside items facing left.

There was a practice round that reinforced correct responses. If the child made more than two errors the computer reminded them of the rule and they did a second practice round. There were 16 total Block 2 trials, eight right facing and eight left facing outside fish. There were ten incongruent trials, where the middle fish faced in the opposite direction as the outside fish; two congruent trials, where the middle fish faced in the same direction as the outside fish; two no distracter trials, where there was not a middle fish present; and two neutral trials, where the middle fish faced up or down.

Block 3 was a rule switch task, where the trial blocks included both blue (middle focus) and pink (outside focus) fish. In Block 3 there were 44 trials split evenly between pink outside and blue middle fish and each hand (22 right presses and 22 left presses). There were 12 incongruent trials; 12 congruent trials; eight no distracter trials; and eight neutral trials. The overall flanker task had two outcome variables, response time in milliseconds (RT) and accuracy (ACC) on 76 total trials. Coding for the trial type was: congruent (1); incongruent (2); no distractor (3); and neutral (4). Coding for item focus was middle (1), and pink outside (2). Response accuracy was coded correct (1) and incorrect (0). Practice trials were coded (0) while regular trials were coded (1), the practice trials were not used in analyses. The first trial of each block was discarded for analysis (Diamond, et al., 2007). Response time (RT) averages and accuracy (ACC) variables for each of the three blocks were created for each type of focus and trial (see Table 2). The overall number of correct responses, accuracy, was used instead of the percent of correct attempts because on the flanker task with children a non-response can be due to slow response time or misunderstanding of the rule shift.

Table 2. *Number of Trials per Flanker Variable*

Variable	Block 1 - Blue Middle	Block 2 -Pink Outside	Block 3 - Switch Trial	Overall Task
Incongruent	10	10	12	32
Congruent	2	2	12	16
No Distractor	2	2	8	12
Neutral	2	2	8	12
Middle Overall	N/A	N/A	22	22
Middle Incongruent	N/A	N/A	6	6
Middle Congruent	N/A	N/A	6	6
Middle No Distractor	N/A	N/A	4	4
Middle Neutral	N/A	N/A	4	4
Outside Overall	N/A	N/A	22	22
Outside Incongruent	N/A	N/A	6	6
Outside Congruent	N/A	N/A	6	6
Outside No Distractor	N/A	N/A	4	4
Outside Neutral	N/A	N/A	4	4
Overall Block	16	16	44	76

Go/No-Go Task. A go/no-go task was used based on limited research showing that this task may be more appropriate for detecting errors in children than the flanker task (Kim, Iwaki, Imashioya, Uno, & Fujita, 2007). This task measured selective attention, inhibition, and working memory (Best & Miller, 2010). The computerized task, run with E-Prime software, was adapted from Durston et al. (2002). The same task was given in pre- and posttest. The task was age-appropriate using Pokémon cartoon

characters that children may be familiar with (see Appendix E). This task had all instructions printed on the computer screen, which the researcher read out-loud. The participants were instructed to press the space bar as fast as they could to capture all Pokémon characters (go trials) except "Meowth," a cat Pokémon character (no-go trial). There were nine practice items. During the practice trials the researcher reinforced correct trials. After completion of the practice round the instructions were displayed on the screen again, reminding children that they should not press the space bar when they saw "Meowth." There were 57 trials taking a total time of 3 minutes and 45 seconds. The stimuli were presented for 500 ms after a fixation point of 1,500 ms. Seventy five percent (43) of trials were "go" trials and 25% (14) were "no-go" trials. There were one, three or five "go" trials before the "no-go" trial. Outcomes were percent correct accuracy (ACC) and average response time (RT) in milliseconds for both the "go" and "no-go" trials.

Heart rate[2]. Heart rate was averaged for the entire activity session creating an *average heart rate* variable. The child's maximum heart rate during the session was recorded as *maximum heart rate.* Variables were created for the amount of time that participants spent in different heart rate zones during the activity session by using percentages of their maximum heart rate. The standard maximum heart rate was

[2] The FitBit had been intended to use for additional data, however complications with the systems software led to problems in data collection and validity. Therefore, calories served as the indicator of energy expenditure as measured by the Polar Heart Rate monitor. In addition, inaccuracies in measuring resting heart rate meant that variable could not be used in analyses.

calculated using the American College of Sports Medicine formula for target heart rate (age subtracted from 220).

The variable *very light intensity* represented the amount of time in minutes that children's heart rate was between rest and 60% of their maximum heart rate. The variable *light intensity* represented the amount of time in minutes that the children's heart rate was between 60 and 70% of their maximum heart rate. The variable *medium intensity* represented the amount of time in minutes that the children's heart rate was between 70 and 80% of their maximum heart rate. The variable *high intensity* represented the amount of time in minutes that the children's heart rate was between 80 and 90% of their maximum heart rate. The variable *very high intensity* represented the amount of time in minutes that the children's heart rate was above 90% of their maximum heart rate. All of the variables above 60% of the maximum heart rate were summed together to create a variable *total time above 60% of maximum heart rate*, a measure of time in a moderate- to high-intensity heart rate zone. Finally, the total amount of *Calories* spent over the course of the activity was used as a measure of energy exertion.

Procedure

Parents completed a consent form and were told the purpose of the study was to understand how children use physically active video games (see Appendix B for complete protocol). Parents completed a basic demographic survey and media use survey in the Child Cognition Lab waiting area (see Appendix C for complete survey). Parents were informed they could choose not to answer any part of the surveys and were assured of privacy and confidentiality. Children verbally assented at the time of the study and

were told they could stop participating at any time. The Principal Investigator (PI) or undergraduate researcher read the verbal instructions for obtaining assent and had the child sign the form. Children were given the media survey as a one-on-one interview, completed the EF tasks pre- and post-activity session, and were asked to participate in an activity dependent on condition for about 20 minutes. Children were involved in the study on a one-time basis for 60 to 90 minutes. There was stratified random sampling, in which the distribution of gender and age was represented equally across conditions. However, based on those distributions, children were randomly placed in the four conditions. The PI ran sessions with the assistance of trained undergraduate researchers, who had completed the Human Research Review Board's Human Subjects Tutorial. Before the activity session began, the researcher measured the child's height and weight and explained how to wear the heart rate monitor and accelerometer, stating:

> We are trying to learn about kids' bodies when they do different things. We have two monitors that measure how fast your heart beats and how much you are moving your body. You don't feel anything but you wear a strap around your chest (like this, demonstrate) and you wear one around your hip (like this, demonstrate). If you don't like how they feel you can take them off at any point, but it will help us if you try to wear them. I am going to show your parent/guardian how to put on the strap for the heart rate monitor now. The strap needs to be on kind of tight so it won't fall off while you are moving around. We want you to keep moving the whole time. While you are exercising/playing the game if you aren't moving around enough or fast enough the watch is going to

beep to let you know to move more. If you exercise/play the game really hard the watch won't beep! It is okay if does beep then you will know how much you need to move around! Now this monitor is a Fitbit and it measures how many steps and movements you take while you are exercising/playing. This one you wear on your hip so that it can record all your movements and how many steps you are taking.

The child's parent put the monitors on the child. The participant, regardless of condition, wore the heart rate monitor the entire activity period. The entire session was videotaped. The above procedures were identical for participants in each condition, except the activity session varied by condition. After the activity session, the PI asked the participant about their level of enjoyment during the activity. The trained researcher gave participants all instructions on their activity session and was available the entire time. In the active conditions, exergame and exercise, the researcher monitored the child for fatigue and ensured the child was following activity procedures.

Activity sessions. The children in the non-playing control were asked to sit and engage in minimal conversation while wearing the heart rate monitor for 20 minutes. The researcher explained, "We are interested in learning how kids bodies work while they rest." Children in the exergame condition played the DDR video game for about 21 minutes using the motion-sensored dance mat following a series of 12 songs. The researcher explained, "I will start the game so you can see the instructions. You will step on the arrows on the mat as they match the arrows on the screen. Once the game is started you will play through a bunch of songs for about 20 minutes. You should keep

playing the whole time even if it is a little hard. While you are exercising the heart rate monitor will be measuring how hard you are working out. If you aren't moving enough the monitor is going to beep, then you should try to move faster!" The PI or trained undergraduate research assistant recorded the total score at the end of each song along with each level of feedback achievement and then started the next song (see Appendix A).

In the sedentary video game condition, participants used a traditional video game controller to complete the DDR game. Children sat in a chair the whole time and followed the same designated order of songs as the exergame condition. The researcher explained "I will start the game so you can see the instructions. You will use this controller pressing these buttons with your left hand and these buttons with your right hand. Once the game is started you will play through a bunch of songs in a row. You should keep playing the whole time even if it is a little hard!" The PI or trained undergraduate research assistant recorded the total score at the end of each song along with each level of feedback achievement and then started the next song (see Appendix A).

Children in the exercise condition participated in a series of 12 aerobic exercises that had similar movements to those used while playing DDR. The researcher demonstrated all exercises to the child before they began. Each exercise series was the same length of time as a song on DDR. The researcher explained to the participant, "We are going to exercise for about 20 minutes, you should keep moving the whole time. While you are exercising the heart rate monitor will be measuring how hard you are

working out. If you aren't moving enough the monitor is going to beep, then you should try to move faster. The Fitbit monitor clipped on your pocket tells us how many steps you took and how fast! I will show you each of the exercises we will do as practice, you will do them with me. Then for about a minute and half you'll do an exercise on your own. You should keep going even if it's hard. After each exercise we will write down how many steps you took during that exercise. I'll be right here if you have any questions or aren't sure what to do." The PI demonstrated each exercise and monitored the time of each exercise. A trained undergraduate researcher counted the number of steps the child took while exercising, told the child the number at the end of the exercise, and recorded the time and number of steps on the research protocol. Children were given a short break between exercises that mirrored the break between songs on DDR. A glass of water was available for children during their break. Example exercises were marching in place and then side stepping to the left and right. See Appendix D for the full protocol of exercises. In the rare case in which a child could not complete the designated games or activity time the researcher recorded any change to the protocol on their participant information sheet.

Chapter 3: Pilot Studies

All of the procedures were piloted before the study began. The first pilot study took place in a New York City based summer camp. During this pilot study, the control, exergame, and video controller conditions were tested along with all EF tasks. Modifications were made to the go/no-go task based on the first pilot study. A second pilot study was conducted at the Child Cognition Lab at University of California, Riverside (UCR) to test the updated go/no-go task. Finally, a third pilot study was conducted at UCR's Child Cognition Lab for the exercise condition's protocol.

Pilot Study 1: Control, Exergame, and Video Game Controller Conditions

Participants. Twelve participants between the ages of 7 and 12 years old (M = 9.09, SD = 1.59) were recruited from Oasis Children's Services summer camp in New York City. This camp was for children from a low-income neighborhood in Manhattan. The ethnic breakdown of the participants was 100% Black or African American. Thirty three percent of children were girls and 66% were boys. Four children participated in the control condition, one participated in the video game controller condition, and seven participated in the exergame condition.

Measures. All three EF measures were piloted. All aspects of the stroop task were conducted as described in the Methods section. The flanker task was conducted as directed by A. Diamond's Developmental Cognitive Neuroscience lab (personal communication, July 6, 2011). The researcher watched a training video, consulted with the lab's computer programmer, and received training and feedback by sending three videos to Diamond's lab. The task was conducted upon completion of the training as

described in the dissertation study. The go/no-go task was conducted in E-prime based on a standard E-prime template. There were three stars (*) in a row and participants were told to focus on the middle star. Participants were told to press the number one key if the color of the middle star was red or green, while they were told to press the number nine key if the color of the middle star was yellow or blue. The task gave an error message every time they pressed an incorrect key. There was a practice block and experimental block. There were total 64 trials where compatible or incompatible trials were randomly selected. There were two cycles of 32 samples. In each cycle 16 trials had the stars close together and 16 trials had the stars far apart. There was an even split of compatible and incompatible trials.

Procedure. All procedures for the control, exergame, and video game controller conditions were conducted as described in the Methods section, modifications based on the pilot study are described below. Children participated in one session that lasted from 60 to 90 minutes. Sessions were run by the Principal Investigator (PI). Children were given the media survey as a one-on-one interview, completed the EF tasks, and were asked to participate in an activity dependent on condition for about 20 minutes. The researcher measured the child's height and weight. Children wore the heart rate monitor and accelerometer during the entire activity session.

Results. Both the stroop task and flanker task were successfully piloted and procedures remained as described in the Methods section. The go/no-go was not successful. First, the task was very similar to the flanker task. Second, the rules were difficult for the children to understand and resulted in many errors. Children were often

too frustrated with the task to complete it in posttest. Additional research was conducted for age-appropriate go/no-go tasks that had been used successfully with children. Durston, Thomas, Yang, Ulug, Zimmerman and Casey (2002) conducted a study with 7 to 11 year olds using a go/no-go task also run in E-prime. This task used Pokémon characters and had one character, "Meowth," used as the "no-go" stimulus. The code for this task to be programmed in E-prime was available for public use. There were several modifications made to the coding for this study. First, the original task had children pressing the number 1 key on the keyboard for "go" trials. This was reprogrammed to be the space bar for ease of pressing, which is typical for go/no-go tasks with children. The Pokémon task was piloted with two additional children. These children said the task was fun, but too long as it lasted 6.90 minutes. Therefore, the task was reprogrammed to be half as long, 3 minutes 45 seconds. Two more additional children completed the task at this length and enjoyed the game.

Children in the control condition were able to complete all procedures as described in the Methods section successfully. In the exergame condition, the first three children completed the procedures successfully and were able to perform the series of programmed songs. However, the fourth child in the exergame condition (Pilot #6) failed the programed songs based on a high amount of errors. The amount of errors meant there was a lot of stopping and restarting of the game. While the child still enjoyed the game, he was not able to keep in constant motion or get his heart rate beyond 60% of the maximum. Based on this finding, the game was set in training mode, such that

participants would not be able to fail a song regardless of the number of errors. All children were then able to complete the entire session in training mode.

Eleven children wore the heart-rate monitor, however one would not assent to wearing the monitor. All children in the exergame condition were able to keep their heart rate above 60% of their maximum heart rate at some points during the session, except Pilot #6, as described above. The procedure was changed based on this child's performance and other children not keeping their heart rate above 60% of their maximum hear rate during every song. The heart rate monitor was set to beep if the participant's heart rate was below 60% of their maximum heart rate, as described in the Methods section. The directions to the children were changed to reflect this addition. This change increased the amount of time that children kept their heart above 60% of maximum as it motivated them to move faster.

Upon completion of the exergame session, all children said they liked the activity a lot. Answers to what they liked about the activity included, "the dancing!" "moving and dancing!" and "the steps and movement." All procedures in the video game controller condition were successful as described in the Methods section. The child in the video controller condition stated he liked the activity a lot because, "I got good scores!"

Pilot Study 2: **Go/No-Go Task**

Participants. Twenty-one participants were recruited to UCR's Child Cognition Lab to participate in the pilot study. Nineteen children were in the control condition and two were in the video game controller condition. Age ranged from 7 to 10 years old (*M*

= 7.62, *SD* = .96). Sixty-two percent of participants were female (*n* = 13). In terms of ethnicity, as reported by their parent, 33% were Caucasian, 10% were Black or African American, 5% were Hispanic, 10% were Asian, 29% were multi-ethnic or biracial participants, and 5% declined to answer.

Measures and procedure. All measures and procedures were conducted in the same way described in the Methods section by the PI. The go/no-go task was the altered task run in E-prime from Pilot Study 1 based on Durston et al.'s (2002) study. The same task was given in pre- and posttest. This task instructed children to press the space bar as fast as you can to capture all Pokémon characters (Go Trial) except "Meowth" (no-go trial). There were nine practice items and 57 trials taking a total time of 3 minutes and 45 seconds. The stimuli were presented for 999 ms after an inter-stimuli fixation point of 3,500 ms. Seventy five percent (43) of trials were "go" trials, and 25% (14) were "no-go" trials. There were one, three or five go trials before the "no-go" trial. Outcomes were accuracy and response time of both "go" and "no-go" trials.

Results. Participants were observed on the go/no-go task. The researcher observed that participants appeared to be hitting ceiling on the task in pretest. Therefore, preliminary results of the current study were compared with Durston et al.'s (2002) findings. In the current study, participants average "go" response time was *M* = 654 ms (*SD* = 63), which was faster than the original study, *M* = 559 ms. In the current study, the average accuracy on the 43 "go" trials where (0) was incorrect and (1) was correct was .986 (*SD* = .034). This was an accuracy rate of 98.6%, compared to an accuracy rate of 90.3% in the original study. The average accuracy on 14 "no/go" trials where (0) was

incorrect and (1) was correct was .85 (*SD* = .12), which was similar to the original study's accuracy rate of 88%. Based on these results, the inter-stimulus fixation point and stimulus times were adjusted based on other previous research.

Research using other go/no-go tasks with children revealed that the stimulus could be shown on the screen from 200 to 1,300 ms; and the inter-stimuli fixation point could range from 300 to 1,750 ms (Kim, Iwaki, Uno & Fujita, 2005; Lamm, White, McDermott & Fox, 2012; Torpey, Hajcak, Kim, Kujawa, Klein, 2012). Lamm et al.'s (2012) study with nine-year-olds found an average response time of 560 ms with a 500 ms stimulus and a inter-stimuli fixation that varied from 1,250 to 1,750 ms, which was similar to Durston et al.'s (2002) results. Torpey et al. (2012) conducted a study with 5 to 8 year olds, the average "go" trial response time was 627 ms (*SD* = 71) with a stimuli of 1,200 ms and an inter-stimuli fixation point that varied from 300 to 800 ms, which was more variation than the current study. Kim et al. (2005) conducted a study with 7 to 11 year olds using a 1,300 ms stimuli and a 500 ms inter-stimuli fixation point finding an average response time of 547 ms on "go" trials and 433 ms on "no-go" trials, both which were faster then the current study. In addition S.P. Drummond was consulted about the current task (personal communication, May 5, 2012) and suggested shortening the inter-stimuli fixation point, which is often longer when conducting EEG/ERP studies like in Durston et al.'s (2002) research. Therefore, the dissertation go/no-go stimulus was reduced from 999 ms to 500 ms and the inter-stimuli fixation point was reduced from 3,500 ms to 1,500 ms.

Pilot Study 3: Exercise Condition

Participants. Five children were recruited to pilot the exercise condition. All children were recruited from the control condition upon completion of the study. Children assented to exercise for 20-minutes while wearing the heart rate monitor. Two girls, ages 7 and 10, and three boys, ages 7, 9, and 11, participated in order to ensure the pilot represented the range of ages in the research study.

Procedure. The researcher followed the same instructions for the exercise condition described in the Methods section stating, "We are going to exercise for about 20-minutes, you should keep moving the whole time. While you are exercising the heart rate monitor will be measuring how hard you are working out. If you aren't moving enough the monitor is going to beep, then you should try to move faster. The Fitbit monitor clipped on your pocket tells us how many steps you took and how fast! I will show you each of the exercises we will do as practice, you will do them with me. Then for about a minute and half you'll do an exercise on your own. You should keep going even if it's hard. After each exercise we will write down how many steps you took during that exercise. I'll be right here if you have any questions or aren't sure what to do." The PI demonstrated each exercise in training. And then asked the child to do each of the training exercises with them. Table 3 displays the list of exercises children performed in training.

Table 3. *Exercises used in training*

Order of Exercise	Exercise
1	Marching in place
2	Hopping in place
3	Side stepping to the left and to the right
4	Stepping forward then back
5	Feet in and then feet out (jumping jack feet)
6	Feet Forward then Back (switching)
7	Step to the right (right foot then left foot)
8	Step to the left (left foot then right foot)
9	Step forward (right foot forward then left)
10	Step backwards (right foot back then left)
11	Hop left (hop with both feet)
12	Hop right (hop with both feet)
13	Hop forward (hop with both feet)
14	Hop back (hop with both feet)
15	Hop in a Circle
16	Step Right (right foot) then step up (left foot)
17	Step right (right foot) then step back (left foot)
18	Step left (left foot) then step up (right foot)
19	Step left (left foot) then step back (right foot)

After the training exercises, the PI gave the child the series of exercises and monitored the time of each exercise. A trained undergraduate researcher counted the number of steps the child took, told the child the number at the end of the exercise, and recorded the time and number of steps on the research protocol (see Appendix D for complete exercise protocol). After completing the series of exercises, children were asked if they liked the activity. They were then asked what they liked or didn't like about the activity. They were asked if they thought other children would like the activity.

Results. All five children were able to follow the instructions given. All five children were able to perform each of the exercises in training, therefore all children were asked to try the full series of exercises. All children were able to perform the series of 12 exercises in the given time frame. During the course of the exercises all children's heart rate exceeded the 60% maximum heart rate threshold. Upon completion of the exercise session, all five children said they liked the activity "a lot." Answers to what they liked about the activity included, "It was fun!" "Hopping!" "Hopping in a circle," and "exercising." All participants said they liked everything about the activity and thought that other children would also enjoy the activity.

Pilot Study Discussion

Three different pilot studies were conducted in order to test the dissertation methods. All four conditions were piloted successfully. Several changes were made to the procedures based on the pilot studies, though most procedures were conducted in the dissertation study as planned.

Two adjustments were made to the exergame condition after Pilot Study 1. The first change was setting the video game to training mode, eliminating the possibility that the participant could fail the game. This allowed participants to continue moving the whole time instead of having to restart with every failure. It also potentially eliminated children becoming frustrated at the game if they could not succeed at it. This change was also beneficial to the video game controller condition as it also allowed children in that condition to play without the risk of failing the song.

The second change was to set the heart rate monitor to beep when children's heart rate dropped below 60% of their maximum heart rate. This change was beneficial to both the exergame and exercise condition. Energy expenditure was expected to mediate the impact on EF. Other studies have found that in order to have acute changes in EF children must have their heart rate above 60% of maximum (Hillman et al., 2009). In both conditions, it was possible for children to not expend a high amount of energy. Therefore, the addition of a heart rate goal encouraged children to move faster or move more.

The major changes to the study occurred with the go/no-go task. This task was problematic twice and took several adjustments. The first task had been chosen based on a standard template go/no-go task, however it was too similar to the flanker task and too difficult for children. The children in Pilot Study 1 may have had lower than average EF skills, however the similarities to the flanker justified changing the task. The second go/no-go task while more age-appropriate had been conducted as an FMRI study (Durston et al., 2002). The original study had a long stimuli presentation and long inter-

stimuli fixation point. Preliminary analysis of children who used that task showed a much faster reaction time and accuracy on go trials when compared with the original Durston et al. (2002) study. Upon reviewing other literature and consulting with researchers familiar with this task it seemed beneficial to change the task. The 21 children who participated while using this task were still used in the dissertation study analysis, however they were dropped from all analyses using the go/no-go task.

Chapter 4: Results

Preliminary analysis revealed that children performed at a high level with little variation on the go/no-go task and the stroop (Maximum = 30) task at baseline; therefore there was a ceiling effect on these two tasks. There were no order effects for the stroop tasks. Paired samples *t*-tests examined changes for the whole sample and by condition from pre- to posttest. The only changes from pre-to posttest were on the stroop task reaction time for two of the subtasks, color and day/night/grass/snow. Given the lack of significant results, only descriptive data are presented for these two tasks in Table 4. These findings suggest minimal change in EF as assessed by these two tasks regardless of condition, and this pattern of findings will be considered in the discussion.

Data Analysis Overview

Analyses were conducted with the Statistical Package for Social Sciences (SPSS) software, Version 22, produced by International Business Machines Corporation (IBM). All remaining analyses were conducted on the flanker task. The flanker task was analyzed for accuracy and response time for each type of trial. There were 20 dependent variables tested at each level of analysis. The first set of analyses explored descriptive statistics by condition and overall outcomes of the flanker task. The second set of analyses used correlational analysis to determine the relationship between potential mediators and covariates and EF outcomes for all conditions. Specifically, age, exercise intensity, and video game experience were examined. The third set of analyses examined the hypothesis that children in the exergame condition (DDR) would demonstrate the greatest improvement in EF skills when compared to the sedentary video game condition,

the exercise-only condition, and the non-playing control condition. The fourth set of analyses examined the hypothesis that energy expenditure would mediate the relationships between condition and EF outcomes. The final set of analyses explored the hypothesis that gender would moderate changes in EF.

Six children were excluded from all analyses due to non-compliance on the EF tasks, and two children did not complete the EF task in pre- and/or posttest due to experimenter or software error. Preliminary analyses examined if the children excluded for non-compliance were different than the overall sample. Chi-Square analyses revealed that there were no significant differences by condition, limitations to physical activity, ADD diagnosis, gender or ethnicity. Independent Samples *t*-tests revealed that there were not significant differences between the dropped participants and the included participants in BMI, energy expenditure or time in activity session.

Table 4. *Means (and Standard Deviations) for Go/No-Go and Stroop Tasks Accuracy (ACC) and Response Time(RT)*

	Overall		Control		Exercise		Sedentary VG		Exergame	
	Go/No-Go ACC on Go Trials									
Pretest	0.95	(0.08)	0.93	(0.16)	0.95	(0.05)	0.95	(0.09)	0.97	(0.04)
Posttest	0.98	(0.04)	0.98	(0.03)	0.98	(0.04)	0.97	(0.04)	0.98	(0.04)
	Go/No-Go ACC on No-Go Trials									
Pretest	0.61	(0.18)	0.61	(0.19)	0.62	(0.19)	0.56	(0.19)	0.63	(0.14)
Posttest	0.62	(0.18)	0.60	(0.25)	0.62	(0.14)	0.62	(0.18)	0.63	(0.17)
	Go/No-Go RT on Go Trials (milliseconds)									
Pretest	464.69	(61.03)	475.19	(70.13)	478.52	(39.82)	446.38	(68.95)	461.43	(63.07)
Posttest	470.58	(64.57)	479.06	(59.12)	477.17	(50.18)	473.01	(88.43)	456.25	(53.45)
	Go/No-Go RT on Go Trials (milliseconds)									
Pretest	175.86	(104.58)	172.63	(95.36)	172.79	(89.17)	205.13	(146.91)	153.33	(68.35)
Posttest	169.59	(119.67)	171.61	(116.87)	172.06	(71.28)	183.84	(179.64)	152.38	(88.15)
	Stroop Day/Grass Task ACC									
Pretest	26.81	(3.49)	25.93	(4.20)	27.67	(1.79)	26.97	(3.31)	26.79	(3.94)
Posttest	27.70	(2.57)	26.78	(3.88)	27.92	(1.83)	27.91	(1.75)	28.38	(1.56)
	Stroop Day/Grass Task RT (seconds)									
Pretest	0.86	(0.28)	0.90	(0.33)	0.85	(0.25)	0.87	(0.23)	0.82	(0.32)
Posttest	0.76	(0.26)	0.79	(0.28)	0.73	(0.23)	0.78	(0.17)	0.73	(0.33)
	Stroop Color Task ACC									
Pretest	28.61	(1.86)	28.44	(2.35)	28.53	(1.69)	28.97	(1.04)	28.55	(2.06)
Posttest	28.96	(1.54)	28.54	(2.20)	29.20	(1.01)	29.31	(1.05)	28.85	(1.33)
	Stroop Color Task RT (seconds)									
Pretest	0.86	(0.28)	0.91	(0.26)	0.85	(0.32)	0.81	(0.15)	0.85	(0.34)
Posttest	0.79	(0.30)	0.81	(0.26)	0.85	(0.36)	0.76	(0.18)	0.76	(0.38)
	Stroop Shape Task ACC									
Pretest	28.64	(2.71)	28.15	(2.98)	28.53	(2.75)	29.41	(1.73)	28.59	(3.07)
Posttest	28.78	(2.52)	28.73	(2.30)	28.33	(3.33)	29.68	(0.59)	28.41	(2.80)
	Stroop Shape Task RT (seconds)									
Pretest	0.95	(0.34)	0.98	(0.28)	1.03	(0.31)	0.92	(0.39)	0.88	(0.35)
Posttest	0.89	(0.33)	0.96	(0.33)	1.01	(0.25)	0.83	(0.32)	0.79	(0.35)

Descriptive Statistics

Video game experience. Prior video game experience was examined based on the total amount of time children spent playing any type of video game in a typical week. Parents reported that children played any type of video games for 0 to 35 hours in a typical week. On average children played 6.9 hours a week or about an hour a day (M = 415.25 minutes, SD = 447.35). There was a trend towards a significant difference by condition in the time spent playing video games, $F(3, 138) = 2.46$, $p = .07$. Bonferonni post-hoc tests revealed the exergame group (M = 566.82, SD = 483.70) played significantly more video games than the control group (M = 288.75, SD = 384.54), $p < .05$. There were not significant differences between the exercise group (M = 438.09, SD = 459.91) or the sedentary video game group (M = 394.71, SD = 438.98) and any other condition. Independent Samples t-tests revealed that there was a significant difference by gender, $t(140) = 3.18$, $p < .01$. Boys (M = 527.87, SD = 460.71) played an average of nine hours a week, significantly more than the average five hours played by girls (M = 296.08, SD = 402.73). Pearson's correlations examined the relationship between the amount of time playing video games and age of participants. There was not significant relationship between age and video game play. In addition, a One-way ANOVA revealed that there were no significant differences in video game play by ethnicity.

Heart rate and exercise intensity. Energy expenditure was expected to be a potential mediator of EF outcomes, therefore the average time participants spent over 60% of maximum heart rate, moderate- to high-intensity physical activity, was calculated. Participants in the control group averaged 0.04 minutes (SD = 0.13) above

60% of their maximum heart rate. Participants in the sedentary video game group averaged 0.68 minutes (*SD* = 3.58) above 60% of their maximum heart rate. Participants in the exercise group averaged 17.91 minutes (*SD* = 9.10) above 60% of their maximum heart rate. Participants in the exergame group averaged 7.06 minutes (*SD* = 8.01) above 60% of their maximum heart rate. A One-way ANOVA revealed significant differences in time spent doing moderate- to high-intensity physical activity by condition, $F(3, 141) = 63.91$, $p < .001$. Bonferonni follow-up tests showed that the control condition was not significantly different than the video game controller group. In addition, the exergame group's time spent above 60% of maximum heart rate was significantly higher than both the control ($p < .001$) and the sedentary video game group ($p < .001$). Finally, the exercise group's time spent in moderate- to high-intensity physical activity was significantly higher than the sedentary video game group ($p < .001$), the exergame group ($p < .001$), and the control group ($p < .001$).

Energy expenditure was also calculated using the average amount of calories expended during the interaction. The average number of calories burned was 87.51 (Range = 0 to 343, *SD* = 68.65). A One-way ANOVA revealed there were significant differences in caloric expenditure by condition, $F(3, 142) = 25.09$, $p < .001$. Bonferonni follow-up tests revealed there were no significant differences between the control and sedentary video game groups. In addition, there were no significant differences between the exergame and exercise groups. Both the exergame and exercise groups were significantly higher than the control and sedentary video game groups ($p < .001$).

Independent Samples *t*-tests showed there were no significant differences in time in moderate- to high-intensity heart rate zone or calories by gender. Correlational analysis examined the relationships between BMI, age, and heart rate and energy expenditure. The amount of time spent in the heart rate zone above 60% of the maximum was related to the amount of calories expended, $r = 0.605$, $p < .001$.

Duration of session, enjoyment and game performance. Additional interaction variables were examined. First, the amount of time spent in the activity session was examined. Participants ranged in the duration of time that they were in the session from 15:16 minutes to 37:47 minutes (*M* = 21:33, *SD* = 02:33). The control group averaged 22:09 minutes (*SD* = 3:53), the exercise group averaged 21:29 minutes (*SD* = 1:58), the sedentary video game group averaged 20:57 minutes (*SD* = 2:07), and the exergame group averaged 21:32 minutes (*SD* = 0:59). There were no significant differences by condition based on the duration in the session. Independent Samples *t*-tests revealed no differences by gender for session duration. Correlational analyses examined the relationship between session duration and age, BMI and total amount of video game experience. There were no significant relationships.

The second variable examined was the level of enjoyment reported by the participants. Overall, participants enjoyed their experience; on average children's rating of enjoyment was 1.66 (*SD* = 0.73, range = -2 to 2). One-way ANOVAs revealed that there were no differences in enjoyment ratings by condition. Independent Samples *t*-tests showed no differences by gender for enjoyment. There were no significant relationships between enjoyment and age, BMI and total video game experience.

Third, the participants' game performance in the exergame and sedentary video game groups was analyzed. The exercise and control conditions did not have an evaluative measure component. Children ranged in game performance ability, from 27% to 92% of perfect performance. On average, children were 70% accurate in game play (SD = 0.15). There were significant differences in game performance between the exergame and sedentary video game groups, $t(68) = 5.66$, $p < .001$. Children in the sedentary video game group (M = 0.79, SD = 0.11) performed significantly higher than those in the exergame group (M = 0.61, SD = 0.14). Independent Samples t-tests examined the differences between boys and girls on game performance. There was a trend in significance, such that boys (M = 0.73, SD = 0.14) performed higher than girls (M = 0.66, SD = 0.16), $t(68) = 1.90$, $p = .06$. Correlational analysis examined game performance's relationship with age, BMI, total amount of video game experience, enjoyment and session duration. Game performance was only significantly related to the length of video game play, $r = 0.28$, $p < .05$.

Descriptive statistics summary. There were no differences by condition for amount of video game experience, duration of session, or enjoyment. However, there were differences by condition for energy expenditure and game performance. The two active conditions, exergame and exercise, had higher energy expenditure as measured by time in moderate- to high-intensity heart rate zones and calories burned when compared to the sedentary video game condition and non-playing control. The sedentary video game condition had higher scores on the game when compared to the exergame condition. The exergame condition required full-body movement, which was more

difficult for children to be accurate. There were significant differences by gender in video game experiences and game performance. Boys had more time playing video games than girls, and in turn performed better on the video games. There were no other differences by gender.

Flanker task outcomes

Each of the flanker variables was examined. First, Paired Samples *t*-tests were conducted on each flanker variable to examine overall change from pre- to posttest (see Table 5 for means, standard deviations, and significant tests). Second, Paired Samples *t*-tests examined differences between the different types of flanker variables in Block 3 (see Table 6). Block 3 was the main block analyzed because it was the most difficult, requiring switching between middle (blue) and outside (pink) focus trials.

Table 5. *Means (Standard Deviations) and Paired Samples t-tests for Flanker Variables*

Block	Focus	Variable	Test	Mean (SD)	*t*-test
Block 1	Middle	Incongruent RT	pretest	755.27 (163.49)	*t*(146) = -9.37***
			posttest	659.22 (149.76)	
	Middle	Incongruent ACC	pretest	8.71 (1.95)	*t*(146) = 3.05**
			posttest	9.15 (1.76)	
	Middle	Congruent RT	pretest	686.43 (157.42)	*t*(144) = -6.88***
			posttest	598.21 (146.21)	
	Middle	Congruent ACC	pretest	1.88 (0.38)	*t*(146) = 0.82
			posttest	1.91 (0.31)	
	Middle	No Distractor RT	pretest	775.12 (219.44)	*t*(143) = -7.51***
			posttest	651.47 (153.13)	
	Middle	No Distractor ACC	pretest	1.77 (0.49)	*t*(146) = 1.87†
			posttest	1.85 (0.39)	
	Middle	Neutral RT	pretest	748.82 (214.06)	*t*(144) = -6.71***
			posttest	651.47 (153.13)	
	Middle	Neutral ACC	pretest	1.85 (0.44)	*t*(146) = 0.33
			posttest	1.86 (0.43)	
	Middle	Overall RT	pretest	750.49 (160.98)	*t*(146) = -10.71***
			posttest	650.05 (135.68)	

	Middle	Overall ACC	pretest	14.21	(2.79)	*t*(146) =	2.73**
			posttest	14.78	(2.49)		
Block 2	Outside	Incongruent RT	pretest	789.14	(198.09)	*t*(146) =	-6.29***
			posttest	697.75	(173.41)		
	Outside	Incongruent ACC	pretest	7.79	(2.34)	*t*(146) =	6.23***
			posttest	8.81	(1.59)		
	Outside	Congruent RT	pretest	677.91	(173.39)	*t*(145) =	-3.50***
			posttest	626.77	(165.89)		
	Outside	Congruent ACC	pretest	1.86	(0.41)	*t*(146) =	1.30
			posttest	1.90	(0.34)		
	Outside	No Distractor RT	pretest	735.65	(211.46)	*t*(145) =	-6.12***
			posttest	624.83	(166.12)		
	Outside	No Distractor ACC	pretest	1.78	(0.52)	*t*(146) =	1.79†
			posttest	1.87	(0.38)		
	Outside	Neutral RT	pretest	827.48	(256.73)	*t*(140) =	-5.14***
			posttest	713.39	(216.20)		
	Outside	Neutral ACC	pretest	1.61	(0.67)	*t*(146) =	2.54*
			posttest	1.76	(0.49)		
	Outside	Overall RT	pretest	770.11	(181.62)	*t*(146) =	-6.94***
			posttest	681.36	(161.22)		
	Outside	Overall ACC	pretest	13.04	(3.41)	*t*(146) =	5.61***
			posttest	14.35	(2.19)		
Block 3	Middle	Incongruent RT	pretest	946.53	(138.13)	*t*(145) =	-3.79***
			posttest	894.35	(162.21)		
	Middle	Incongruent ACC	pretest	4.06	(1.90)	*t*(145) =	6.26***
			posttest	5.10	(1.88)		
	Middle	Congruent RT	pretest	901.82	(148.12)	*t*(145) =	-4.49***
			posttest	838.68	(155.64)		
	Middle	Congruent ACC	pretest	4.75	(1.27)	*t*(145) =	4.86***
			posttest	5.22	(1.05)		
	Middle	No Distractor RT	pretest	791.43	(151.96)	*t*(145) =	-7.07***
			posttest	703.72	(144.31)		
	Middle	No Distractor ACC	pretest	3.36	(0.98)	*t*(146) =	4.11***
			posttest	3.68	(0.67)		
	Middle	Neutral RT	pretest	1002.41	(203.61)	*t*(141) =	-4.14***
			posttest	923.73	(200.25)		
	Middle	Neutral ACC	pretest	2.48	(1.19)	*t*(146) =	5.79***
			posttest	3.12	(1.05)		
	Middle	Overall RT	pretest	908.01	(103.58)	*t*(146) =	-6.77***
			posttest	846.95	(124.44)		
	Middle	Overall ACC	pretest	14.67	(3.95)	*t*(146) =	9.23***
			posttest	17.14	(3.31)		
	Outside	Incongruent RT	pretest	989.92	(144.85)	*t*(145) =	-5.37***

			posttest	909.42	(161.01)	
	Outside	Incongruent ACC	pretest	4.30	(1.83)	$t(145) =$ 4.07***
			posttest	5.00	(1.66)	
	Outside	Congruent RT	pretest	865.98	(140.06)	$t(145) =$ -4.99***
			posttest	803.82	(150.97)	
	Outside	Congruent ACC	pretest	5.05	(1.06)	$t(145) =$ 4.61***
			posttest	5.44	(0.86)	
	Outside	No Distractor RT	pretest	889.18	(161.98)	$t(146) =$ -4.89
			posttest	808.65	(166.11)	
	Outside	No Distractor ACC	pretest	3.20	(0.97)	$t(146) =$ 2.52*
			posttest	3.40	(0.84)	
	Outside	Neutral RT	pretest	1019.82	(167.22)	$t(146) =$ -6.81***
			posttest	911.51	(178.39)	
	Outside	Neutral ACC	pretest	2.61	(1.07)	$t(146) =$ 6.44***
			posttest	3.20	(0.96)	
	Outside	Overall RT	pretest	936.92	(109.26)	$t(146) =$ -7.11***
			posttest	863.48	(128.34)	
	Outside	Overall ACC	pretest	15.18	(3.63)	$t(146) =$ 7.17***
			posttest	17.06	(3.00)	
		Overall Congruent RT	pretest	884.02	(120.90)	$t(146) =$ -5.60***
			posttest	822.72	(140.75)	
		Overall Congruent ACC	pretest	9.82	(2.09)	$t(146) =$ 5.84***
			posttest	10.66	(1.67)	
		Overall Incongruent RT	pretest	968.09	(122.35)	$t(146) =$ -5.63***
			posttest	902.53	(140.73)	
		Overall Incongruent ACC	pretest	8.38	(2.98)	$t(146) =$ 7.58***
			posttest	10.13	(2.84)	
		Overall RT	pretest	923.12	(98.42)	$t(146) =$ -7.83***
			posttest	855.27	(121.75)	
		Overall ACC	pretest	29.86	(6.87)	$t(146) =$ 11.34***
			posttest	34.20	(5.65)	
Overall		Overall RT	pretest	848.36	(110.74)	$t(146) =$ -10.41***
			posttest	771.85	(111.82)	
		Overall ACC	pretest	57.11	(10.94)	$t(146) =$ 10.88***
			posttest	63.32	(8.81)	

Note: Variable abbreviations: Accuracy (ACC) and response time (RT)

† < .10, *p < .05, ** p < .001, *** p < .001

Most flanker variables significantly improved from pre- to posttest on both accuracy and speed. They did not improve in Block 1 on congruent, no distracter or

neutral accuracy. In Block 2, they also did not improve on congruent or no distracter accuracy. However, each of these variables had only two trials; and participants were close to ceiling at pretest.

Paired Samples *t*-tests examined differences between the different types of flanker trials in Block 3, the switch focus trial (Table 6). Participants were significantly faster in both pre- and posttest on middle (blue fish) trials than outside (pink fish) trials, however they were not more accurate on middle than outside trials. Participants also were significantly faster and more accurate on congruent trials compared with incongruent trials. Participants were faster on middle and outside congruent trials compared to middle and outside incongruent trials. Children were more accurate on middle congruent trials compared to middle incongruent trials in pretest; however there was no significant difference at posttest. Participants were more accurate in both pre- and posttest on outside congruent trials compared to outside incongruent trials.

Table 6. *Paired Samples t-tests for Flanker Variables in Block 3*

Variable	Test	*t*-test	*p*-value
Middle vs. Outside focus RT	pretest	$t(146) = -4.23$	.000
	posttest	$t(146) = -2.95$	.004
Middle vs. Outside focus ACC	pretest	$t(146) = 1.89$	.060
	posttest	$t(146) = 0.32$	.749
Middle focus Congruent vs. Incongruent RT	pretest	$t(146) = -3.38$	.001
	posttest	$t(146) = -4.57$	.000
Outside focus Congruent vs. Incongruent RT	pretest	$t(146) = -9.97$	.000
	posttest	$t(146) = -8.74$	.000
Middle focus Congruent vs. Incongruent ACC	pretest	$t(146) = 4.35$	.000
	posttest	$t(146) = 0.73$	.466
Outside focus Congruent vs. Incongruent ACC	pretest	$t(146) = 4.98$	.000
	posttest	$t(146) = 2.88$	.005

Congruent vs. Incongruent trial RT	pretest	$t(146) = -9.45$	.000
	posttest	$t(146) = -8.89$	.000
Congruent vs. Incongruent trial ACC	pretest	$t(146) = 6.23$	.000
	posttest	$t(146) = 2.26$	.025

Note: Variable abbreviations: Accuracy (ACC) and response time (RT)

Correlational Analyses. The next step of the analysis was to explore the relationships between the 20 Block 3 and overall flanker variables and other measured variables using Pearson correlations. First, the relationship between the different flanker variables was examined (see Table 7). The relationship between flanker variables (pretest and posttest) and potential mediators (i.e. age, video game experience, duration of session, enjoyment, energy expenditure, and game performance) were examined. Only significant and trends towards significant relationships are reported in Table 8. Duration of the session was not related to any of the flanker variables. Enjoyment was unrelated to overall performance or reaction time, therefore is not included in any analyses.

Table 7. *Correlations between Flanker Variables at Pretest*

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Overall ACC	1	-.33 ***	.91 ***	-.15 †	.06	.11	-.02	.20 *	.82 ***	-.15 †	.82 ***	-.12	.05	-.05	.09	.06	.06	-.01	.01	-.05
2. Overall RT		1	-.33 ***	.87 ***	.02	.11	.08	.11	-.43 ***	.83 ***	-.15 †	.78 ***	.07	.15 †	-.03	.01	.05	-.01	-.17 *	.09
3. B3 ACC	--	--	1	-.19 *	.03	.06	-.04	.13	.91 ***	-.16 *	.89 ***	-.19 *	.08	-.05	.11	.02	.04	-.05	-.06	-.08
4. B3 RT	--	--	--	1	.04	.07	.11	.10	-.28 **	.91 ***	-.06	.93 ***	.14 †	.07	.05	.00	.05	-.04	-.12	.04
5. Con ACC	--	--	--	--	1	-.12	.43 ***	.07	.01	.01	.03	.06	-.11	.03	-.08	.01	-.16 †	.09	-.02	.02
6. Con RT	--	--	--	--	--	1	-.23 **	.61 ***	.02	.09	.09	.03	-.12	-.03	.01	-.02	-.04	-.03	.05	-.03
7. Inc ACC	--	--	--	--	--	--	1	-.06	-.05	.10	-.02	.11	-.08	.04	.01	.00	-.08	.11	-.05	-.01
8. Inc RT	--	--	--	--	--	--	--	1	.05	.09	.19 *	.09	.03	-.03	.05	-.08	-.00	.00	-.01	-.07
9. Middle ACC	--	--	--	--	--	--	--	--	1	-.23 **	.64 ***	-.27 **	.01	-.11	.05	.01	-.06	-.06	-.09	-.11
10. Middle RT	--	--	--	--	--	--	--	--	--	1	-.05	.70 ***	.12	-.02	.07	-.06	.03	-.03	-.11	-.06
11. Outside ACC	--	--	--	--	--	--	--	--	--	--	1	-.06	.13	.03	.15 †	.02	.14 †	-.03	-.01	-.03
12. Outside RT	--	--	--	--	--	--	--	--	--	--	--	1	.13	.15 †	.01	.06	.05	-.03	-.11	.12
13. Middle Con ACC	--	--	--	--	--	--	--	--	--	--	--	--	1	-.09	.30 ***	.02	.59 ***	-.14	.30 ***	.01
14. Middle Con RT	--	--	--	--	--	--	--	--	--	--	--	--	--	1	-.24 **	.37 ***	-.02	.42 ***	-.05	.50 ***
15. Middle Inc ACC	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	-.03	.33 ***	-.27 **	.28 **	-.22 **
16. Middle Inc RT	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	.04	.46 ***	.09	.51 ***
17. Outside Con ACC	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	-.11	.29 ***	.15
18. Outside Con RT	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	-.07	.44 ***
19. Outside Inc ACC	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1	.01
20. Outside Inc RT	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1

Note: Variable abbreviations: Congruent (Con), Incongruent (Inc), Accuracy (ACC) and Response Time (RT)
† < .10, *p < .05, ** p < .001, *** p < .001

Age was related to several variables at pre- and posttest. At pretest and posttest, the older a child was the faster and more accurate he or she performed on congruent and incongruent trials. Video game experience was related to flanker performance. The more video game experience children had the more accurate they were in pretest on congruent trials. However, the more video game experience the worse children did at pretest on the outside trial accuracy. In posttest, the more video game experience children had the faster they were on incongruent and middle incongruent trials. In addition, in posttest video game experience was negatively related to outside congruent accuracy. The more video game experience the less accurate they were in posttest.

Energy expenditure, operationalized as the amount of time spent above 60% of maximum heart rate, was related to several variables. Calories expended were unrelated to any variables. There was a relationship between several pretest variables and amount of energy expended. At pretest, the higher the accuracy on congruent trials the less energy expended. The faster the reaction time on incongruent trials in pretest the more energy expended. The more energy expended the more accurate at pretest on middle incongruent trials and the faster response time at pretest on outside congruent trials. At posttest, the higher energy expended the more accurate on outside congruent trials. The more energy expended the more accurate participants were on middle congruent trials and the faster on middle incongruent reaction time at both pre- and posttest.

Finally, game performance for the exergame and sedentary video game conditions were related to congruent and incongruent trial accuracy at pre- and posttest. The higher the game performance the more accurate they were on these trials. At pretest, game

performance was related to middle trial and middle incongruent trial response time where the faster they were in pretest the better they performed on the game. In posttest, game performance was related to overall Block 3, outside focus, incongruent and congruent trials reaction time. The better the game performance, the faster the response time in posttest.

Table 8. *Correlations with Flanker Variables*

Flanker Variable	Covariate	Pretest	Posttest
Block 3 RT	Game Performance	N.S.	-.236*
CON ACC	Age	.370***	.353**
	Video Game Experience	.189*	N.S.
	Energy Expenditure	-.171*	N.S.
	Game Performance	.446**	.456**
CON RT	Age	-.259**	-.319**
	Game Performance	N.S.	-.215†
INC ACC	Age	.380***	.327***
	Game Performance	.376***	.332***
INC RT	Age	-.158†	-.268***
	Video Game Experience	N.S.	-.185*
	Energy Expenditure	.201*	N.S.
	Game Performance	N.S.	-.225†
Middle RT	Game Performance	-.217†	N.S.
Outside ACC	Video Game Experience	-.182*	N.S.
Outside RT	Game Performance	N.S.	-.245*
Middle CON ACC	Energy Expenditure	.161†	.197*
Middle INC ACC	Energy Expenditure	.180*	N.S.
Middle INC RT	Energy Expenditure	.158†	.142†
	Video Game Experience	N.S.	-.193*
	Game Performance	-.268*	N.S.
Outside CON ACC	Video Game Experience	N.S.	-.168*
	Energy Expenditure	N.S.	.192*
Outside CON RT	Energy Expenditure	.145†	N.S.

Note: Variable abbreviations: Congruent (Con), Incongruent (Inc), Accuracy (ACC) and Response Time (RT)
† < .10, *p < .05, ** p < .001, *** p < .001

Summary of relationships between flanker outcomes. Many of the flanker variables were related, especially by type of trial. For example, congruent accuracy was related to incongruent accuracy. Participants improved on the various trials in different ways. These differences justified analyzing the task using the entire range of trial types as the dependent variables as opposed to analyzing just the overall task. Participants were faster on middle trials than they were on outside trials, however they were not more accurate. Similar to previous research, participants were faster and more accurate on congruent compared to incongruent trials. Also, the older a child was the faster their reaction time on congruent and incongruent trials. Participants were faster and more accurate on congruent than incongruent for the outside trials. A different pattern emerged for the middle trials. At pretest, participants were faster and more accurate on the middle congruent trials than the middle incongruent trials. However, at posttest there were no differences in accuracy for the middle congruent and incongruent trials.

Video game experience impacted both pre- and posttest outcomes. Children with more video game experience were more accurate on congruent trials at pretest, but not at posttest. Children who had more video game experience were faster at posttest on the incongruent and middle incongruent trials; incongruent trials were more difficult overall. More video game experience meant that children did worse on posttest accuracy on the outside trials, similarly they did worse on posttest on the outside congruent trials. This relationship may because these children were more comfortable with the medium and may have been sacrificing accuracy for speed. Video game performance had a similar relationship where the better children did at the game the faster they were at posttest on

several variables. They also were more accurate on several trials the better they were at the game. Children with a faster pretest reaction time on middle trial and middle incongruent trial response time performed better at the video game, which could mean that higher baseline EF skills aided in game performance.

Moderate- to high-intensity physical activity was related to both pre- and posttest variables. The relationship at pretest could reflect higher EF for children who are more physically active, which has been supported by previous research (Buck et al., 2008; Hillman et al., 2005; Tomporowski et al., 2011). At both pre- and posttest, the more time in moderate- to high-intensity physical activity the more accurate participants were on middle congruent trials and the faster on middle incongruent reaction time; therefore, energy expenditure will be treated as a covariate for these trials in future analyses.

Condition Analysis

Repeated Measures ANOVAs with simple planned contrasts were used to examine the hypothesis that children in the exergame condition (DDR) would demonstrate the greatest improvement in EF skills when compared to the inactive video game condition, the exercise-only condition and the non-playing control. For each flanker variable, a 4 x 2 Repeated Measures ANOVA, with condition (exercise vs. exergame vs. inactive vs. non-playing control) as the between-subjects variable and time (pretest vs. posttest) as the within-subjects variable, examined if participants from the different conditions were more or less likely to increase or decrease from pretest to posttest, as well as to test for an interaction between condition and time of measurement. The exergame group was used as the reference group for all the simple planned contrasts.

A 4 (condition) x 2 (time) Repeated Measures Analysis of Covariance (ANCOVA), where age served as a covariate, was used when there was a significant correlation between age and the dependent variables at pre- and posttest (see Table 8). The variables for which an ANCOVA was used were congruent trial accuracy, congruent trial response time, incongruent trial accuracy and incongruent trial response time. The relationship between age and the various flanker dependent variables will be considered in the discussion. All 20 flanker variables were analyzed; however only ANOVAs with significant main effects of condition, age by time, or the time by condition interaction effects are reported (see Table 10 for all results). Means, standard deviations and Paired Samples *t*-tests by condition are reported in Table 9.

Table 9. *Means (and Standard Deviations) and Paired Samples t-tests by Condition*

	Condition	Pretest		Posttest		*t*-tests
Overall ACC	Control	58.02	(11.11)	64.44	(7.14)	$t(40) = 6.77$***
	Exercise	61.69	(8.63)	65.83	(7.51)	$t(35) = 3.72$***
	Video Controller	53.37	(11.72)	60.83	(9.86)	$t(34) = 5.86$***
	Exergame	55.06	(10.59)	61.91	(10.08)	$t(34) = 5.57$***
Overall RT	Control	824.70	(115.57)	763.49	(109.93)	$t(40) = -4.46$***
	Exercise	834.84	(116.97)	757.17	(126.46)	$t(35) = -6.89$***
	Video Controller	873.36	(88.28)	782.59	(110.48)	$t(34) = -5.32$***
	Exergame	865.00	(115.18)	786.00	(100.83)	$t(34) = -4.76$***
Block 3 Overall ACC	Control	30.76	(6.80)	34.61	(5.69)	$t(40) = 5.38$***
	Exercise	32.61	(6.54)	35.64	(5.79)	$t(35) = 3.63$***
	Video Controller	27.86	(6.83)	33.49	(5.08)	$t(34) = 8.06$***
	Exergame	27.97	(6.38)	32.94	(5.83)	$t(34) = 6.49$***
Block 3 Overall RT	Control	905.00	(104.11)	844.71	(116.27)	$t(40) = -3.87$***
	Exercise	915.59	(103.27)	846.03	(116.25)	$t(35) = -5.45$***
	Video Controller	930.77	(83.75)	854.14	(141.80)	$t(34) = -3.29$***
	Exergame	944.42	(99.33)	878.27	(113.85)	$t(34) = -3.81$***
Block 3 CON ACC	Control	9.78	(1.81)	10.42	(1.66)	$t(40) = 2.31$*
	Exercise	9.50	(2.06)	10.83	(1.61)	$t(35) = 4.06$***
	Video Controller	9.91	(2.47)	10.86	(1.68)	$t(34) = 3.08$**
	Exergame	10.11	(2.05)	10.60	(1.77)	$t(34) = 2.15$*

Block 3 CON RT	Control	907.08 (116.78)	865.18 (120.56)	$t(40) = -2.04$*
	Exercise	909.46 (102.08)	844.33 (133.45)	$t(35) = -2.66$*
	Video Controller	855.77 (143.02)	793.13 (146.16)	$t(34) = -2.81$**
	Exergame	859.09 (112.95)	780.35 (151.19)	$t(34) = -3.84$**
Block 3 INC ACC	Control	7.90 (2.65)	9.81 (3.10)	$t(40) = 4.94$***
	Exercise	8.17 (2.92)	9.86 (2.86)	$t(35) = 3.89$***
	Video Controller	8.91 (3.61)	10.45 (2.86)	$t(34) = 3.11$**
	Exergame	8.63 (2.72)	10.45 (2.51)	$t(34) = 3.31$**
Block 3 INC RT	Control	974.05 (111.94)	917.76 (143.49)	$t(40) = -2.82$**
	Exercise	1006.42 (111.39)	913.79 (132.06)	$t(35) = -3.25$**
	Video Controller	917.08 (132.94)	883.83 (166.97)	$t(34) = -1.48$
	Exergame	972.69 (121.64)	891.79 (118.74)	$t(34) = -3.73$**
Block 3 Middle ACC	Control	14.95 (3.89)	17.32 (3.09)	$t(40) = 5.17$***
	Exercise	15.92 (4.09)	17.94 (3.23)	$t(35) = 4.84$***
	Video Controller	13.69 (3.98)	16.97 (2.92)	$t(34) = 5.89$***
	Exergame	14.06 (3.66)	16.26 (3.85)	$t(34) = 3.21$**
Block 3 Middle RT	Control	886.90 (111.69)	833.59 (122.41)	$t(40) = -2.97$**
	Exercise	902.71 (105.85)	849.59 (112.02)	$t(35) = -3.59$**
	Video Controller	915.22 (92.69)	840.41 (142.98)	$t(34) = -3.31$**
	Exergame	930.99 (100.52)	866.47 (121.82)	$t(34) = -3.89$***
Block 3 Outside ACC	Control	15.80 (3.78)	17.29 (3.00)	$t(40) = 2.95$**
	Exercise	16.69 (3.30)	17.69 (3.08)	$t(35) = 1.56$
	Video Controller	14.17 (3.53)	16.51 (3.18)	$t(34) = 4.52$***
	Exergame	13.91 (3.24)	16.69 (2.69)	$t(34) = 7.91$***
Block 3 Outside RT	Control	921.65 (111.15)	855.79 (121.06)	$t(40) = -3.72$**
	Exercise	926.15 (110.06)	842.34 (127.21)	$t(35) = -5.95$***
	Video Controller	946.26 (97.12)	867.93 (151.51)	$t(34) = -2.80$**
	Exergame	956.53 (109.26)	889.76 (112.23)	$t(34) = -3.01$**
Block 3 Middle CON ACC	Control	4.83 (1.26)	5.12 (1.12)	$t(40) = 2.02$*
	Exercise	5.06 (1.26)	5.53 (0.74)	$t(35) = 2.62$*
	Video Controller	4.60 (1.33)	5.17 (1.01)	$t(34) = 2.28$*
	Exergame	4.50 (1.21)	5.06 (1.23)	$t(33) = 2.88$**
Block 3 Middle CON RT	Control	906.54 (148.25)	828.84 (163.09)	$t(40) = -2.61$*
	Exercise	902.85 (187.93)	830.01 (137.03)	$t(35) = -2.74$*
	Video Controller	914.57 (123.62)	858.51 (157.95)	$t(34) = -2.07$*
	Exergame	881.92 (126.22)	839.32 (167.19)	$t(33) = -1.48$
Block 3 Middle INC ACC	Control	4.22 (1.75)	5.12 (1.79)	$t(40) = 3.01$**
	Exercise	4.69 (2.01)	5.53 (2.02)	$t(35) = 3.00$**
	Video Controller	3.23 (1.83)	4.89 (1.73)	$t(34) = 4.87$***
	Exergame	4.06 (1.79)	4.82 (1.99)	$t(33) = 1.92$*
Block 3 Middle INC RT	Control	926.59 (136.54)	881.91 (148.24)	$t(40) = -2.23$*
	Exercise	955.95 (139.32)	909.17 (140.94)	$t(35) = -1.68$

	Video Controller	910.24 (124.51)	858.43 (197.72)	$t(34) = -1.39$
	Exergame	997.93 (141.29)	930.64 (156.44)	$t(33) = -2.68$*
Block 3 Outside CON ACC	Control	5.10 (1.07)	5.51 (0.87)	$t(40) = 2.43$*
	Exercise	5.39 (0.80)	5.64 (0.64)	$t(35) = 1.66$
	Video Controller	4.97 (1.18)	5.20 (0.93)	$t(34) = 1.31$
	Exergame	4.74 (1.11)	5.38 (0.95)	$t(33) = 3.97$***
Block 3 Outside CON RT	Control	832.96 (132.39)	786.22 (152.73)	$t(40) = -1.88$†
	Exercise	872.55 (140.48)	786.66 (136.79)	$t(35) = -4.23$***
	Video Controller	856.69 (132.62)	819.52 (172.22)	$t(34) = -1.269$
	Exergame	908.37 (150.19)	826.84 (141.29)	$t(33) = -3.37$**
Block 3 Outside INC ACC	Control	4.73 (1.75)	4.93 (1.57)	$t(40) = 0.60$
	Exercise	5.00 (1.77)	5.44 (1.86)	$t(35) = 1.09$
	Video Controller	3.71 (1.66)	4.69 (1.76)	$t(34) = 3.13$**
	Exergame	3.65 (1.82)	4.94 (1.35)	$t(33) = 4.27$**
Block 3 Outside INC RT	Control	996.40 (145.83)	911.34 (147.67)	$t(40) = -3.44$**
	Exercise	985.61 (141.33)	877.38 (158.17)	$t(35) = -4.67$***
	Video Controller	981.15 (142.58)	907.28 (174.84)	$t(34) = -2.03$*
	Exergame	995.68 (155.25)	943.25 (164.76)	$t(33) = -1.47$

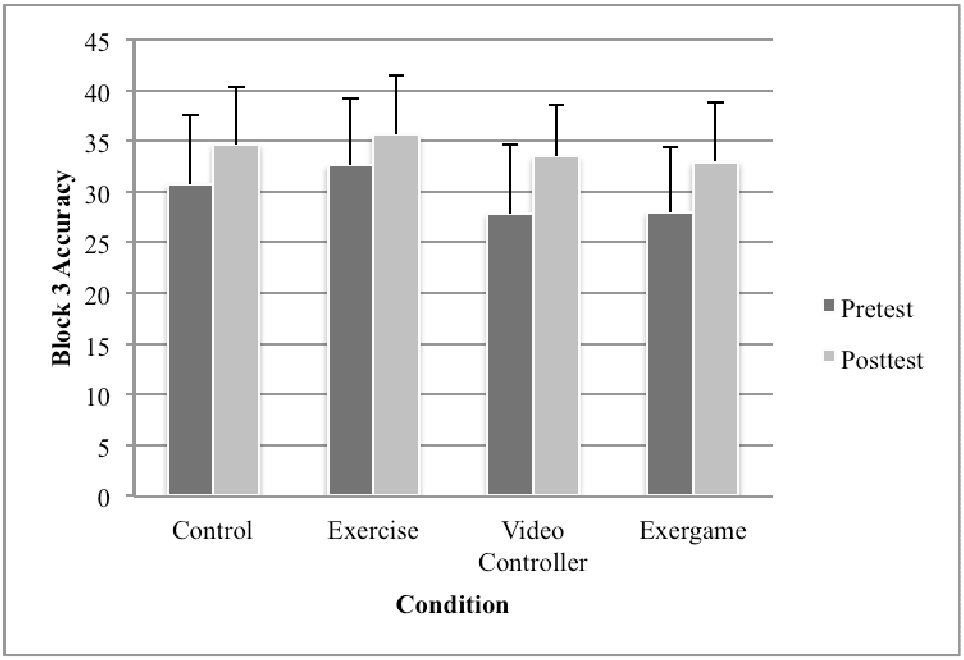
Note: Variable abbreviations: Congruent (Con), Incongruent (Inc), Accuracy (ACC) and Response Time (RT)
† < .10, *p < .05, ** p < .001, *** p < .001

Overall flanker task. The Repeated Measures ANOVA for overall flanker accuracy revealed a significant main effect of condition, $F(3, 143) = 3.83$, $p <$. 05. Simple planned contrast treating the exergame group as the reference group revealed significant differences between the exergame and exercise groups, $F(1,145) = 5.23$, $p <$. 05. There was a significant main effect of time, $F(3, 143) = 119.55$, $p < .001$. There was not a significant time by condition interaction. The Repeated Measures ANOVA for overall flanker response time revealed no significant main effects of condition or interaction effects.

Overall Block 3 trials. The Repeated Measures ANOVA for overall Block 3 accuracy revealed a significant main effect of condition, $F(3, 143) = 3.34$, $p <$.05. Simple planned contrast treating the exergame condition as the reference group revealed

significant differences between the exergame and exercise groups, $F(1,145) = 3.67$, $p < .05$. There was a significant main effect of time, $F(3, 143) = 133.29$, $p < .001$. The time by condition interaction trended towards significance, $F(3, 143) = 2.85$, $p = .08$, indicating the groups had varying patterns of differences between pretest and posttest scores (see Figure 1). All groups improved from pre- to posttest (see Table 9). Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition to compare standardized means (Rosenthal, 1991). The sedentary video game ($d = 2.77$) and the exergame group ($d = 2.23$) had higher effect sizes than the exercise ($d = 1.23$) and the control ($d = 1.70$) groups. The Repeated Measures ANOVA for overall Block 3 response time revealed no significant main effects of condition or interaction effects.

Figure 1. Pre- and Posttest by Condition for Block 3 Accuracy



Note: There were 44 possible trials in Block 3

Congruent and incongruent trials. These four variables, congruent trial accuracy and response time and incongruent trial accuracy and response time, were all correlated with age at pre- and posttest, therefore age was included as a covariate. The Repeated Measures ANCOVA for overall congruent trial response time revealed a significant main effect of condition, $F(3, 142) = 2.81$, $p < .05$. Simple planned contrast treating the exergame condition as the reference group revealed significant differences between the exergame and exercise group, $F(1,145) = 53.43$, $p <. 05$; and significant differences between the exergame and control group, $F(1,145) = 56.94$, $p <. 05$. There was not a significant main effect of time. Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition to compare standardized means (Rosenthal, 1991). The exergame group ($d = 1.32$) had the highest effect size compared to the: sedentary video game group ($d = .96$), exercise ($d = .89$) and the control ($d = .65$) group. There was a significant main effect of age, $F(3, 142) = 15.56$, $p < .001$. Regression analysis entering pretest in the first step and age in the second step significantly predicted the posttest congruent trial response time. These two predictors collectively accounted for 28% of the variance and each remained significant when included in the same model ($R^2 = .28$, $\beta = -2.85$, $p < .01$). Older children were faster in reaction time. There were no significant interaction effects. The Repeated Measures ANCOVAs for overall congruent trial accuracy, incongruent trial accuracy, and incongruent trial response time revealed no significant main effects of condition or interaction effects.

Middle focus trials. The Repeated Measures ANOVAs for overall middle focus trial accuracy and response time revealed no significant main effects of condition or interaction effects.

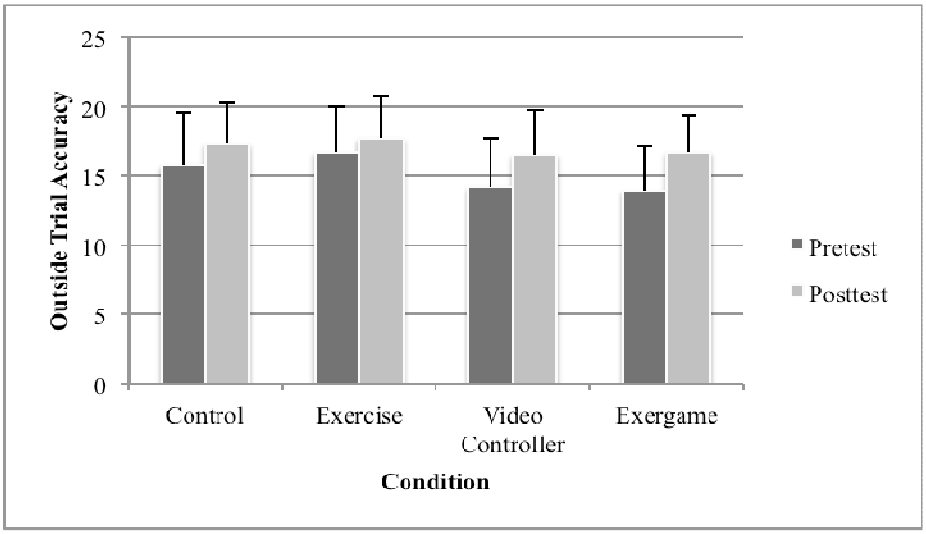
Middle focus congruent and incongruent trials. The Repeated Measures ANOVAs for middle congruent trial's accuracy and response time revealed no significant main effects of condition or interaction effects. The Repeated Measures ANOVA for middle incongruent trial accuracy revealed a significant main effect of condition, $F(3, 142) = 2.77$, $p < .05$. Simple planned contrast treating the exergame condition as the reference group revealed a trend towards significance between the exergame and exercise group, $F(1,145) = .67$, $p = .08$. There was a significant main effect of time $F(3, 142) = 39.75$, $p < .001$. There were no significant interaction effects.

The Repeated Measures ANOVA for middle incongruent response time revealed a significant main effect of condition, $F(3, 142) = 2.78$, $p < .05$. Simple planned contrast treating the exergame condition as the reference group revealed significant differences between the exergame and non-playing control group, $F(1,144) = -60.04$, $p <. 05$; and significant differences between the exergame and sedentary video game group, $F(1,144) = -79.95$, $p <. 01$. There was a significant main effect of time $F(3, 142) = 14.29$, $p < .001$. There were no significant interaction effects.

Outside focus trials. The Repeated Measures ANOVA for outside trial response time revealed no significant main effects of condition or interaction effects. The Repeated Measures ANOVA for overall outside trial accuracy revealed a significant main effect of condition, $F(3, 143) = 3.86$, $p < .05$. Simple planned contrast treating the

exergame condition as the reference group revealed significant differences between the exergame and exercise group, $F(1,145) = 1.89$, $p <. 01$; and a trend toward a significant difference between the exergame and control group, $F(1,145) = 1.23$, $p = .06$. There was a significant main effect of time, $F(3, 143) = 53.84$, $p < .01$. The time by condition interaction trended towards significance, $F(3, 143) = 2.36$, $p = .07$, indicating the groups had varying patterns of differences between pre-test and post-test scores (see Figure 2). Follow-up paired samples *t*-tests revealed the exercise group did not improve from pre- to posttest (see Table 9). The non-playing control, the sedentary video game and the exergame group, all improved from pre- to posttest. Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition to compare standardized means (Rosenthal, 1991). The exergame group ($d = 2.70$) had the highest effect size compared to the: sedentary video game group ($d = 1.55$), exercise ($d = .53$) and the control ($d = .93$) group.

Figure 2. Pre- and Posttest by Condition for Outside Trial Accuracy



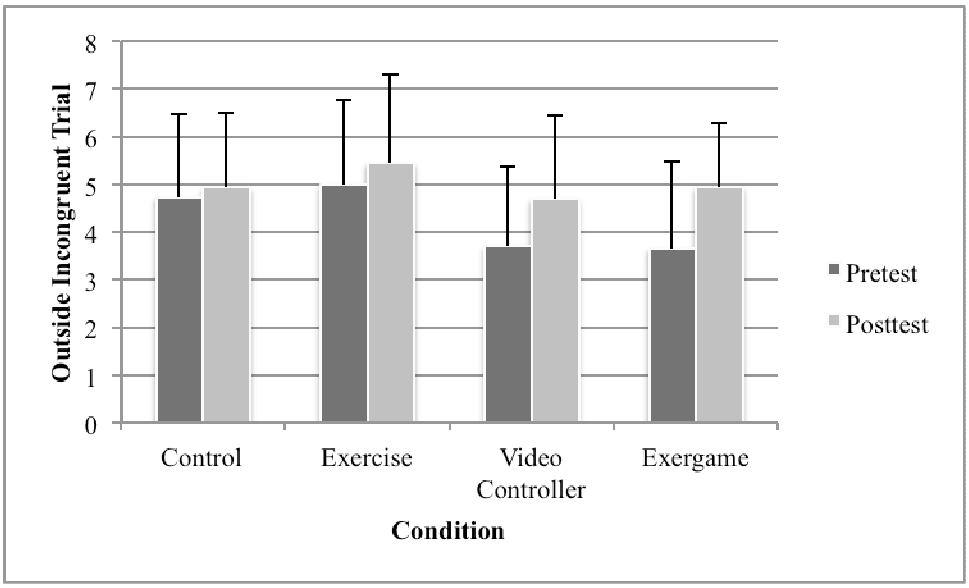
Note: There were 22 possible outside trials in Block 3

Outside focus congruent and incongruent trials. The Repeated Measures ANOVAs for outside congruent trial's accuracy revealed a trend towards a significant main effect of condition, $F(3, 142) = 2.42$, $p = .07$. Simple planned contrast treating the exergame group as the reference group revealed significant differences between the exergame and exercise group, $F(1,144) = .46$, $p <. 05$. There was a significant main effect of time, $F(3, 142) = 21.44$, $p < .001$. There was not a significant interaction effect. However, the exercise and sedentary video game group did not improve from pre- to posttest, while the exergame and control group did improve (see Table 9). Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition to compare standardized means (Rosenthal, 1991). The exergame group ($d = 1.36$) had the highest effect size compared to the: sedentary video game group ($d = .45$), exercise ($d = .56$) and the control ($d = .77$) group. The Repeated Measures ANOVA for outside congruent trial response time revealed no significant main effects of condition or interaction effects.

The Repeated Measures ANOVA for outside incongruent accuracy revealed a significant main effect of condition, $F(3, 142) = 4.45$, $p < .01$. Simple planned contrast treating the exergame condition as the reference group revealed significant differences between the exergame and exercise group, $F(1, 144) = .93$, $p <. 01$; and a trend toward a significant difference between the exergame and control group, $F(1, 144) = .54$, $p = .09$. There was a significant main effect of time, $F(3, 142) = 18.21$, $p < .001$. There was a trend towards significance for a time by condition interaction effect, $F(3, 142) = 2.17$, $p = .09$. The follow-up Paired Samples *t*-tests revealed that the exergame and sedentary video game groups improved from pre- to posttest, while the exercise and control group

did not significantly change (see Figure 3). Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition to compare standardized means (Rosenthal, 1991). The exergame group (d = 1.49) had the highest effect size compared to the: sedentary video game group (d = 1.07), exercise (d = .37) and the control (d = .19) group. The Repeated Measures ANOVA for outside incongruent trial response time revealed no significant main effects of condition or an interaction effects.

Figure 3. Pre- and Posttest by Condition for Outside Incongruent Trial Accuracy



Note: There were six possible outside incongruent trials in Block 3

Summary of the condition analysis. There were differences by condition on several variables using the exergame group as the reference group, however the analyses of interest were the time by condition interaction effects. These reveal varying patterns of change from pre- to posttest for the different conditions. These interaction effects were present for accuracy on the variables overall Block 3 trials, outside trials and outside incongruent trials. Overall, outside trials were more difficult for participants than

middle trials, and incongruent trials were more difficult than congruent trials. These three tests, therefore, were some of the hardest for participants. In Block 3, all conditions improved from pre- to posttest, however both video game conditions (i.e. exergame and sedentary video game) had larger effect sizes than the non-video game conditions (i.e. exercise and control). In addition, the simple planned contrast revealed that the exergame group was significantly lower than the exercise group. Similar findings emerged for the outside trials, where the exergame group had the largest effect from pre- to posttest. In addition, for the outside trials, the exercise group did not improve from pre- to posttest. The same pattern was revealed for the outside incongruent trials. The exergame group had the largest effect of change from pre- to posttest. For the outside trials, neither the exercise group nor the control group improved from pre- to posttest.

Table 10. *Repeated Measures ANOVA for Time by Condition Effects*

Overall Flanker ACC					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	3.83	3	.011	.978	Condition	2.64	3	.056	.974
Time	119.55	1	.000	.455	Time	57.51	1	.000	.444
Condition by Time	1.59	3	.195	.032	Condition by Time	0.45	3	.719	.018
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	2.65	3	.056	.106
					Time	61.38	1	.000	.478
					Condition by Time	2.73	3	.051	.109
Overall Flanker RT									
Effect	*F*	*df*	*p*	*η*					
Condition	1.19	3	.314	.024					
Time	109.98	1	.000	.432					
Condition by Time	0.71	3	.549	.015					
Block 3 ACC					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	3.34	3	.021	.066	Condition	2.82	3	.045	.967
Time	133.29	1	.000	.482	Time	75.34	1	.000	.511
Condition by Time	2.29	3	.081	.046	Condition by Time	1.06	3	.374	.042
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	2.59	3	.059	.976
					Time	56.45	1	.000	.457
					Condition by Time	2.673	3	.054	.107
Block 3 RT									
Effect	*F*	*df*	*p*	*η*					
Condition	1.00	3	.395	.021					
Time	60.52	1	.000	.297					

Condition by Time	0.16	3	.926	.003					
Congruent Trial ACC: Condition x Time x Age					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	0.04	3	.991	.001	Condition	0.16	3	.923	.007
Time	5.09	1	.026	.035	Time	3.40	1	.069	.046
Age	27.26	1	.000	.161	Age	14.03	1	.000	.165
Condition by Time	1.75	3	.160	.36	Condition by Time	1.84	3	.148	.072
Age by Time	1.76	1	.187	.012	Age by Time	1.56	1	.211	.072
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	0.44	3	.724	.020
					Time	1.69	1	.197	.025
					Age	13.07	1	.001	.165
					Condition by Time	1.25	3	.300	.054
					Age by Time	0.33	1	.570	.005
Congruent Trial RT: Condition x Time x Age					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	2.81	3	.042	.056	Condition	2.69	3	.053	.102
Time	0.04	1	.841	.000	Time	0.33	1	.567	.005
Age	15.75	1	.000	.099	Age	15.08	1	.000	.175
Condition by Time	0.41	3	.746	.009	Condition by Time	1.23	3	.305	.049
Age by Time	1.25	1	.265	.009	Age by Time	0.13	1	.723	.002
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	2.09	3	.110	.087
					Time	0.43	1	.514	.006
					Age	2.89	1	.093	.042
					Condition by Time	0.28	3	.843	.012
					Age by Time	1.03	1	.315	.015
Incongruent Trial ACC: Condition x Time x Age					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*

Condition	0.36	3	.779	.008	Condition	2.34	3	.888	.009
Time	3.98	1	.049	.027	Time	4.91	1	.030	.065
Age	25.70	1	.000	.153	Age	13.16	1	.001	.56
Condition by Time	0.08	3	.971	.002	Condition by Time	0.52	3	.667	.022
Age by Time	0.64	1	.427	.004	Age by Time	1.51	1	.223	.021
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	0.64	3	.593	.028
					Time	0.45	1	.503	.007
					Age	11.44	1	.001	.148
					Condition by Time	0.28	3	.844	.012
					Age by Time	0.00	1	.982	.000
Incongruent Trial RT: Condition x Time x Age					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	1.45	3	.232	.030	Condition	0.91	3	.443	.037
Time	0.61	1	.436	.004	Time	0.22	1	.640	.003
Age	8.58	1	.004	.057	Age	9.27	1	.003	.116
Condition by Time	1.41	3	.243	.029	Condition by Time	1.52	3	.217	.060
Age by Time	2.94	1	.089	.020	Age by Time	1.48	1	.228	.020
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	1.19	3	.321	.051
					Time	.16	1	.691	.002
					Age	1.41	1	.240	.021
					Condition by Time	1.44	3	.240	.061
					Age by Time	.91	1	.343	.014
Middle Trial ACC					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*

Condition	2.28	3	.082	.046	Condition	2.27	3	.088	.086
Time	85.51	1	.000	.374	Time	45.46	1	.000	.387
Condition by Time	1.06	3	.367	.022	Condition by Time	0.87	3	.461	.035
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	2.44	3	.072	.099
					Time	39.40	1	.000	.370
					Condition by Time	2.42	3	.074	.098
Middle Trial RT									
Effect	*F*	*df*	*p*	*η*					
Condition	0.92	3	.431	.019					
Time	45.54	1	.000	.242					
Condition by Time	0.32	3	.809	.007					
Middle Congruent ACC									
Effect	*F*	*df*	*p*	*η*					
Condition	1.71	3	.168	.035					
Time	24.06	1	.000	.145					
Condition by Time	0.47	3	.703	.010					
Middle Congruent RT									
Effect	*F*	*df*	*p*	*η*					
Condition	0.27	3	.844	.006					
Time	19.24	1	.000	.119					
Condition by Time	0.32	3	.811	.007					
Middle Incongruent ACC					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	2.77	3	.044	.055	Condition	2.48	3	.068	.095
Time	39.75	1	.000	.219	Time	24.54	1	.000	.257
Condition by Time	1.54	3	.207	.031	Condition by Time	0.98	3	.408	.040
					Females				
					Effect	*F*	*df*	*p*	*η*

					Condition	0.99	3	.402	.043
					Time	14.93	1	.000	.182
					Condition by Time	0.83	3	.483	.036
Middle Incongruent RT					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	2.78	3	.043	.056	Condition	0.52	3	.671	.021
Time	14.29	1	.000	.091	Time	7.09	1	.010	.091
Condition by Time	0.13	3	.941	.003	Condition by Time	0.52	3	.671	.021
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	4.47	3	.006	.167
					Time	6.35	1	.014	.087
					Condition by Time	2.14	3	.104	.087
Outside Trial ACC					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	3.86	3	.011	.075	Condition	2.79	3	.046	.104
Time	53.84	1	.000	.274	Time	36.59	1	.000	.337
Condition by Time	2.36	3	.074	.047	Condition by Time	0.47	3	.700	.019
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	2.23	3	.092	.091
					Time	17.06	1	.000	.203
					Condition by Time	2.67	3	.054	.107
Outside Trial RT									
Effect	*F*	*df*	*p*	*η*					
Condition	1.13	3	.341	.023					
Time	49.88	1	.000	.259					
Condition by Time	0.18	3	.910	.004					
Outside Congruent ACC					Males				

Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	2.42	3	.069	.049	Condition	2.42	3	.074	.093
Time	21.44	1	.000	.131	Time	10.68	1	.002	.131
Condition by Time	1.29	3	.281	.027	Condition by Time	0.47	3	.702	.020
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	0.41	3	.748	.018
					Time	11.03	1	.001	.141
					Condition by Time	2.33	3	.082	.095
Outside Congruent RT					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	1.38	3	.251	.028	Condition	0.23	3	.878	.009
Time	25.29	1	.000	.151	Time	2.62	1	.110	.036
Condition by Time	0.95	3	.420	.020	Condition by Time	1.12	3	.348	.045
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	3.31	3	.025	.129
					Time	35.79	1	.000	.348
					Condition by Time	0.82	3	.486	.036
Outside Incongruent ACC					Males				
Effect	*F*	*df*	*p*	*η*	Effect	*F*	*df*	*p*	*η*
Condition	4.45	3	.005	.086	Condition	2.83	3	.045	.107
Time	18.21	1	.000	.114	Time	10.46	1	.002	.128
Condition by Time	2.17	3	.094	.044	Condition by Time	1.43	3	.242	.057
					Females				
					Effect	*F*	*df*	*p*	*η*
					Condition	2.03	3	.118	.083
					Time	7.27	1	.009	.098

Condition by Time	1.50	3	.222	.063

Outside Incongruent RT				
Effect	*F*	*df*	*p*	*η*
Condition	0.59	3	.626	.012
Time	27.99	1	.000	.165
Condition by Time	0.57	3	.634	.012

Note: Variable abbreviations: Accuracy (ACC) and Response Time (RT)

Contrast Analyses

Based on previous research, it is unclear if the exercise aspect or the video game aspect of the study would drive improvement (Best, 2011). Therefore, contrast analyses were conducted to test for differences between the exercise groups and the video game groups. For each flanker variable, a 2 (contrasted condition) x 2 (time) Repeated Measures ANOVA was conducted. ANCOVA's with age as the covariate were used for the overall congruent and incongruent accuracy and response time. All 20 flanker variables were analyzed, however only ANOVA's with effects that are different from the original full condition analysis are reported. Means and standard deviations by condition are reported in Table 9.

Video game conditions vs. non-video game conditions. First, based on the results from the previous section, the exergame and sedentary video controller groups were combined and compared to the exercise and non-playing control groups to assess the impact of playing video games. A 2 (video game conditions vs. non-video game conditions) x 2 (time) Repeated Measures ANOVA was conducted for each of the dependent variables for the flanker task. There were no significant time by condition interaction effects revealed that were different than the original ANOVAs, see Table 11 for full results. The overall Block 3, outside trial and outside incongruent accuracy variables maintained the time by condition interaction. Larger effects of the exergame and video game controller groups drove these interaction effects. In sum, the video game conditions had different patterns of change from pre- to posttest when compared to the non-video game conditions.

Table 11. *Video Game Conditions vs. Non-Video Game Conditions Repeated Measures ANOVAs*

Overall Flanker ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	9.58	1	.002	.062
Time	121.02	1	.000	.455
Condition by Time	2.53	1	.114	.017
Overall Flanker RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	3.62	1	.069	.024
Time	109.23	1	.000	.430
Condition by Time	1.18	1	.279	.008
Block 3 ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	8.82	1	.003	.057
Time	135.33	1	.000	.483
Condition by Time	5.91	1	.016	.039
Block 3 RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	2.29	1	.132	.016
Time	61.08	1	.000	.296
Condition by Time	0.15	1	.699	.001
Congruent Trial ACC	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	0.05	1	.827	.000
Time	4.24	1	.041	.029
Age	27.62	1	.000	.161
Condition by Time	0.48	1	.492	.003
Age by Time	1.31	1	.255	.009
Congruent Trial RT	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	8.34	1	.004	.055
Time	0.05	1	.837	.000
Age	15.77	1	.000	.099
Condition by Time	0.43	1	.514	.003
Age by Time	1.29	1	.257	.009
Incongruent Trial ACC	Condition x Time x Age			

Effect	*F*	*df*	*p*	*η*
Condition	1.11	1	.294	.008
Time	4.16	1	.043	.028
Age	26.21	1	.000	.154
Condition by Time	0.02	1	.889	.000
Age by Time	0.71	1	.401	.000
Incongruent Trial RT	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	2.61	1	.108	.018
Time	0.59	1	.443	.004
Age	8.73	1	.004	.057
Condition by Time	0.85	1	.358	.006
Age by Time	2.86	1	.093	.006
Middle Trial ACC				
Effect	*F*	*df*	*p*	*η*
Condition	5.64	1	.019	.037
Time	85.95	1	.000	.372
Condition by Time	1.00	1	.318	.007
Middle Trial RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	1.55	1	.216	.011
Time	46.22	1	.000	.242
Condition by Time	0.83	1	.365	.006
Middle Congruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	3.03	1	.084	.021
Time	24.08	1	.000	.143
Condition by Time	0.97	1	.327	.007
Middle Congruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.10	1	.751	.001
Time	19.61	1	.000	.120
Condition by Time	0.85	1	.358	.006
Middle Incongruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	5.78	1	.000	.894
Time	39.75	1	.000	.216
Condition by Time	1.10	1	.296	.008
Middle Incongruent RT	Condition x Time			

Effect	*F*	*df*	*p*	*η*
Condition	0.09	1	.765	.001
Time	14.47	1	.000	.091
Condition by Time	0.25	1	.619	.002
Outside Trial ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	10.66	1	.001	.068
Time	54.85	1	.000	.274
Condition by Time	6.34	1	.013	.042
Outside Trial RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	2.93	1	.089	.020
Time	50.09	1	.000	.257
Condition by Time	0.01	1	.935	.000
Outside Congruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	6.02	1	.015	.040
Time	21.39	1	.000	.129
Condition by Time	0.34	1	.562	.002
Outside Congruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	2.68	1	.104	.018
Time	24.57	1	.000	.146
Condition by Time	0.06	1	.814	.000
Outside Incongruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	11.67	1	.001	.075
Time	18.15	1	.000	.112
Condition by Time	5.85	1	.017	.039
Outside Incongruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.42	1	.519	.003
Time	28.13	1	.000	.163
Condition by Time	1.18	1	.28	.008

Note: Variable abbreviations: Accuracy (ACC) and Response Time (RT)

Active conditions vs. sedentary conditions. Next, the exergame and exercise groups were combined and compared to the sedentary video game controller group and non-playing control groups to assess the impact of being active. 2 (active conditions vs. sedentary conditions) x 2 (time) Repeated Measures ANOVAs were conducted for each of the dependent variables for the flanker task. There were no significant interaction effects for any of the 20 dependent variables (see Table 12). Therefore, the active conditions did not have a different pattern of change from pre- to posttest when compared to the inactive conditions.

Table 12. *Active Conditions vs. Sedentary Conditions Repeated Measures ANOVAs*

Overall Flanker ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	1.43	1	.234	.010
Time	117.78	1	.000	.448
Condition by Time	1.54	1	.216	.011
Overall Flanker RT				
Effect	*F*	*df*	*p*	*η*
Condition	0.00	1	.960	.000
Time	107.61	1	.000	.426
Condition by Time	0.06	1	.813	.000
Block 3 ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.37	1	.563	.002
Time	127.61	1	.000	.468
Condition by Time	0.79	1	.373	.005
Block 3 RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.64	1	.424	.004
Time	60.80	1	.000	.295
Condition by Time	0.00	1	.997	.000
Congruent Trial ACC	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	0.00	1	.949	.000
Time	4.78	1	.030	.032
Age	28.45	1	.000	.165
Condition by Time	0.24	1	.622	.002

Age by Time	1.57	1	.221	.011
Congruent Trial RT	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	0.22	1	.643	.001
Time	0.09	1	.763	.001
Age	18.36	1	.000	.113
Condition by Time	0.85	1	.359	.006
Age by Time	1.52	1	.220	.010
Incongruent Trial ACC	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	0.00	1	.966	.000
Time	4.33	1	.039	.029
Age	28.02	1	.000	.163
Condition by Time	0.00	1	.952	.000
Age by Time	0.76	1	.386	.005
Incongruent Trial RT	Condition x Time x Age			
Effect	*F*	*df*	*p*	*η*
Condition	1.53	1	.219	.010
Time	0.39	1	.536	.003
Age	10.29	1	.002	.067
Condition by Time	3.13	1	.079	.021
Age by Time	2.48	1	.118	.017
Middle Trial ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.29	1	.589	.002
Time	84.72	1	.000	.369
Condition by Time	1.62	1	.206	.011
Middle Trial RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	1.31	1	.255	.009
Time	45.33	1	.000	.238
Condition by Time	0.06	1	.807	.000
Middle Congruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.42	1	.519	.003
Time	23.66	1	.000	.141
Condition by Time	0.24	1	.629	.002
Middle Congruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.37	1	.542	.003
Time	19.86	1	.000	.121
Condition by Time	0.12	1	.735	.001

Middle Incongruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	2.25	1	.136	.015
Time	38.59	1	.000	.211
Condition by Time	1.86	1	.175	.013
Middle Incongruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.09	1	.765	.001
Time	14.47	1	.000	.091
Condition by Time	0.25	1	.619	.002
Outside Trial ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.30	1	.582	.002
Time	50.92	1	.000	.260
Condition by Time	0.00	1	.987	.000
Outside Trial RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.14	1	.711	.001
Time	50.29	1	.000	.258
Condition by Time	0.03	1	.854	.000
Outside Congruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.42	1	.518	.003
Time	21.40	1	.000	.129
Condition by Time	0.47	1	.496	.003
Outside Congruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	1.52	1	.220	.010
Time	25.89	1	.000	.152
Condition by Time	2.79	1	.097	.019
Outside Incongruent ACC	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.99	1	.320	.007
Time	16.78	1	.000	.104
Condition by Time	0.78	1	.378	.005
Outside Incongruent RT	Condition x Time			
Effect	*F*	*df*	*p*	*η*
Condition	0.00	1	.980	.000
Time	28.59	1	.000	.166
Condition by Time	0.00	1	.968	.000

Note: Variable abbreviations: Accuracy (ACC) and Response Time (RT)

Energy Exertion as Mediator Analyses

The second hypothesis, that EF skills will change the most for children who exert the most energy, was examined. Correlational analyses revealed that time spent in moderate- to high-intensity physical activity was related to pre- and posttest for Block 3 middle congruent accuracy and middle incongruent response time. Therefore, there was justification to treat it as covariate for these two variables. A 4 (condition) x 2 (time) ANCOVA controlling for intensity revealed that there was a trend toward a significant main effect of energy expenditure for the middle congruent trials, $F(1, 139) = 3.68$, $p = .06$. Regression analysis entering pretest in the first step and energy expenditure in the second step significantly revealed that energy expenditure did not predict posttest. Pretest was the only significant predictor in the model ($R^2 = .27$, $\beta = .486$, $p < .01$). There were no significant effects for middle incongruent response time.

Gender Analyses

The third hypothesis, that gender will influence changes in EF, was examined (see Table 13 for means and standard deviations by gender). The first step of this analysis was to conduct *t*-tests comparing the means of the flanker posttest by gender. This test would show if there are significant mean differences in the outcome based on gender. The second step of the analysis was to conduct a *t*-test to compare the mean difference in the change from pretest to posttest (difference score) by gender. A significant result would mean that one gender improved more than the other gender. The third step of the analysis was to conduct a 4 (condition) x 2 (time) ANOVA for each gender, with age as a covariate when appropriate. In addition, ANOVA's for each of the contrast conditions

were conducted. These tests allowed for the examination of an interaction of gender and condition. The next step was to conduct a 4 (condition) x 2 (time) ANCOVA controlling for intensity of exercise by each gender. This test was important, as it was possible that there would be gender differences in level of intensity.

Table 13. *Means, Standard Deviations and Paired Samples t-tests by Gender by Condition*

	Condition	Gender	Pretest		Posttest		*t*-tests
Overall ACC	Control	Male	59.74	(11.57)	65.37	(6.67)	*t*(18) = 3.56**
		Female	56.55	(10.75)	63.64	(7.58)	*t*(21) = 6.26***
	Exercise	Male	59.15	(9.68)	64.45	(8.97)	*t*(19) = 3.01**
		Female	64.88	(5.97)	67.56	(4.89)	*t*(15) = 2.32*
	Video Controller	Male	52.26	(13.29)	58.26	(11.40)	*t*(18) = 4.50***
		Female	54.69	(9.79)	63.88	(6.78)	*t*(15) = 4.05***
	Exergame	Male	52.61	(10.40)	60.39	(11.22)	*t*(17) = 4.34***
		Female	57.65	(10.84)	63.53	(8.75)	*t*(16) = 3.45**
Overall RT	Control	Male	810.01	(103.75)	750.71	(85.55)	*t*(18) = -2.67*
		Female	837.39	(125.89)	774.55	(128.34)	*t*(21) = -3.62**
	Exercise	Male	858.29	(121.71)	777.86	(138.76)	*t*(19) = -4.75***
		Female	805.52	(107.29)	837.85	(105.25)	*t*(15) = -5.10***
	Video Controller	Male	887.97	(79.17)	791.78	(119.65)	*t*(18) = -3.36**
		Female	855.99	(97.73)	771.68	(101.25)	*t*(15) = -5.78***
	Exergame	Male	863.16	(113.96)	803.84	(80.63)	*t*(17) = -2.52*
		Female	866.95	(119.95)	767.11	(118.14)	*t*(16) = -4.33**
Block 3 Overall ACC	Control	Male	32.11	(6.62)	35.58	(4.65)	*t*(18) = 3.39**
		Female	29.59	(6.89)	33.77	(6.44)	*t*(21) = 4.11**
	Exercise	Male	30.50	(7.34)	34.80	(6.57)	*t*(19) = 3.33**
		Female	35.25	(4.27)	36.69	(4.66)	*t*(15) = 1.68
	Video Controller	Male	26.63	(7.89)	32.32	(5.84)	*t*(18) = 5.56***
		Female	29.31	(5.16)	34.88	(3.72)	*t*(15) = 5.78***
	Exergame	Male	26.28	(5.84)	32.17	(6.06)	*t*(17) = 5.51***
		Female	29.76	(6.60)	33.76	(5.63)	*t*(16) = 3.71**
Block 3 Overall RT	Control	Male	893.19	(91.96)	835.14	(103.02)	*t*(18) = -2.29*
		Female	915.21	(114.73)	852.96	(128.45)	*t*(21) = -3.17**

	Exercise	Male	943.42 (96.05)	852.58 (126.67)	$t(19) = -5.22$***
		Female	880.82 (104.29)	837.85 (105.25)	$t(15) = -2.52$*
	Video Controller	Male	939.68 (64.67)	866.52 (147.18)	$t(18) = -1.87$*
		Female	920.19 (103.24)	839.45 (138.42)	$t(15) = -3.63$**
	Exergame	Male	946.44 (94.36)	898.27 (92.95)	$t(17) = -2.19$*
		Female	942.28 (107.23)	857.09 (132.06)	$t(16) = -3.15$**
Block 3 CON ACC	Control	Male	10.26 (1.56)	10.63 (1.12)	$t(18) = 1.02$
		Female	9.36 (1.94)	10.23 (2.02)	$t(21) = 2.12$*
	Exercise	Male	10.10 (1.71)	11.05 (1.47)	$t(19) = 2.45$*
		Female	8.75 (2.26)	10.56 (1.79)	$t(15) = 3.29$**
	Video Controller	Male	9.95 (2.57)	11.16 (1.39)	$t(18) = 3.13$**
		Female	9.88 (2.42)	10.50 (1.97)	$t(15) = 1.27$
	Exergame	Male	10.33 (2.14)	10.56 (2.20)	$t(17) = 0.89$
		Female	9.88 (1.99)	10.64 (1.22)	$t(16) = 2.02$†
Block 3 CON RT	Control	Male	921.41 (98.93)	874.64 (123.44)	$t(18) = -1.46$
		Female	894.69 (131.31)	857.02 (120.30)	$t(21) = -1.39$
	Exercise	Male	893.43 (92.76)	817.82 (132.19)	$t(19) = -2.45$*
		Female	929.49 (112.43)	877.46 (131.57)	$t(15) = -1.29$
	Video Controller	Male	894.85 (133.69)	791.73 (142.88)	$t(18) = -3.51$**
		Female	809.36 (143.81)	794.79 (154.66)	$t(15) = -.47$
	Exergame	Male	849.80 (113.18)	724.91 (148.51)	$t(17) = -6.39$***
		Female	868.94 (115.32)	839.06 (134.26)	$t(16) = -0.89$
Block 3 INC ACC	Control	Male	8.11 (2.58)	10.84 (2.81)	$t(18) = 6.25$***
		Female	7.73 (2.76)	8.91 (3.11)	$t(21) = 2.05$†
	Exercise	Male	8.20 (3.19)	10.25 (3.02)	$t(19) = 3.34$**
		Female	8.13 (2.66)	9.38 (2.67)	$t(15) = 2.03$*
	Video Controller	Male	8.79 (3.07)	10.37 (2.67)	$t(18) = 3.10$**
		Female	9.06 (4.27)	10.56 (3.16)	$t(15) = 1.63$
	Exergame	Male	9.17 (2.96)	10.83 (2.62)	$t(17) = 1.97$†
		Female	8.06 (2.41)	10.06 (2.41)	$t(16) = 2.77$*

Block 3 INC RT	Control	Male	985.54 (115.31)	916.37 (139.28)	*t*(18) = -2.23*
		Female	964.13 (150.30)	918.95 (150.30)	*t*(21) = -1.72
	Exercise	Male	989.53 (97.61)	898.84 (154.36)	*t*(19) = -2.08*
		Female	1027.52 (126.61)	932.48 (99.19)	*t*(15) = -2.67*
	Video Controller	Male	918.93 (108.17)	882.74 (148.89)	*t*(18) = -0.97
		Female	914.89 (161.27)	885.13 (191.27)	*t*(15) = -1.23
	Exergame	Male	972.34 (126.71)	828.72 (100.00)	*t*(17) = -5.43***
		Female	973.06 (119.94)	958.57 (100.59)	*t*(16) = -.54
Block 3 Middle ACC	Control	Male	16.16 (2.71)	17.68 (2.87)	*t*(18) = 2.81*
		Female	13.91 (4.48)	17.00 (3.31)	*t*(21) = 4.50***
	Exercise	Male	14.80 (4.46)	17.30 (3.79)	*t*(19) = 4.32***
		Female	17.31 (3.18)	18.75 (2.21)	*t*(15) = 2.43*
	Video Controller	Male	13.26 (4.54)	16.21 (3.34)	*t*(18) = 3.29**
		Female	14.19 (3.27)	17.88 (2.06)	*t*(15) = 6.04***
	Exergame	Male	12.94 (3.61)	16.00 (3.59)	*t*(17) = 3.36**
		Female	15.24 (3.46)	16.53 (4.20)	*t*(16) = 1.23
Block 3 Middle RT	Control	Male	881.75 (109.36)	812.78 (118.80)	*t*(18) = -2.25*
		Female	891.35 (116.05)	851.57 (125.36)	*t*(21) = -1.93†
	Exercise	Male	933.08 (98.46)	850.67 (124.91)	*t*(19) = -4.04**
		Female	864.74 (105.34)	848.12 (97.53)	*t*(15) = -0.92
	Video Controller	Male	926.28 (89.55)	844.42 (152.03)	*t*(18) = -2.20*
		Female	902.07 (97.52)	835.65 (136.25)	*t*(15) = -2.83*
	Exergame	Male	927.84 (86.18)	892.11 (100.69)	*t*(17) = -1.91†
		Female	934.33 (116.42)	839.33 (138.71)	*t*(16) = -3.61**
Block 3 Middle CON ACC	Control	Male	4.84 (1.30)	5.32 (1.06)	*t*(18) = 2.67*
		Female	4.82 (1.23)	4.95 (1.17)	*t*(21) = 0.62
	Exercise	Male	5.15 (0.81)	5.55 (0.76)	*t*(19) = 2.03†
		Female	4.94 (1.69)	5.50 (0.73)	*t*(15) = 1.71
	Video Controller	Male	4.58 (1.12)	4.95 (1.13)	*t*(18) = 1.24
		Female	4.63 (1.59)	5.44 (0.81)	*t*(15) = 1.93†

	Exergame	Male	4.59	(1.12)	4.82	(1.47)	$t(17) = 1.07$
		Female	4.41	(1.33)	5.29	(0.92)	$t(16) = 2.87$*
Block 3 Middle CON RT	Control	Male	849.31	(159.51)	799.71	(183.14)	$t(18) = -1.06$
		Female	955.97	(120.55)	854.00	(143.17)	$t(21) = -2.66$*
	Exercise	Male	877.40	(164.65)	826.89	(148.86)	$t(19) = -1.42$
		Female	934.65	(214.77)	833.90	(122.38)	$t(15) = -2.50$*
	Video Controller	Male	913.12	(119.14)	860.82	(179.51)	$t(18) = -1.26$
		Female	916.30	(132.67)	855.76	(133.65)	$t(15) = -1.75$
	Exergame	Male	871.70	(142.97)	818.58	(189.12)	$t(17) = -1.36$
		Female	892.15	(110.44)	860.06	(144.81)	$t(16) = -.74$
Block 3 Middle INC ACC	Control	Male	4.53	(1.81)	5.63	(1.83)	$t(18) = 2.89$**
		Female	3.95	(1.70)	4.68	(1.67)	$t(21) = 1.59$
	Exercise	Male	4.70	(2.23)	5.75	(1.92)	$t(19) = 2.62$*
		Female	4.69	(1.78)	5.25	(2.18)	$t(15) = 1.49$
	Video Controller	Male	3.21	(1.90)	4.89	(1.59)	$t(18) = 3.57$**
		Female	3.25	(1.81)	4.88	(1.93)	$t(15) = 3.20$**
	Exergame	Male	4.00	(1.87)	4.59	(1.66)	$t(17) = 1.09$
		Female	4.12	(1.76)	5.06	(2.30)	$t(16) = 1.56$
Block 3 Middle INC RT	Control	Male	910.13	(161.91)	885.12	(166.09)	$t(18) = -.95$
		Female	940.81	(112.19)	879.13	(134.88)	$t(21) = -2.08$*
	Exercise	Male	981.99	(152.37)	892.53	(139.39)	$t(19) = -2.89$**
		Female	923.45	(117.66)	929.97	(144.62)	$t(15) = -.14$
	Video Controller	Male	931.00	(134.88)	848.18	(240.07)	$t(18) = -1.45$
		Female	885.59	(110.07)	870.59	(138.41)	$t(15) = -.33$
	Exergame	Male	937.49	(159.78)	925.58	(165.12)	$t(17) = -0.34$
		Female	1058.38	(88.79)	935.71	(152.18)	$t(16) = -3.88$***
Block 3 Outside ACC	Control	Male	15.95	(4.44)	17.89	(2.26)	$t(18) = 2.34$*
		Female	15.68	(3.21)	16.77	(3.49)	$t(21) = 1.78\dagger$
	Exercise	Male	15.70	(3.66)	17.50	(3.33)	$t(19) = 1.84\dagger$
		Female	17.94	(2.35)	17.94	(2.82)	$t(15) = 0.00$

	Video Controller	Male	13.37	(3.98)	16.11	(3.57)	$t(18) = 4.17$**
		Female	15.13	(2.73)	17.00	(2.68)	$t(15) = 2.26$*
	Exergame	Male	13.33	(2.81)	16.17	(3.28)	$t(17) = 6.27$***
		Female	14.53	(3.63)	17.24	(1.86)	$t(16) = 4.88$***
Block 3 Outside RT	Control	Male	903.53	(92.96)	856.59	(96.25)	$t(18) = -1.74$†
		Female	937.29	(124.77)	855.10	(141.34)	$t(21) = -3.52$**
	Exercise	Male	950.64	(107.43)	855.21	(134.25)	$t(19) = -4.81$***
		Female	895.54	(108.85)	826.27	(120.15)	$t(15) = -3.49$**
	Video Controller	Male	954.94	(74.52)	888.15	(155.22)	$t(18) = -1.47$
		Female	935.95	(120.45)	843.92	(148.28)	$t(15) = -3.06$**
	Exergame	Male	961.82	(122.84)	904.51	(92.87)	$t(17) = -1.86$†
		Female	950.93	(116.23)	874.14	(130.78)	$t(16) = -2.34$*
Block 3 Outside CON ACC	Control	Male	4.89	(1.29)	5.53	(0.77)	$t(18) = 2.27$*
		Female	5.27	(0.83)	5.50	(0.96)	$t(21) = 1.09$
	Exercise	Male	5.40	(0.68)	5.65	(0.67)	$t(19) = 1.31$
		Female	5.38	(0.96)	5.63	(0.62)	$t(15) = 1.00$
	Video Controller	Male	4.74	(1.05)	5.05	(0.97)	$t(18) = 1.30$
		Female	5.25	(1.29)	5.38	(0.89)	$t(15) = 0.49$
	Exergame	Male	4.71	(1.26)	5.12	(1.11)	$t(17) = 1.51$
		Female	4.76	(0.97)	5.65	(0.70)	$t(16) = 5.22$***
Block 3 Outside CON RT	Control	Male	797.01	(152.87)	790.71	(175.24)	$t(18) = -0.15$
		Female	864.01	(105.71)	782.35	(134.44)	$t(21) = -2.95$**
	Exercise	Male	850.59	(138.92)	765.55	(133.49)	$t(19) = -3.49$**
		Female	899.99	(141.97)	813.51	(140.45)	$t(15) = -2.48$*
	Video Controller	Male	830.87	(144.09)	826.76	(199.39)	$t(18) = -0.09$
		Female	887.36	(114.47)	810.92	(139.19)	$t(15) = -2.09$*
	Exergame	Male	817.48	(140.85)	794.01	(144.17)	$t(17) = -0.70$
		Female	999.27	(95.53)	859.67	(134.54)	$t(16) = -4.72$***
Block 3 Outside INC ACC	Control	Male	4.63	(1.89)	4.74	(1.88)	$t(18) = 0.19$
		Female	4.82	(1.65)	5.09	(1.27)	$t(21) = 0.74$

	Exercise	Male	5.00	(1.56)	5.80	(1.68)	$t(19) = 1.30$
		Female	5.00	(2.07)	5.00	(2.03)	$t(15) = 0.00$
	Video Controller	Male	3.89	(1.56)	4.68	(1.92)	$t(18) = 2.33$*
		Female	3.50	(1.79)	4.69	(1.62)	$t(15) = 2.13$*
	Exergame	Male	3.59	(1.77)	5.24	(1.39)	$t(17) = 3.45$**
		Female	3.71	(1.93)	4.65	(1.27)	$t(16) = 2.55$*
Block 3 Outside INC RT	Control	Male	923.10	(155.09)	876.90	(164.64)	$t(18) = -1.21$
		Female	1059.67	(104.11)	941.08	(127.68)	$t(21) = -3.81$**
	Exercise	Male	976.08	(136.52)	870.25	(178.42)	$t(19) = -3.95$**
		Female	997.51	(150.74)	886.29	(133.77)	$t(15) = -2.71$*
	Video Controller	Male	985.15	(145.55)	908.65	(214.65)	$t(18) = -1.35$
		Female	976.40	(143.58)	905.66	(118.30)	$t(15) = -1.59$
	Exergame	Male	954.55	(165.86)	941.74	(185.71)	$t(17) = -.24$
		Female	1036.81	(136.41)	944.75	(146.62)	$t(16) = -1.95$†

Note: Variable abbreviations: Congruent (Con), Incongruent (Inc), Accuracy (ACC) and Response Time (RT)
† < .10, *p < .05, ** p < .001, *** p < .001

Pre- and posttest outcomes by gender. Independent Samples *t*-tests with gender as the grouping variable and each flanker dependent variable at pre- and posttest were conducted. At pretest, there were several significant differences between males and females. There was a significant difference for outside trial accuracy, $t(145) = 1.97$, $p < .05$. Females ($M = 15.79$, $SD = 3.32$) had significantly higher pretest scores than males ($M = 14.62$, $SD = 3.91$). There was a significant difference by gender for middle congruent response time, $t(145) = 2.02$, $p < .05$. Males ($M = 878.04$, $SD = 146.83$) had significantly faster pretest scores than females ($M = 926.95$, $SD = 146.29$). There was a significant difference by gender for outside congruent response time, $t(145) = 3.85$, $p < .001$. Males ($M = 824.51$, $SD = 142.75$) had significantly faster pretest scores than females ($M = 909.77$, $SD = 123.72$). There was a significant difference by gender for outside incongruent response time, $t(145) = 2.61$, $p < .01$. Males ($M = 960.08$, $SD = 149.42$) had significantly faster pretest scores than females ($M = 1021.43$, $SD = 133.80$). At posttest, the only significant difference was for the overall incongruent trial accuracy, $t(145) = 1.95$, $p = .05$. Males ($M = 10.57$, $SD = 2.75$) had significantly higher posttest scores than females ($M = 9.66$, $SD = 2.88$).

Summary of gender differences at pre- and posttest. In summary, girls were more accurate on the outside trials at pretest, while boys were faster at pretest on three variables. At posttest, girls made up the difference in reaction time on all of those variables; and boys made up the difference in accuracy on the outside trials. Boys also increased their accuracy at posttest overall on the incongruent trials compared to girls. Further analysis examined the change from pre- to post by gender.

Difference scores by gender. Next, difference scores were created for the 20 variables of interest by subtracting pretest from posttest (see Table 14 for means and standard deviations). These were created in order to examine the degree of change regardless of baseline for each gender. Independent Samples *t*-tests with gender as the grouping variable and each flanker dependent variable difference score were conducted.

Table 14. *Means (Standard Deviations) of Difference Scores for Flanker*

Variable	Mean (Standard Deviation)
Block 3 Middle Trials RT	-61.06 (109.41)
Block 3 Middle Trials ACC	2.46 (3.23)
Block 3 Outside Trials RT	-73.44 (125.17)
Block 3 Outside Trials ACC	1.88 (3.18)
Block 3 Middle Congruent Trials RT	-61.97 (169.99)
Block 3 Middle Congruent Trials ACC	0.46 (1.15)
Block 3 Outside Congruent Trials RT	-60.62 (151.03)
Block 3 Outside Congruent Trials ACC	0.38 (1.00)
Block 3 Middle Incongruent Trials RT	-51.29 (166.06)
Block 3 Middle Incongruent Trials ACC	1.05 (1.99)
Block 3 Outside Incongruent Trials RT	-79.84 (180.73)
Block 3 Outside Incongruent Trials ACC	0.71 (2.07)
B3 Overall Congruent RT	-61.29 (132.67)
B3 Overall Congruent ACC	0.84 (1.75)
B3 Overall Incongruent RT	-65.56 (141.32)

B3 Overall Incongruent ACC	1.75	(2.79)
Block 3 Overall RT	-67.85	(105.07)
Block 3 Overall ACC	4.34	(4.63)
Flanker Task Overall RT	-76.51	(89.15)
Flanker Task Overall ACC	6.21	(6.92)

Note: Variable abbreviations: Accuracy (ACC) and Response Time (RT)
A decrease in RT means participants were faster in posttest than pretest

There were gender differences in accuracy. There was a trend toward significance by gender for overall accuracy on the task, $t(145) = 1.88$, $p = .06$. Females ($M = 7.31$, $SD = 7.27$) had a higher change in accuracy from pre- to posttest than males ($M = 5.18$, $SD = 6.46$). There was trend toward significance by gender for middle accuracy trials, $t(145) = 1.86$, $p = .07$. Females ($M = 2.97$, $SD = 3.32$) had a significantly higher change in accuracy from pre- to posttest than males ($M = 1.99$, $SD = 3.10$).

There were also gender differences in response time. There was a significant difference by gender for the congruent trials response time, $t(145) = 2.45$, $p < .05$. Males ($M = -84.22$, $SD = 156.98$) were significantly faster from pre- to posttest than females ($M = -33.84$, $SD = 134.97$). There was a significant difference by gender for the middle trials response time, $t(145) = 2.10$, $p < .05$. Males ($M = -79.17$, $SD = 119.39$) were significantly faster from pre- to posttest than females ($M = -41.68$, $SD = 94.63$). There was a trend toward a significant difference by gender for the middle incongruent trials response time, $t(145) = 1.86$, $p = .07$. Males ($M = -79.17$, $SD = 119.39$) were significantly faster from pre- to posttest than females ($M = -41.68$, $SD = 94.63$). There was a significant difference by gender for the middle congruent trials response time,

$t(145) = 2.49$, $p < .05$. Males ($M = -95.21$, $SD = 157.59$) were significantly faster from pre- to posttest than females ($M = -26.39$, $SD = 176.57$). There was a trend toward a significant difference by gender for the outside trials response time, $t(145) = 1.77$, $p = .08$. Males ($M = -90.92$, $SD = 132.03$) were significantly faster from pre- to posttest than females ($M = -54.72$, $SD = 115.39$).

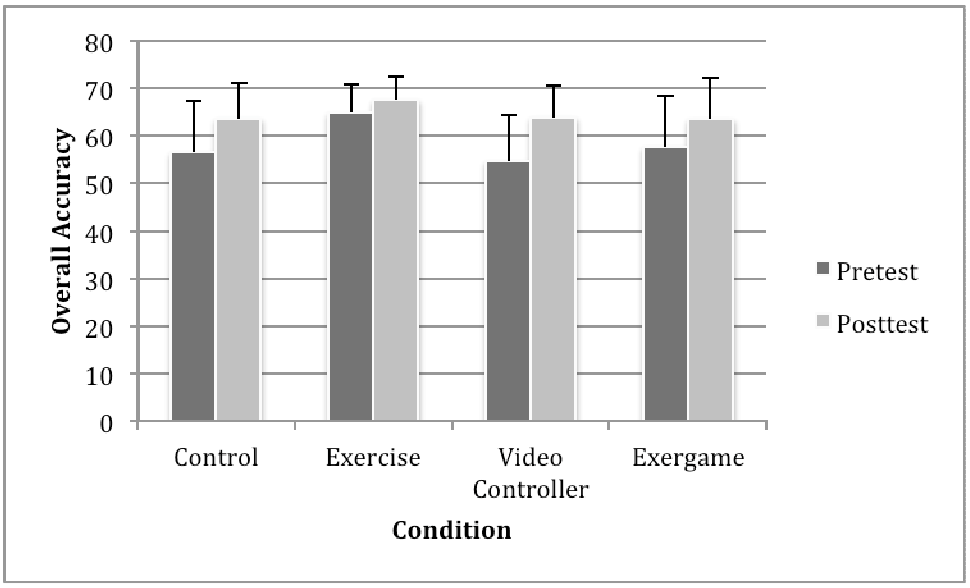
Summary of change scores by gender. In summary, there were differences in change from pre- to posttest by gender. Girls had a higher change in accuracy on the overall task and middle trials. Boys had a greater change in reaction time than girls, becoming faster, on congruent, middle, outside, middle incongruent and middle congruent trials.

Condition with gender. 4 (condition) x 2 (time) ANOVAs were conducted for each flanker variable by gender. The ANOVAs for the gender analysis were compared to the 4 (condition) x 2 (time) ANOVA's and differences were reported in Table 10 and means, standard deviations and Paired Samples *t*-tests are reported in Table 13. If there were no differences in significant interaction effects then the gender analysis was not reported. There were differences by gender for several types of flanker trials where girls had a condition by time interaction and boys did not.

Girls had a significant time by condition interaction for the overall flanker task, however boys did not. This interaction was not present in the original ANOVA. Paired Samples *t*-tests revealed that all conditions improved from pre- to posttest. Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition to compare standardized means (Rosenthal, 1991). The control group ($d = 2.73$) had the highest

effect size compared to the: sedentary video controller group (d = 2.09), exercise (d = 1.06) and the exergame (d = 1.73) group (see Figure 4).

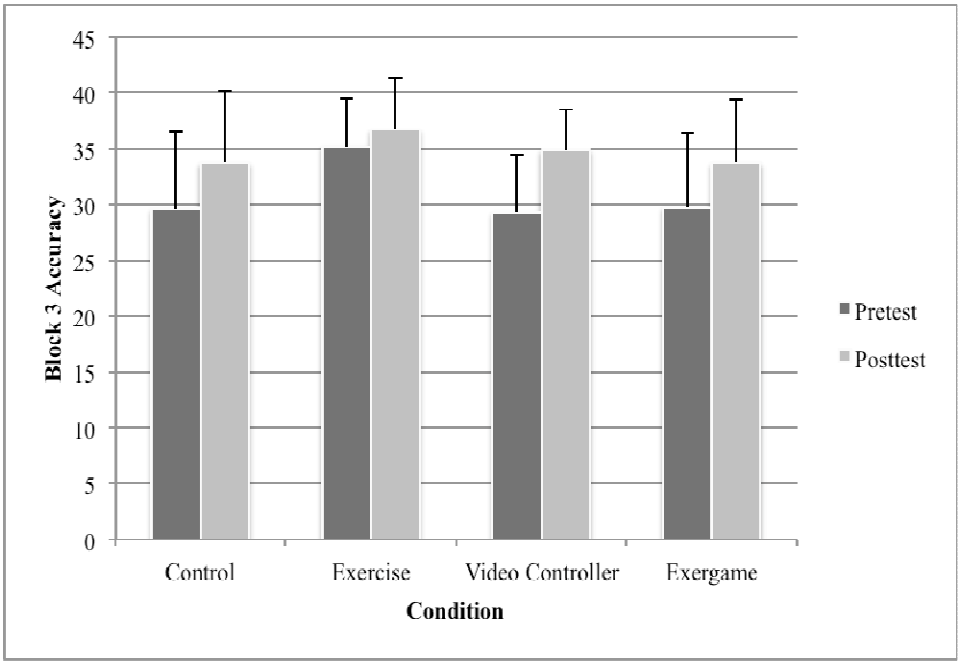
Figure 4. Girls Pre- and Posttest for Overall Accuracy



Note: There were 76 possible trials in the overall flanker task

On Block 3 accuracy, the main ANOVA had a trend towards a condition by time interaction. Girls had a significant condition by time interaction on the Block 3 trials but boys did not. For girls, Paired Samples *t*-tests revealed that all conditions improved from pre- to posttest, except for the exercise condition. Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test (Rosenthal, 1991). The sedentary video game group (d = 2.99) had the highest effect size compared to the: control group (d = 1.79), exercise (d = .87) and the exergame (d = 1.85) group (see Figure 5).

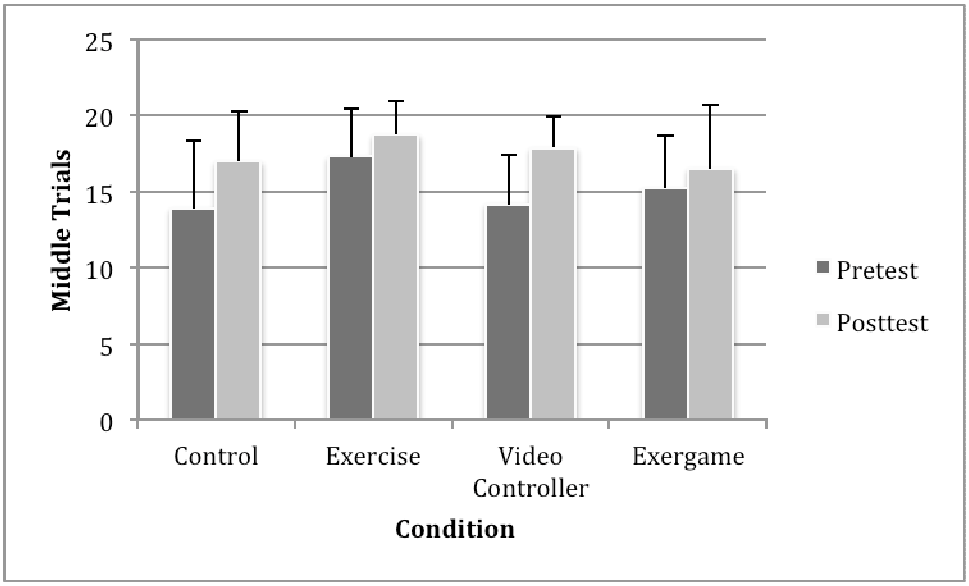
Figure 5. Girls Pre- and Posttest for Overall Block 3 Accuracy



Note: There were 44 possible trials in Block 3 overall

Girls had a significant time by condition interaction for the middle trials, however boys did not. This interaction was not present in the original ANOVA. Paired Samples *t*-tests revealed that all conditions improved from pre- to posttest, except the exergame group. Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition (Rosenthal, 1991). The sedentary video controller group (d = 3.12) had the highest effect size compared to the control group (d = 1.96), exercise group (d = 1.25) and the exergame (d = .62) group (see Figure 6).

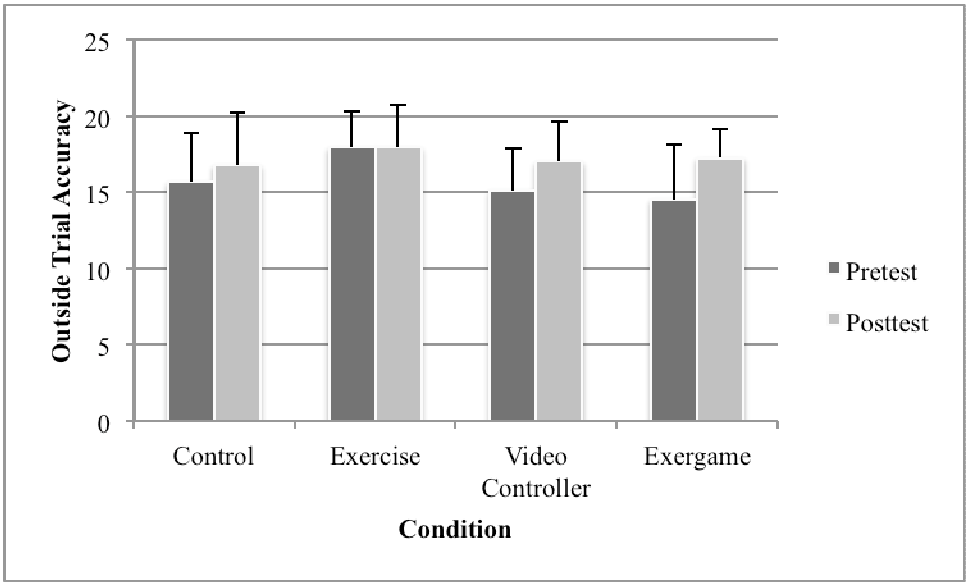
Figure 6. Girls Pre- and Posttest for Middle Trial Accuracy



Note: There were 22 possible middle trials

For outside trial accuracy, the main ANOVA had a trend towards a condition by time interaction. By gender, girls had a significant condition by time interaction on the outside trials while boys did not. Paired Samples *t*-tests revealed that for girls, all conditions improved from pre- to posttest, except for the exercise condition; and the control group only trended towards significance. Cohen's *d* effect sizes were calculated using the Paired Samples *t*-test for each condition (Rosenthal, 1991). The exergame group (d = 2.44) had the highest effect size compared to the control group (d = .78), the exercise group (d = .00) and the sedentary video controller group (d = 1.17) group (see Figure 7).

Figure 7. Girls Pre- and Posttest for Outside Trial Accuracy



Note: There were 22 possible middle trials

Summary of gender by condition analyses. The four variables that had differences by gender were all based on time by condition differences for girls. There were varying patterns of change from pre- to posttest for different conditions, however these patterns were different for each of the four variables. For example, on the overall Block 3 and middle trial accuracy the video controller group had the largest effect, but not for the overall task or outside trial accuracy. The exercise group had no change from pre- to posttest on the outside trials or Block 3 overall accuracy. The exergame group did not change significantly from pre- to posttest on the middle trials, but had the largest effect size for the outside trials. On the outside trials the control group did not change from pre- to posttest, however the control group had the largest effect size for the overall task. Therefore, it is difficult to interpret how participating in the different conditions impacts girls EF.

Gender with exercise intensity. Based on previous research, it was hypothesized that there may be a difference in level of energy expenditure by gender. Therefore, the following analyses examined differences by gender in energy expenditure. Previously reported analyses showed that there were no differences in gender for overall level of energy expenditure, as measured by calories and time in the moderate- to high-intensity heart rate zone. The relationship between the difference score for each EF outcome and heart rate zone were examined with Bivariate Correlations by gender. There were no significant relationships between any of the EF difference scores for boys. However, there were several relationships for girls (see Table 15). The higher level of energy expenditure the more accurate girls were on the congruent trials, middle congruent trials and outside congruent trials. In addition, the higher level of energy expenditure was related to reaction time for girls. The more energy expended the faster overall on the task from pre- to posttest, overall on Block 3 and on middle trials.

Table 15. *Correlations between Energy Expenditure and Flanker Outcomes for Girls*

Variable	Time in Heart Rate Zone
Overall Task RT	.38***
Block 3 RT	.24*
Blue RT	.24*
Congruent ACC	.37**
Middle Congruent ACC	.36**
Outside Congruent ACC	.24*

Note: Variable abbreviations: Congruent (Con), Incongruent (Inc), Accuracy (ACC) and Response Time (RT)
*$p < .05$, ** $p < .001$, *** $p < .001$

Independent sample *t*-tests by each condition revealed that only the exergame group had differences in energy expenditure by gender. Girls in the exergame group ($M = 10.79$, $SD = 9.05$) expended more energy then boys in the exergame group ($M = 3.54$, $SD = 4.95$), $t(33) = 2.96$, $p < .01$. Next, a 4 (condition) x 2 (time) Repeated Measures ANCOVA controlling for intensity of exercise was conducted for the middle congruent accuracy and middle incongruent response time by gender. There were no main effects of energy expenditure or interaction effects by gender. Finally, a 2 (active vs. sedentary condition) x 2 (time) Repeated Measures ANCOVA controlling for intensity of exercise was conducted for the middle congruent accuracy and middle incongruent response time by gender. The middle congruent accuracy trials ANCOVA revealed a main effect of energy expenditure for both girls, $F(1, 66) = 4.18$, $p < .05$ and for boys, $F(1, 72) = 3.99$, $p < .05$. There were no main effects of condition or any interaction effects. There were no significant findings for the middle incongruent response time ANCOVA.

Summary of energy expenditure by gender. In the overall study, there were no differences in energy expenditure between girls and boys. However, further analysis revealed that girls in the exergame group did have significantly higher energy expenditure than boys. The exercise group, however, had no differences in energy expenditure between boys and girls. There were correlational relationships between the changes from pre- to post for girls. The more energy girls expended improved the change in accuracy and response time. This pattern was not revealed for boys; there were no significant relationships between energy expenditure and the change score.

Chapter 5: Discussion

Interactive media plays a central role in children's lives (Rideout et al., 2010); however, few studies have examined how engagement with different interactive media platforms impacts children's cognitive development (Blumberg et al., 2013). Research has found that a variety of interventions, including exercise and video game play, can improve EF skills in the short and long term (Diamond, 2012). The current study examined if it is the nature of the activity, such as physical movement, or cognitive engagement in an enjoyable activity that drives changes in EF (Best, 2011; Green & Bavelier, 2007). Acute change in EF was examined using a between-subjects design with four conditions. The conditions varied in the level of physical activity and cognitive engagement. The current study is one of few studies comparing playing an exergame to exercise. In addition, there has been only one other known study by Gao and Mandryk (2012) that compared the same video game across platforms (i.e. active vs. inactive). These levels of control allowed for comparisons of the impact of physical activity versus video game play on children's EF.

Children in all conditions improved from pre- to posttest on the flanker task as well as many of the sub trials on the flanker task; however, the exergame group improved more than the other three conditions from pre- to posttest on two sub trials that require the highest level of inhibition skills. In addition, both the exergame and the sedentary video game groups had the largest changes from pre- to posttest on the block of the flanker task that required switching between rules. The results are discussed first in terms of previous literature on EF and the cognitive processing skills required for the

various measurements. Second, differences between the exergame and exercise conditions will be discussed based on previous research that has compared these two types of experiences including, energy expenditure's role in impacting EF. Third, the differences between the active and sedentary video game groups will be considered in context of prior research on video games. Finally, potential mediators and moderators of the experience are discussed, especially video game experience and gender.

Executive Function

EF skills are the cognitive skills that work together to achieve higher-order functions, such as problem solving and planning (Zelazo et al., 1997). Inhibition is a central component of EF (Best & Miller, 2010; Miyake et al. 2000). However, EF also includes selective attention, task switching, working memory and manipulation of information in long-term memory. Whether EF is domain-general or a set of independent skills has been debated in the literature, however most scholars agree that EF is one construct of skills that work together to organize processes (Best & Miller, 2010; Zelazo & Frye, 1998; Zelazo et al., 2005). Interventions that improve EF are of interest as research has connected higher EF skills with improved academic outcomes and classroom behavior (Best et al., 2009). A variety of contexts may impact EF because these skills have an extended development (Best et al., 2009; Zoelch et al., 2005). With age, children develop increased processing efficiency and attentional resources allowing for better coordination of lower-level cognition (Best et al., 2009; Zoelch et al., 2005). Research found successful EF interventions increased in difficulty, engaged more cognitive resources, and were activities children enjoyed (Diamond, 2012).

In the current study, three age-appropriate EF tasks were used pre- and post-activity in order to capture a range of EF levels in a sample of 7 to 12 years old. Three tasks that measured selective attention and inhibition were selected in order to isolate these two processes (Best & Miller, 2010). However, children demonstrated ceiling effects on the stroop and go/no-go tasks in accuracy at pretest, whereas the flanker task had enough variation for analysis. The findings of the ceiling effects in the stroop and go/no go tasks are considered briefly, and then the analyses of the flanker task are discussed in detail.

Measuring EF is challenging because it is difficult to isolate the different processes (Zelazo et al., 2005; Zoelch et al., 2005). If tasks require multiple processes then the interpretation of results is difficult because it is unclear if overall EF or a sub-component is driving the result (Best & Miller, 2010). An additional complication of measuring EF is that different components have different developmental trajectories (Zelazo et al., 2005; Zoelch et al., 2005). Therefore, older children may have ceiling effects if the task is too easy, but younger children cannot succeed if the task is too difficult or requires multiple processes.

Ceiling effects in the current study were not anticipated as previous research found a strong linear developmental trend for both the stroop and go/no-go task (Kim et al., 2007; Zoelch et al., 2005). Even though EF develops throughout childhood and into adolescence, research on some tasks has found that by age 8 children achieve an adult-level performance (Zelazo et al., 2004; Zoelch et al., 2005). It has been hypothesized that the lack of a linear trend through childhood may be because some processes develop

earlier or because the task is not challenging enough (Zelazo et al., 2004; Zoelch et al., 2005). McDemott, Perez-Edgar, and Fox (2007) discussed that the developmental changes in EF may be driven by inhibitory control. They stated that the flanker task requires processes beyond selective attention and inhibition, including related skills such as cuing effects, spatial-attention and susceptibility to interference (McDermott et al., 2007). Children must be able to suppress distractors and override competing information/rules in order to reduce the conflicting rule and implement the task (McDermott et al., 2007). These additional processing challenges may be why the flanker task was the most difficult of the three tasks for children. The stroop and go/no-go tasks did not have these additional challenges, therefore may have been too easy for children in the sample.

The flanker task analyses concentrated on the last block, which required switching back and forth between middle and outside focus trials. This switch trial block yielded larger effects than the single focus blocks, similar to previous research (Diamond, 2009). The switch trials accuracy and reaction time were the main variables of interest as they represented the ability to switch between focusing on the middle and outside fish as well as whether the target fish faced the same direction or the opposite direction as the other fish (i.e., congruent and incongruent trials). Diamond (2009) explained that because the block combines classic flanker trials (i.e. middle) with reverse flankers (i.e. outside), participants can never use global processing commands, such as "slow down" or "change" or "repeat."

Similar to previous research (Hillman et al., 2009; Rueda, et al., 2004), participants were faster and more accurate on congruent trials compared to incongruent trials on the flanker task. Older children were also faster on both congruent and incongruent trials, which was also similar to previous findings (Hillman et al., 2009; Rueda, et al., 2004). Older children have more cognitive resources, therefore, are able to process these trials faster than younger children. Incongruent trials during the task-switching block are the most difficult trial type for children (Rueda et al., 2004). Incongruent trials require reducing the interference of the distracting stimuli (i.e. fish facing in the opposite direction) while selectively attending to the area of focus (i.e. middle or outside) and inhibiting the rule from the previous trial.

The first hypothesis examined if participants in the exergame condition had higher EF scores after the intervention when compared to children in the exercise, sedentary video game and non-playing control conditions. This hypothesis was supported. The participants in the exergame group had a larger change from pre- to posttest on the outside trials and outside incongruent trials compared to the other three conditions. Outside or reverse flanker trials are more difficult because they require the participant to take their focus off of the middle fish and shift rules to focus on the outside fish. Outside incongruent trials are the most difficult trial type; not only does the child have to shift rules to the outside fish, he or she also has to reduce the interference from the conflicting direction of the middle fish. At pretest, children in the exergame group were significantly less accurate on these trials; and children in the exergame had larger gains than on the other trial types. In addition, in the block in which children had to

switch between rules the participants in the exergame group had a larger effect of change from pre- to posttest in the block in which children had to switch between rules compared to the exercise and non-playing control groups. The sedentary video game group also had a larger effect of change compared to the exercise and the non-playing control groups on this same block.

It is important to note that these patterns of findings were not replicated for response time. Children in the video game conditions became more accurate than the other conditions after the activity, but did not become faster. This means that while children became better at understanding and responding to the rule, their processing speed did not improve. One of the reasons for the differences between accuracy and response time may be because children use all their cognitive resources in order to succeed on these difficult trials, meaning had to go slow enough to process all of the rules. In addition, Rueda et al. (2004) found that 10-year-olds were almost as accurate as adults on the flanker task, but they were significantly slower. This supports the current finding; children are still developing these processes of coordinating inhibition, rule shift, and conflict interference. They are able to become more accurate, but this depletes resources so they cannot also speed up their response.

The video game DDR may be uniquely suited to improve the inhibition skills needed for the flanker task. During DDR, there are many arrows that scroll across the screen. Children must focus on the direction of the topmost arrow stepping in the coordinated direction; at the same time, they must also attend to the sequence of upcoming arrows. This process requires inhibition and reduction of conflict interference.

The gross motor movements of stepping may reinforce these skills even more than the fine motor skills of pressing a button, driving the increased improvement between the exergame and sedentary video game groups on the trials that require the most inhibition. In addition, the combination of video game play with exercise in the exergame group had a greater impact than exercise alone. This suggests that exergame play may have challenged children in a way that improved inhibition skills above and beyond physical exertion.

Exergame Compared to Exercise Condition

The exergame group had larger improvements from pre- to posttest compared to the exercise group on the switch trial block and the trials requiring the most processes, outside and outside incongruent trials. Previous research has found that children in an exercise condition significantly improved their response time on incongruent trials of the flanker task more than a control group (Hillman et al., 2009). In the current study, children in the exercise group did not show a larger effect than the exergame group from pre- to posttest on the block where children have to switch back and forth between middle and outside focus trials. The exercise group did not improve from pre- to posttest on the trials requiring the most inhibition (i.e. outside and outside incongruent). Although the participants in the exercise group had to use gross motor skills and exert energy, they did not have to inhibit their responses in anyway to perform the exercises. The exercises were aerobic and goal-directed, but there was not feedback for incorrect movements. In addition, in the exercise condition there were no conflicting or distracting

stimuli for the children to process. These findings suggest that exergame play provided benefits to EF beyond the benefits of exercise.

Previous research on exercise has suggested that at least 20 minutes is needed for EF change (Tomporowski, 2003). Therefore, all participants in the current study averaged about 20 minutes of either exergame play or exercise in the sessions. Previous research on exergames has had mixed results demonstrating that exergames may be more suited to promote EF than exercise (Anderson-Hanley et al., 2011; Anderson-Hanley et al., 2012; Best 2011; Gao & Mandryk, 2012; O'Leary et al., 2011). However, there have been variations in the amount of time participants used exergames in these studies. Anderson-Hanley et al. (2012) found that older adults in an exergame condition improved cognitive skills more than their peers in an exercise condition after three months of daily sessions up to 45 minutes. O'Leary et al. (2011) found the opposite, that participants increased attentional resources more after exercise than exergame play after a single 20-minute session. However, Gao and Mandryk (2012) found no differences in cognition after 10 minutes of exergame play or exercise. Gao and Mandryk's (2012) exercise and exergame session was only 10 minutes long, though participants improved after both types of activity. Previous research has suggested that there may be a certain "dose" of exercise or exergame play needed to improve EF.

The current research controlled for several factors that varied in previous studies comparing exergames to exercise. First, in the current study children performed aerobic movements similar to DDR in the exercise condition ensuring that the types of movements were similar. Second, there were no differences in levels of competition

between the exergame and exercise group because Staiano et al. (2012) found that competitive exergame play increased EF for youth more than cooperative exergame play. Finally, the current study used tasks that measured the cognitive processes (i.e. attention and inhibition) that were needed to play the video game. Controlling type of movement and competition, as well as ensuring the EF task measured the skills practiced in the video game, allowed for a clearer comparison between the exergame and exercise group.

Previous research on exergames and cognition had variations in several factors: type of movements, competition and amount of inhibition needed. Anderson-Hanley and colleagues (2012) compared cyber-cycling to a traditional sedentary bike, which are the same types of physical activity. The exergame group did better than the exercise group on cognitive skills. There was not more inhibition needed to cyber-cycle, however there was a competitive element to exergame play. The increased competition was found to motivate participants, which may have contributed to the increase in EF for this group (Anderson-Hanley et al., 2012).

Gao and Mandryk (2012) and O'Leary et al. (2011), in within-subjects designs, compared playing an exergame to running on a treadmill. There were differences in the type of movements required for these two activities. The exergame involved more complicated aerobic movements compared to running, and aerobic exercise has been found to increase EF more than repetitive exercise (Best, 2011). In addition, the exergames both had a competitive element compared to running. Based on these two factors, it would be expected that the exergame session would increase EF more than exercise; however, neither study found that after exergame play participants improved

more than after the exercise session (Gao & Mandryk, 2012; O'Leary et al., 2011). There were also differences in the video games in terms of if inhibition was needed. The exergame played in O'Leary et al.'s (2011) study was an exercise-based game that did not require inhibition. The exergame used by Gao and Mandryk (2012) required inhibition as participants had to grab red and green apples while avoiding grabbing bombs. The discrepancies in findings from three studies suggest that perhaps any type of movement or physical exertion can improve EF for adults; however, there may be certain aspects of exergame play that can boost these improvements, such as competition or practice using inhibition skills.

Energy expenditure's impact on EF. Previous research has shown that acute changes in EF can occur after 10 to 40 minutes of exercise at a moderate intensity, at least 60% of their maximum heart rate (Tomporowski, 2003). Therefore, in the current study energy expenditure was operationalized as the amount of time spent above 60% of maximum heart rate. Participants in the active conditions did spend more time in a moderate to high physical activity zone when compared to the sedentary conditions. The exercise group spent about 18 minutes at moderate intensity, however the exergame group only averaged 7 minutes at this level of intensity.

There were not differences between the two active conditions in BMI, a factor that could impact level of energy expenditure (Unnithan, Houser & Fernhall, 2006). In addition, BMI was unrelated to energy expenditure; and it was also unrelated to pre- or posttest EF scores. This suggests that BMI did not account for lower amounts of energy expenditure in the exergame group. One of the reasons that the exergame group spent

less time in a moderate- to high-intensity physical activity zone is that it is possible to play the game without expending much energy. Children were able to step on the dance mat without much exertion, while children in the exercise condition were moving quickly the entire time. Even though the heart rate monitored alerted the children that they were under 60% of their maximum heart rate, children in the exergame group struggled to increase expenditure. When children in the exercise condition were alerted that they needed to expend more energy they were able to take more steps or speed up their movement. Children in the exergame condition were constrained by the number of steps and pace of the game. Some children in the exergame group began stepping even when the game did not prompt them, in order to increase the number of steps, which in turn increased their heart rate. In a systematic review, Biddis and Irwin (2010) found energy expended during exergame play was higher than sedentary video games, but did not achieve moderate- to high-intensity long enough improve physical fitness.

The second hypothesis was that EF skills would change the most for children who exerted the most energy during exercise, as measured by heart rate and accelerometer during exercise. This hypothesis was not supported in the current study. This means that the relationship between condition and EF was not mediated by intensity of exercise. In addition, the video game groups had larger changes in EF when they were combined and compared to the non-video game groups. However, this was not the case when the active conditions were combined and compared to the inactive conditions. Based on previous research that EF skills changed after 10 to 40 minutes in moderate- to high-intensity

physical activity, it was surprising that the exercise group did not have a larger change in EF from pre- to posttest when compared to the exergame group.

Similarly, Anderson-Hanley et al. (2012) found no relationship between energy expenditure and cognitive outcomes between their exergame and exercise conditions. The researchers hypothesized that the lack of relationship may be because the benefits of exercise on cognition are not related to physical fitness outcomes; instead, they may be related psychological factors, neurochemical change or cerebral circulation from increased oxygen (Anderson-Hanley et al., 2012; Etnier, Nowell, Landers & Sibley, 2006). In Anderson-Hanley et al.'s (2012) study, both the levels of competition and enjoyment were higher for the exergame group compared to the exercise group. A meta-analysis of 37 studies of physical activity and cognitive performance found that although increased physical activity was related to increased cognition, it was not due to changes of cardiovascular fitness or physiological changes (Etnier et al., 2006). Therefore, there is evidence that energy expenditure alone may not account for increased EF skills in prior exercise research. This further supports the hypothesis that the combination of physical activity and cognitive engagement might be uniquely suited to promote EF.

Even though energy expenditure did not mediate the relationship between condition and EF, there were relationships between amount of time spent in moderate to high-energy intensity and several EF outcomes. Participants who were faster on incongruent, middle incongruent, and outside congruent trials at pretest expended more energy during the interaction. Participants who were more accurate at pretest on both middle congruent and middle incongruent trials also expended more energy. The range

of relationships with the range of different trial types and energy expenditure reflects higher EF skills at baseline. Therefore, children with higher fitness might have had higher baseline EF scores and then were able to expend higher amounts of energy in the active conditions. Previous research has found children with higher fitness have higher EF skills when compared to their peers (Buck et al., 2008; Hillman et al., 2005; Tomporowski et al., 2011).

The relationship between energy expenditure and cognitive engagement may be different for children compared to adults. Children are still developing their EF skills, which means they have more to gain through interventions. For example, research has found children are slower than adults in reducing conflicting interference up to the age of 10 (Rueda et al., 2004). The studies by Anderson-Hanley et al. (2012), Gao and Mandryk (2012) and O'Leary et al. (2011) were all conducted with adults, therefore the findings may be driven more by physical exertion than cognitive engagement in a task that improves inhibition. In the current study, even though children in the exercise condition were expending more energy than those in the exergame condition, this increased energy expenditure did not impact EF improvement. The increased effect of change for both the active and sedentary DDR conditions demonstrate that children's inhibition skills improved through video game play that allowed them to practice these skills. The exercise condition increased energy exertion, but did not allow children to practice inhibition skills. Given that the exergame group had the largest effects of change on the trial types that involved the most cognitive processes, it is likely that the combination of video game play and exercise had more of an effect on EF than energy expenditure alone.

Exergame Compared to Sedentary Video Game Condition

The exergame group had a larger change from pre- to posttest compared to the sedentary video game group on the trial types that required the most inhibition, outside and outside incongruent trials. However, the sedentary video game group had a large effect of change from pre- to posttest on these same trials compared to the exercise and control groups. In addition, the sedentary video game group had the largest change from pre- to posttest on the block that required rule switching between middle and outside focus. When the two video game groups were combined and compared to the two non-video game groups, even larger effects of change from pre- to posttest were found on the switch trial block, outside trials and outside incongruent trials. While the combination of video game play and physical activity improved EF, video game play in general also impacted EF change.

Previous research has had mixed results when comparing exergame play to traditional sedentary video game play. O'Leary et al. (2011) found no EF differences between exergame and sedentary video game groups. On the other hand, Best (2012) found that exergame play had benefits to cognition above sedentary video game play. Gao and Mandryk (2012) also found that exergaming improved EF more than sedentary video game play when the game was the same, reducing other confounded factors of video game play, such as level of competition or pace. Comparing the same video game allows for an examination of the additional impact of physical activity. The current study found that the video game groups improved more than the non-video game groups on several aspects of the flanker task, however the physical activity in the exergame group

conferred additional benefits on the trials that required the most EF processes: inhibition, rule shift and reduction of distractors.

An additional factor to consider in understanding the impact of video game play on EF in the current study is if aspects of the video game could influence or train certain EF processes. The structure and mechanics of video game play can impact participants' experience (Bavelier et al. 2010; Boyan & Sherry, 2011; Gentile, 2011). For example, scanning the screen for information could enhance visual attention (Gentile, 2011). Game mechanics, such as pressing a controller button or stepping on the dance mat, could increase fine or gross motor skills (Gentile, 2011). The structure and mechanics of video games are closely linked (Gentile, 2011). For example, when playing DDR when children see an arrow scroll across the screen (i.e. structure), they must step or press in the corresponding direction (i.e. mechanics). Learning transfer can occur when children create a mental representation that can be later transferred to new situations (Bransford, Brown, & Cocking, 2000). Transfer from video game play occurs when the game structure and mechanics are similar to the skill to be learned (Bransford et al., 2000; Boyan & Sherry, 2011; Gentile, 2011). The game structure of DDR resembles the flanker task. In DDR, children must attend to the direction of the arrows and then press or step in that direction while in the flanker task children attend to the direction of the fish and then press in the corresponding direction. These similarities may have, in part, driven the larger effects for the video game conditions, over the exercise condition.

Diamond (2012) found that interventions that are challenging, yet fun, for children can improve EF skills. Research has shown that video games that are

challenging as well as fun motivate players to succeed (Boyan & Sherry, 2011). Although game challenges can be frustrating for children, the balance of cognitive effort, focused attention and enjoyment provides a context for cognitive change (Boyan & Sherry, 2011; Diamond, 2012; Greenfield, 1996). In the current study, children reached a higher level of game performance in the sedentary video game group compared with the exergame group. DDR as an exergame requires gross motor movements, while the video controller requires fine motor movements. The coordination of full-body movements needed for the exergame may have been more difficult for children, as reflected in the poorer performance. Although both video game conditions improved EF, the additional cognitive effort needed to achieve DDR through stepping may account for the larger effects on the more difficult trials between these two groups. A potential reason the exergame group improved more than the exercise and sedentary video game groups could be that practice inhibiting full body movements has a greater influence than inhibiting movements with the hands or energy expenditure alone.

Potential Mediators

Several variables were expected to mediate the relationship between condition and EF outcomes. The hypothesized mediators, duration of the session, enjoyment, and BMI, were all unrelated to EF outcomes. Overall, children enjoyed the experience regardless of the condition in which they participated. According to Diamond (2012), enjoyment of an activity may be enough to improve EF skills. Anderson-Hanley et al. (2012) found that older adults in an exergame condition enjoyed the experience more than adults in an exercise condition. The researchers did not find an impact of energy

expenditure, therefore they hypothesized other factors, such as enjoyment, may have driven the difference between the two groups (Anderson-Hanley et al., 2012). Children in the current study enjoyed all conditions equally; therefore enjoyment was not a factor impacting differences between the conditions. Because all conditions improved from pre- to posttest, this could mean that being part of an enjoyable activity may be enough to improve EF to some extent, though other experiences beyond enjoyment improve EF more.

Prior video game experience was expected to relate to baseline EF as well as posttest EF scores. Previous research has found some baseline differences between experienced and inexperienced video game players (Bavelier, Green & Dye, 2010; Greenfield, Brannon & Lohr, 1994). In addition, children with prior video game experience could have performed better at the video games, which could have additional benefits. Previous video game experience did not mediate the relationship between condition and EF outcomes; however, exploratory analysis found that video game experience was related in various ways to performance on the flanker task. At baseline, children with more experience playing video games had higher scores on congruent trials. In general, children did better on the congruent trials, as they are easier to process than the incongruent trials (Rueda et al., 2004).

One reason children with more video game experience may have done better on the flanker task is that the processes needed to complete the flanker task were similar to the processes needed to succeed in a video game. Video game play requires attention, inhibition and reduction of conflict interference, the very skills needed to be successful

on the flanker task (Green & Bavelier, 2007; Rueda et al., 2004). In addition, the task was conducted on a computer (Thorell et al., 2009). Therefore, children with more experience with this medium may have adapted more quickly to the task, performing better on the easier trials in pretest than those without video game experience. Participants who had more video game experience were faster at posttest on the more difficult incongruent trials. Participants with video game experience were also faster on the middle incongruent trials, however middle focus trials were easier overall. In terms of accuracy at posttest, children with more video game experience did worse on the outside trials and outside congruent trials.

Previous research indicated adult video game players have increased EF. For example, Green and Bavelier (2003) found that video game players had higher attentional capacity and ability to task switch when compared to non-video game players. Boyan and Sherry (2011) explained that experienced video game players approach new video games understanding that they need to learn the rules through trial and error in order to achieve mastery. In contrast, the current finding is mixed because children with prior video game experience became faster, but less accurate on certain trials at posttest. These children may have sacrificed accuracy for speed, as they became more comfortable with the task.

Children's accuracy and performance while playing DDR also was related to EF, but could not be included as a mediator. The better children did at playing DDR, either actively or inactively, the faster and more accurate they were at posttest on several

variables. These findings are similar to previous research. Nouchi et al. (2013) found that participants' processing speed became faster after a video game training program.

The relationship between prior video game experience and EF in children, while not a mediating factor, adds to the literature supporting video game play as a way to improve aspects of cognition (Green & Bavelier, 2003; Greenfield et al., 1994). Baseline differences by video game experience may be because children who play video games have higher EF. However, they may be because the EF measurements were computerized. If EF measurements have structures similar to video game play, then participants could learn the task quicker. In the current study, children with more video game experience became faster on several types of trials, but did not become more accurate. This pattern may reflect a lack of inhibition as children are pressing too fast to internalize the rule. Some researchers have suggested playing video games may cause problems in attention and inhibition (Gentile, Swing, Lim, & Khoo, 2012). Finally, game performance was unrelated to prior video game experience, but was related to improved posttest outcomes. The process of achieving mastery through active learning may contribute to the improvements in EF (Boyan & Sherry, 2011).

EF Changes by Gender

The first gender hypothesis was that males would have larger gains in EF compared to females, because prior research found that boys have more video game experience and expend more energy during exergame play (Blumberg et al., 2013; Graf et al., 2009; Graves et al., 2008). Both are factors that can lead to larger EF gains. This hypothesis was partially supported. Boys had a greater change in reaction time compared

to girls on five different EF trial types. However, contrary to prediction, girls had a higher change in accuracy on the overall task and on middle focus trials. When pre- and posttest scores were examined, girls started slower on pretest on several trial types and then made up the difference in posttest. A similar pattern happened with accuracy on the outside trials, such that boys were less accurate at pretest, but made up the difference in posttest. Diamond (2012) reviewed interventions supporting EF and found that those with the most to gain often had the largest improvements. These gender differences may also be partially explained by prior video game experience. Boys had more prior experience playing video games than girls, which may mean they were able to learn the task more quickly. However, girls were slower and more accurate on some trials. Some research has found that when females had lower baseline cognitive skills compared to males they were able to reduce this difference through video game play (Feng et al., 2007). This suggests gender differences in inhibition skills, both at baseline and through video game practice.

In the current study, there were also significant gender differences in video game performance, such that boys performed better on the video games in both the exergame and sedentary video controller conditions. Previous research has demonstrated that prior video game experience resulted in higher game performance, which in turn may have impacted improved cognitive performance (Subrahmanyam & Greenfield, 1994). The differences by gender where boys sacrifice speed for accuracy may reflect boys having more video game experience and higher mastery of the game, however this may also be explained by differences in cognitive skills. Increased cognitive resources are needed to

improve on both speed and accuracy. Children must be able to attend to the current rule, inhibit the previous rule while reducing interference from conflicting distractors. Children with higher EF are able to balance these processes, reflecting higher accuracy. After a response becomes automatic, children are able to speed up the processing. Boys' increased reaction time may reflect higher EF skills or may reflect lower inhibition skills, pressing faster without processing the rule. Girls may have slowed down in order to be accurate, which could reflect higher EF skills compared to boys.

The second gender hypothesis was that there would be a condition by gender interaction, such that female participants in both video game conditions would have lower EF scores than all males and females in exercise conditions. This hypothesis was partially supported in that there were differences by gender for the condition by time interaction, but female participants in both video game conditions did not have lower EF scores than all males and females in the exercise condition. This hypothesis was based on past research suggesting girls typically have less video game experience than boys, which was true in the current study, and that energy expenditure would mediate EF change, which was not true in the current study. Boys did not have varying patterns of change from pre- to posttest for the different conditions.

Girls, however, did have different patterns of change depending on condition for four variables. However, each condition improved more on some trials than the other conditions, while performing worse on other trials. For example, girls in the exergame group did not change from pre- to posttest on middle trials, but had the largest change in accuracy from pre- to posttest for outside trials. The outside trials were more difficult

than the middle trials, however both trial types had room for growth. Girls in the sedentary video game group had the largest change from pre- to posttest for accuracy on the switch trial block and middle trials, but did not improve for the overall task or outside trial accuracy. On the outside trials girls in the control group did not change from pre- to posttest, however the control group had the largest effect size for the overall task. These condition differences for girls did not have a clear pattern even though the processes needed for each type of flaker sub trial were considered. All conditions led to greater improvements from pre- to posttest on some types of trials. Thus, future research should consider differences in cognitive processes by gender when designing cognitive training interventions.

The third gender hypothesis, that boys would exert more energy in the exercise and exergame condtion than girls, was not supported. Girls in the exergame group had significantly higher energy expenditure than boys. However, there were no differences in energy expenditure between girls and boys in the exercise condition. Previous research has been mixed in terms of energy expenditure by gender. Fawkner et al. (2010) found that teenage girls expended a moderate amount of energy, as measured by heart rate and oxygen uptake, during three different 30 minute session of DDR. On the other hand, several studies on physically active video games have found that boys exert more energy than girls while exergaming (Graf et al., 2009; Graves et al., 2008). The girls in the current study may have enjoyed the dance-based video game more than boys, and therefore engaged more, exerting more energy. In addition, because boys had more video game experience, they may have been able to perform the game with less movement and

exertion. Girls did not perform as well at the game compared to boys. Therefore, when they were alerted that they were not expending as much energy, they may have sacrified game performance to expend more energy.

Limitations and Future Directions

There are several potential lines for future research based on the current findings and study limitations. One limitation to the study was that participants performed at a high level on all three executive functioning tasks. A sample with a wider range of EF skills would allow for increased generalizability. Research is also needed that examines EF interventions with populations of children with traditionally lower EF skills, such as autistic children, children with ADD and children living in poverty (Anderson-Hanley et al., 2011; Diamond, 2012). These populations have lower academic outcomes, and often struggle to behave appropriately in the classroom; both factors that increased EF can improve (Best & Miller, 2010). Previous research has found that children with the most to gain have the biggest change in EF, therefore these populations may greatly benefit from EF skill based interventions (Diamond, 2012).

A second limitation is that parents inaccurately reported their children's video game experience beyond the overall time spent playing video games. The type of video game experience children had could influence baseline EF skills as well as game performance. For example, research with adults has found that participants with experience playing first person shooter or action-video games had higher baseline cognitive skills compared to non-action video game players (Green & Bavelier, 2007). Therefore, children with experience playing action-video games may have higher

baseline EF skills compared to children without experience playing these action-video games. In addition, children with prior experiences with exergames may have achieved higher game mastery, and in turn had higher EF change. Therefore, a limiting factor is that type of prior video game experience is unknown.

A third limitation was that the current study examined the acute impact of video game play on EF, however it is unclear if these acute changes last and if so, for how long. Additional research should examine the length of video game or exergame training needed for lasting EF change. Recent evidence supported that change in cognition can last up to six months after a video game intervention (Anguera et al., 2013). Anderson-Hanley et al. (2012) found that older adults had EF gains after three months of exergame intervention. In addition, Anguera et al. (2013) found improvements in cognitive skills after four weeks of video game training lasted for over six months post-intervention. However, more research with children is needed.

More evidence on the combined impact of physical activity and cognitive engagement is needed as research thus far has shown mixed results. Follow-up studies should continue to examine gender differences in cognition and the relationship with video game experience. Additional research is also needed that examines the individual difference factors that impact EF change. Diamond and Lee (2011) found that a wide range of interventions can improve EF, however more evidence of what might be driving that change is need. Thus far, research-based interventions that improve EF were enjoyable activities in which children were motivated to participate. Competition is an additional factor that has led to increased EF. There is very little research on the impact

of sports, dance or music on EF in children, which could be areas of research that could extend the current findings.

Another area of potential research is learning transfer from exergame play. Previous research has struggled to demonstrate learning transfer from playing video games (Bavelier et al., 2010; Gentile, 2011; Thorell et al., 2009). The current findings demonstrate the need for continued investigation into whether EF gains from video game play, especially exergames, can transfer to other contexts, such as school classrooms. EF has been linked to both academic outcomes and behavior difficulties. Inhibition skills are central to regulating behavior (Riggs et al., 2004). Children who have a hard time self-regulating and attending in the classroom have poorer academic outcomes (Best et al., 2009; Riggs et al., 2004). Therefore, interventions that help children practice and improve inhibition skills could have implications for schools in relation to classroom behavior, and academic outcomes.

Finally, an examination of how children participated in the activities could be conducted. There may be differences based on baseline EF in how children engage in the task. For example, children with higher baseline EF may have been able to complete the exercises as directed as compared to those with lower baseline EF. Additionally, children with higher baseline EF may have attended more during video game play gaining inhibition skills through increased practice. Establishing whether there are differences in video game play and exercise will be key for interpreting potential gains in attention and inhibition as a result of game play, as attending more during a task may lead to larger gains in posttest measures.

Impact

The current study has several strengths. It adds to recent research suggesting that the combination of physical movement and cognitive engagement in an enjoyable activity has benefits to EF beyond just exercise or cognitive engagement (Anderson-Hanley et al., 2012). Some researchers believe interactive games can be cognitively beneficial by engaging, and in a way training, children; however, other researchers believe playing these games may cause problems in attention (Gentile et al., 2012). Despite this controversy, limited empirical research has focused on the cognitive impact of video games with children; therefore, the current research adds to the growing body of research demonstrating positive benefits of video game play on cognition (Blumberg et al., 2013).

The current study provides additional evidence that different EF tasks (i.e. stroop, go/no-go and flanker), as well as sub trials (i.e. congruent and incongruent, middle and outside focus) on the task, are processed differently. The findings revealed different patterns between accuracy and reaction times, which reflects differences in inhibitory processes. Interestingly, these differences were partially related to prior video game experience in that those with more video game experience were faster, but not necessarily more accurate. Gender differences reflected the same pattern where boys became faster, but not more accurate. Girls were more accurate, but not faster. Historically, girls have played video games less than boys (Greenfield et al., 1994); however, newer generations of games, such as dance games, have been more popular for girls (Blumberg et al., 2013). The continued evidence that boys have more video game experience than girls and that

EF outcomes are impacted by amount of video game experience are important, but warrants more research.

This research also contributes to parents', teachers', and practitioners' understanding of the ways in which interactive media operates as potential interventions for children. Activities and contexts that can improve EF, even in the short-term, are of interest, as these skills are needed to succeed academically. Exergames are a prevalent and popular activity for youth; therefore these games may be a fun way to increase EF while being physically active. The current study contributes to the literature supporting the theory that many contexts that children enjoy can improve EF in the short-term (Diamond, 2012).

Conclusion

Children in the exergame condition became more accurate, but not faster, than children in the other three conditions on the flanker task on trials that required the most inhibition, as well as other processing skills. Children with more video game experience became faster, but not more accurate from pre- to posttest on several sub trials on the flanker task. Energy expenditure did not mediate EF change, suggesting that factors beyond physiological outcomes account for EF improvements. In summary, the current research provides insight into the relationship between engagement with everyday activities of childhood (i.e. exergames, video games and exercise) and EF skills (which have long-term implications for children's academic achievement and success).

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Appendix A

Dance Dance Revolution Playlist

TOTAL TIME:

Song	**Time**	**Number of Perfects**	**Number of Greats**	**Number of Goods**	**Number of Almosts**	**Number of Boos**	**Max Combo**	**Total Score**
1. Song: Lesson by DJ	2:18							
2. Song: Black or White	1:35							
3. Song: Umbrella	1:35							
4. Song: We got the beat	1:37							
5. Song: Everybody Dance	1:35							
6. **Song**: Can't help falling in love	1:42							
7. Song: Tootsee Roll	1:34							
8. **Song**: Call on me	1:32							
9. **Song**: I Ran	1:48							
10. Song: Obession	1:34							
11. **Song**: Feel Together	1:38							
12. Song: My Destiny	1:42							
13. Song: Tribulations	1:39							

Notes:

Appendix B

Protocol for Conducting Study

Participant #_____ Grass Pre/Day Post

Active vs. Passive Video Game Play for Children's Executive Functioning Skills

Date of interview: _____ Interview conducted by: _____

Note: You **MUST** obtain verbal assent from each child for the interview.
Gender: M F Age: _____ Hello!

My name is *(insert your name here)*. **I work over at University of California - Riverside. I am doing a project and your parents said that that you could participate if it's okay with you. The project will last about an hour. You can stop at any time if you want to. Thank you for agreeing to participate in our project. You will be answering some questions, playing some games, including (***Insert name of game, exercise, DDR, or video games***), and getting your heart rate measured using a heart rate monitor. This is what the heart rate monitor looks like. You wear this part (***Show watch part)* **on your wrist and this part (***show waistband)* **on your hip. You won't feel anything as it measures your heart beat through this sensor. I will show you how it works before we get started and you can decide if you want to wear it. Will wearing this be ok with you?** (*If child says no, say that is ok you can still participate in the project without wearing it if you want. Would you like to still participate?).* **The sessions will be with myself and (***Insert name of research assistant***).** **Is that ok with you? Great! Remember you can stop participating at any time and you can skip any questions that you would like. OK? Also, if you ever want to stop you can. OK?**
Assent to participate: Yes No

Printed Name:_____

Signature:_____ Date:_____

Condition: Exergame Video Controller Exercise Control

Counterbalance EF Measures: A B C D E F

Children's Media Survey Interview

We want to find out some information about you and some of the games you've played before and how you feel about things. **There are no right or wrong answers to any of these questions!**

1. What grade are you in fall? _____

2. What is your birthday? (MMDDYYYY) ___/____/_____ (___ years ___ months)

3. Have you heard of Nintendo's Wii Fit? Yes No

4. Have you played Wii Fit? Yes No
If No skip to #5

Do you like playing Wii Fit?

a. I really like playing
b. I sort of like playing
c. I sort of don't like playing
d. I really don't like playing

What Wii Fit games have you played?

5. Why do you think people use the Wii Fit?

a) Mostly for exercise
b) Mostly for fun and games
c) For both exercise and fun
d) I'm not sure why people use the Wii Fit

6. Do you think that people can get in better shape by playing Wii Fit? Yes No
I don't know

7. Have you heard of Dance Dance Revolution? Yes No

8. Have you played Dance Dance Revolution? Yes No
If No skip to #9

Do you like playing Dance Dance Revolution?

a. I really like playing
b. I sort of like playing
c. I sort of don't like playing
d. I really don't like playing

9. Why do you think people use Dance Dance Revolution?

a) Mostly for exercise
b) Mostly for fun and games
c) For both exercise and fun
d) I'm not sure why people play Dance Dance Revolution

10. Do you think that people can get in better shape by playing Dance Dance Revolution?

Yes No I don't know

11. Have you ever played any Nintendo Wii Games? Yes No

If No skip to #15

Do you like playing Wii?

a. I really like playing
b. I sort of like playing
c. I sort of don't like playing
d. I really don't like playing

What Wii games have you played?

12. Have you ever played any Other Video Games? Yes No

If No skip to #14

Which game platforms have you played (Xbox, PlayStation, DS, Computer)?

Do you like playing other video games?

a. I really like playing
b. I sort of like playing
c. I sort of don't like playing
d. I really don't like playing

13. What are your favorite video or computer games to play OR what other games have they played?

14. How much do you **enjoy** physical activity?

a) Activity is very un-enjoyable
b) Activity is somewhat un-enjoyable
c) Neutral
d) Activity is somewhat enjoyable
e) Activity is very enjoyable

14a. What is your favorite kind of physical activity or exercise?

15. How much do you enjoy physical education classes at school?

a) PE is very un-enjoyable
b) PE is somewhat un-enjoyable
c) Neutral
d) PE is somewhat enjoyable
e) PE is very enjoyable
f) My school doesn't have PE

15a. What is your favorite thing to do in PE?

15b. Do you do any after school activities that have exercise?

Executive Functioning Tests

Stroop Order =

Grass/Snow Order =

Bring out both squares representing grass and snow. "We are going to play a new game. Let's look at these. Do you know which one is the color of grass? Now, which square is the color of snow? "**Make sure the child correctly identifies the squares of grass and snow, reinforce.**
E: Good job! Now we are going to play a game with these squares. This is how the game works. When I say grass, you point to the white square. When I say snow, you point to the green square. Let's practice.

E: Grass

If child answers correctly: That's right! Now let's practice one more time.

If child does not point to the white square: Remind child to point to the white square. E should then run this practice trial again until child points correctly.

E: Snow

If child answers correctly: Yeah! Now let's play this game some more.

If child does not point to the green square: Remind child to point to the green square. E should then run this practice trial again until child answers correctly. For both of these practice trials, E should assist the child in pointing correctly if child is having trouble with the game.
Real trials: Now run 10 trials in this order allowing time for the child to point to the picture in between each trial. Do not reinforce correct answers or try to fix incorrect responses. **Do not look at the pictures when asking the child to point.**
Codes for each trial:
(0) Fails to point; (1) Incorrect and never self-corrects (or starts correct but changes mind);
(2) Self-corrects; (3) Correct on first attempt and doesn't change mind

Trial	Word	Code
1	Grass	
2	Snow	
3	Snow	
4	Grass	
5	Snow	
6	Grass	
7	Snow	
8	Snow	
9	Grass	
10	Grass	

Global Code _____

# of 3's: ___ ; # of 2's ___ ; # of 1's ___; # of 0's ___ Total # of Trials ____ Total Score ____

Color Task Order =

We are going to play a new game. (place the compatible Red and incompatible Red pictures on the table.) Do you know what this says? What color is this one (point to Red) written in? What color is this one written in (point to Green)? ****If the child cannot read the word on identification do the shape task in pre and posttest**** Good job! Now, we are going to play a game with these pictures. This is how the game works. When I hold a card you always say the color the word is written in. So, when I hold up this card (written Red in Red) you say the color the word is printed in, Red. When I hold up this card (written Red in Green), you say the color the word is printed in, Green. Let's practice.

E: Hold Red Red

Child says Red: That's right! Now let's practice one more time.

E: Hold Red Green

If child says Green correctly: Yeah! Good job!

If child does not say Green: Remind child to say the color it is printed in. Run this practice trial again until child answers correctly. For both of these practice trials, E should assist the child in if child is having trouble with the game.

E: Great job! (E picks up the compatible and incompatible Blue pictures). Now, let's look at these pictures. What does this card say? What color is this one (point to Blue) written in? What color is this one written in (point to Green)? **Make sure the child correctly identifies the Blue and Green, reinforce**

E: Good job! Now, we are going to play a game with these pictures. This is how the game works. When I hold a card you always say the color the word is written in. So, when I hold up the card (written Blue in Blue) you say the color the word is printed in, blue. When I hold up this card (written Blue in Green), you say the color the word is printed in, Green. Let's practice

E: Hold up Blue Blue

If child says Blue correctly: That's right! Now let's practice one more time.

E: Hold up Blue Green

If child answers Green correctly: Yeah! Now let's play this game some more.

If child does not say green: Remind child to say the color the word is written in. E should then run this practice trial again until child answers correctly. For both of these practice trials, E should assist the child in pointing correctly if child is having trouble with the game.

E: Now, we're going to play a really silly game with all four of these pictures!

Real trials: Now run 10 trials in this order. **Do not reinforce correct answers or try to fix incorrect** responses. **Do not look at the pictures when asking the child to point.**
Codes for each trial:
(0) Fails to point; (1) Incorrect and never self-corrects (or starts correct but changes mind);
(2) Self-corrects; (3) Correct on first attempt and doesn't change mind

Trial	Card	Code
1	**Red/Red**	
2	**Blue/Blue**	
3	**Red/Green**	
4	**Blue/blue**	
5	**Blue/Green**	
6	**Red/Green**	
7	**Red/Red**	
8	**Red/Green**	
9	**Red/Red**	
10	**Blue/Green**	

Global Code _____
# of 3's: ___ ; # of 2's ___ ; # of 1's ___; # of 0's ___ Total # of Trials ____ Total Score ____

Shapes Order =
We are going to play a new game. Let's look at some pictures. (E places the compatible Circle and incompatible pictures on the table.) Do you know what this shape is? What shapes make up the circle (point to circles)? What shapes is this circle made of (point to triangle)? **Make sure the child correctly identifies Circles, reinforce. E:** Good job! Now, we are going to play a game with these pictures. This is how the game works. When I hold a card you always say the color the shape it is made up of. So, when I hold up this card (compatible circle) you say the color the shape it is made up of, circle. When I hold up this card (incompatible), you say the shape it is made up of, triangle. Let's practice.

E: Hold Compatible
Child says Circle: That's right! Now let's practice one more time.
E: Hold incompatible
If child says circle/triangle correctly: Yeah! Good job!
If child does not say triangle: Remind child to say the word it is made up in. E should then run this practice trial again until child answers correctly. For both of these practice trials, E should assist the child in if child is having trouble with the game.

E: Great job! (E picks up the compatible and incompatible triangle pictures). Now, let's look at these pictures. What shape does this card have? What shape is this one made up of (point to compatible triangle) written in? What word is this one made up of (point to incompatible triangle)? **Make sure the child correctly identifies the shapes, reinforce**. **E:** Good job! Now, we are going to play a game with these pictures. This is how the game works. When I hold a card you always say shape that it is made up of, the smaller shapes. So, when I hold up the card (compatible) you say the shape it's made up of, triangle. When I hold up this card (incompatible), you say the shape it's made up of, square, Let's practice

E: Hold up compatible triangle
If child says triangle correctly: That's right! Now let's practice one more time.
E: Hold up incompatible triangle
If child answers square correctly: Yeah! Now let's play this game some more.

If child does not say square: Remind child to say the smaller shapes. E should then run this practice trial again until child answers correctly. For both of these practice trials, E should assist the child in pointing correctly if child is having trouble with the game.

E: Now, we're going to play a really silly game with all four of these pictures!

Real trials: Now run 10 trials in this order. Do not reinforce correct answers or try to fix incorrect responses. Do not look at the pictures when asking the child to point. Codes for each trial:

(0) Fails to point; (1) Incorrect and never self-corrects (or starts correct but changes mind);
(2) Self-corrects; (3) Correct on first attempt and doesn't change mind

Trial	Card	Code
1	Circle	
2	Triangle	
3	Incompatible Circle	
4	Triangle	
5	incompatible triangle	
6	incompatible circle	
7	Circle	
8	incompatible triangle	
9	Incompatible circle	
10	Circle	

Global Code _____

# of 3's: ___ ; # of 2's ___ ; # of 1's ___; # of 0's ___ Total # of Trials ____ Total Score ____

Flanker Fish Task Order =

Now we are going to play a fun game with fish on the computer. (Have the flanker fish directions available if needed). Read **directly from the screen, do not add in any more directions**. Make sure to praise during the practice when they get it right!

Go/No/Go Order =

Now we are going to play a fun game on the computer. Read **directly from the screen, do not add in any more directions**. Make sure to praise during the practice when they get it right!

Transition to the Heart Rate Monitor and Accelerometer.
We are trying to learn about kids bodies when they do different things. We have to monitors that measure how fast your heart beats and how much you are moving your body. You don't feel anything but you wear on strap around your chest (like this, demonstrate) and you wear one around your hip (like this, demonstrate). If you don't like how they feel you can take them off at any point, but it will help us if you try.

To understand how kids bodies work we need to get your weight and height.

Record Height:_____Weight:_____

Polar Heart Rate Monitor (See Notes about how to use)
I am going to show you how to put on the strap for the heart rate monitor now. We need to get this part a little wet so it will stay on your skin. The strap needs to be on kind of tight so it won't fall off while you are moving around. (Exercise and DDR only). We want you to keep moving the whole time. While you are exercising if you aren't moving around enough or fast enough the watch is going to beep to let you know to move more. If you exercise really hard the watch won't beep! It is okay if does beep then you will know how much you need to move around!

Energy Expenditure Monitor (see notes about how to use)
Now this monitor measures how many steps and movements you take while you are exercising/playing. This one you wear on your hip so that it can record all your movements. You **DON'T** use or say this for the control group.

Transition to playing the games.
Now that you have the monitors on we are going to __"Insert Condition"__ for half an hour.

Non-Playing control: I am going to have you sit here and rest for a little while so we can see how kids bodies work while they sit. I am going to ask you some questions about what kinds of things you like to do. After you rest for awhile and the monitors measure your heart rate we are going to do some more games. Then when we are all done and you can play the wii for a little while and pick out a toy prize!

Exercise group: I am going to have you exercise for about 20 minutes so we can see how kids bodies work while they exercise. You should keep moving the whole time at a good pace. While you are exercising the heart rate monitor will be measuring how hard you are working out. If you aren't moving enough the monitor is going to beep, then you should try to move faster. I will also have you wear this montior on your waistband or clipped on your pocket. This monitor tells us how many steps you took and how fast! I will show you each of the exercises we will do as practice, you will do them with me. Then for about a minute and half you'll do an exercise. I'll show you which one. You should keep going even if its hard. After each exercise we will write down how many times you did that exercise. I'll be right here if you have any questions or aren't sure what to do. When you are done playing I have a few more games for you. Then you can play the wii for a little while and pick out a toy prize!

DDR controller group: I am going to have you play this video game for about 20 minutes so we can see how kids bodies work while they play video games. I will start the game so you can see

the instructions. You will use this controller pressing these buttons with your left hand or these buttons with your right hand. (ask what hand they write with and show them that side). Once the game is started you will play through a bunch of songs. You should keep playing the whole time even if it is a little hard. After each song please don't push any buttons so we can write down the score. Don't worry if it says you are going to fail or are in danger - you can't fail out, just keep trying. **Record the score, along with each number of perfects, goods, almosts, boo, etc.**

DDR dance mat group: I am going to have you play this video game for about 20 minutes so we can see how kids bodies work while they play video games. I will start the game so you can see the instructions. You will step on the arrows on the mat as they match the arrows on the screen. Once the game is started you will play through a bunch of songs. You should keep playing the whole time even if it is a little hard. After each song please don't push any buttons so we can write down the score. Don't worry if it says you are going to fail or are in danger - you can't fail out, just keep trying. You should keep playing the whole time even if it is a little hard. You should keep moving the whole time at a good pace. While you are exercising the heart rate monitor will be measuring how hard you are working out. If you aren't moving enough the monitor is going to beep, then you should try to move faster. I will also have you wear this montior on your waistband or clipped on your pocket. This monitor tells us how many steps you took and how fast! **Record the score, along with each number of perfects, goods, almosts, boo, etc.**

****Play in Training Mode and Make sure to put on Beginner!****

Measurement of enjoyment

For these questions, I am going to ask you about how much you liked the game

1. How much did you like the activity you just did? Circle child's response:

+2 A lot +1 A little 0 Neutral -1 didn't like a little -2 Really didn't like

1. What did you like/not like about the activity?

POST TEST

Stroop Order =

Day/Night order =

Bring out both the picture of the day and night skies. "We are going to play a new game. Let's look at some pictures. Do you know which is a day sky? Now, which is a night sky?"

Make sure the child correctly identifies the day and night sky, reinforce. Now we are going to play a game with these pictures. This is how the game works. When I say day, you point to the night sky. When I say night, you point to the day sky. Let's practice.

E: Day

If child answers correctly: That's right! Now let's practice one more time.

If child does not point to the night sky: Remind child to point to the night sky. E should then run this practice trial again until child points correctly.

E: Night

If child answers correctly: Yeah! Good job! Now let's play this game some more.

If child does not point to the day sky: Remind child to point to the day sky. E should then run this practice trial again until child answers correctly. For both of these practice trials, E should assist the child in pointing correctly if child is having trouble with the game.

Real trials: Now run 10 trials in this order allowing time for the child to point to the picture in between each trial. Do not reinforce correct answers or try to fix incorrect responses. **Do not look at the pictures when asking the child to point to either day or night.**

Codes for each trial:

(0) Fails to point; (1) Incorrect and never self-corrects (or starts correct but changes mind);
(2) Self-corrects; (3) Correct on first attempt and doesn't change mind

Trial	Word	Code
1	Day	
2	Night	
3	Night	
4	Night	
5	Day	
6	Night	
7	Day	
8	Day	
9	Night	
10	Day	

Global Code _____

# of 3's: ___ ; # of 2's ___ ; # of 1's ___; # of 0's ___ Total # of Trials ____ Total Score ____

Color Task Order =

Reminders of rules

(0) Fails to point; (1) Incorrect and never self-corrects (or starts correct but changes mind); (2) Self-corrects; (3) Correct on first attempt and doesn't change mind

Trial	Word	Code
1	Blue/Blue	
2	Red/Red	
3	blue/green	
4	red/red	
5	red/green	
6	blue/green	
7	blue/Blue	
8	blue/green	
9	blue/blue	
10	red/green	

Global Code _____

# of 3's: ___ ; # of 2's ___ ; # of 1's ___; # of 0's ___ Total # of Trials ____ Total Score ____

Shape Order =

Reminders of rules.

(0) Fails to point; (1) Incorrect and never self-corrects (or starts correct but changes mind); (2) Self-corrects; (3) Correct on first attempt and doesn't change mind

Trial	Word	Code
1	incompatible triangle	
2	incompatible circle	
3	triangle	
4	incompatible triangle	
5	incompatible circle	
6	triangle	
7	Circle	
8	incompatible triangle	
9	triangle	
10	circle	

Global Code _____

# of 3's: ___ ; # of 2's ___ ; # of 1's ___; # of 0's ___ Total # of Trials ____ Total Score ____

Flanker Fish Task Order =

Go/No/Go Order =

Appendix C
Parent Survey

UNIVERSITY OF CALIFORNIA, RIVERSIDE
CONSENT TO ACT AS A HUMAN RESEARCH SUBJECT
Active vs. Passive Video Game Play for Children's Executive Functioning Skills

You and your child are being asked to participate because you have a child who is 6 to 11-years-old. Participation in this research study is completely voluntary. Please read this information below and ask questions about anything that you do not understand before deciding if you want your child to participate. A researcher listed below will be available to answer your questions.

INVESTIGATORS AND SPONSOR
Lead Researcher: Rachel Flynn MA - Department of Psychology
Faculty Sponsor: Rebekah Richert PhD - Department of Psychology
Study Location(s): UCR Main Campus
Study Sponsor(s): This study is a student project.

PURPOSE OF STUDY
The purpose of this research study is to understand more about children's use of interactive media, such as video game play.

SUBJECTS
Inclusion Requirements: You are being asked to participate because you have a child who is 6 to 11-years-old.
Exclusion Requirements: You and your child must speak fluent English.
Number of participants: The investigator plans to enroll 140 participants
Total Time Involved: You and your child will be involved in this study for 1 session. The session will last for 60 minutes. During the session you will be asked to fill out a survey while your child is participating.

PROCEDURES
- **Educational tests (cognitive, diagnostic, aptitude, achievement)** - Your child will participate in a series of games and cognitive tasks that take about 15 minutes.
- **Observational studies** - Your child will participate in a 30 minute activity session either exercising or playing video games
- **Surveys/Questionnaires** - You will fill out information about your child and your household. You and your child will fill out a questionnaire about media use and opinions. The information that you fill out about your child will be kept private so that your child will not have access to your answers.
- **Standard Paper/Pencil format (handwritten)** - The data will be collected by standard paper and pencil format.

- **Video recording** - The entire session will be video recorded.

RISKS

- This study involves no more than minimal risk.
- Some of the questions you will answer ask you to rate different aspects of your child's behavior. There is slight risk that your child might be upset if they were to learn your responses. Therefore, these answers should be kept private. When you complete the survey we will put it in a locked room inaccessible to your child.
- Other than the above, there are no known harms or discomforts associated with this study beyond those encountered in daily life.
- These activities are not anticipated to be any riskier than other exercise, however if your child were to get sick or injured while participating in this study UCR's campus Health Center is available at (951) 827-3031. Your child will be monitored the entire time for fatigue, discomfort and/or injury/illness

BENEFITS

To Others or Society

You and your child's participation will be very helpful in understanding more about the effects of media on children.

ALTERNATIVES TO PARTICIPATION

The alternative is to not participate in this study.

COMPENSATION/COST/REIMBURSEMENT

Compensation for participation

You will receive $15 for the time taken to participate in this study.
You will not be required to pay for research related procedures/treatments.

Reimbursement

You will be provided on-campus parking

WITHDRAWAL OR TERMINATION FROM STUDY

You are free to withdraw from the study at any time. You do not have to complete the survey in order for your child to participate in this study. Your child may choose not to participate in the study at any time, even if you give permission. The researcher will honor the child's request. not to participate regardless of parent consent.

CONFIDENTIALITY

Data Storage

Your research records including, computer-based data, will be stored in a locked cabinet, in a secured building. Video data and other files for coding and analysis will be stored by Participant ID number on a password-protected computer.

Data Access

Only members of our research team may have access to your study records to protect your safety and welfare.

Level of Privacy

- To protect your privacy and the confidentiality of the data, all personal identifiers will be removed from the data records at the end of the study.

Data Privacy

- The research data will be maintained indefinitely.

NEW FINDINGS

If during the course of this study, significant new information becomes available that may relate to your willingness to continue to participate, this information will be provided to you by the investigator

IF I HAVE QUESTIONS

If you have any comments or questions regarding the conduct of this research or your rights as a research subject, please contact the Office of Research Integrity by phone (951-827-4811/4810/6332), by email (irb@ucr.edu) or at University Office Bldg. #200, Riverside, CA 92521.

Contacts:

- Rachel Flynn MA, Department of Psychology
  Daytime Phone: (951) 827-7001 **After Hours Phone:** (917) 972-8003
  Email: rflyn001@ucr.edu
- Rebekah Richert PhD, Department of Psychology
  Daytime Phone: 951-827-4804 **Email:** rebekahr@ucr.edu

OTHER CONSIDERATIONS

Conflict of Interest

Investigators must satisfy campus requirements for identifying and managing potential conflicts of interest before a research study can be approved. The purpose of these requirements is to ensure that the design, conduct and reporting of the research will not be affected by any conflicting interests. If at any time you have specific questions about the financial arrangements or other potential conflicts for this study, please feel free to contact any of the individuals listed above.

VOLUNTARY PARTICIPATION STATEMENT and VIDEO RELEASE FORM

I understand that participation in this study is voluntary. My child may refuse to answer any question and we may discontinue his/her involvement at any time without penalty or loss of benefits to which s/he might otherwise be entitled. My decision will not affect our future relationship with UC Riverside. My signature below indicates that I have read the information in this consent form and have had a chance to ask any questions I have about the study. I agree to allow my child to participate in the study.

The UCR Childhood Cognition Lab would like to have video and still photo examples of experimental procedures to use when training new research assistants or explaining a study. We request your permission to show video or photos of your children interacting either with you or the experimenter in an educational, conference or research setting. Refusal of permission will not affect your standing or you child's standing in our ongoing study or at UCR. Your child's personal information will not be released.

_____ YES, I give my permission for the UCR Childhood Cognition Lab to use video or photos of my child in an educational or research setting.

We also have a website that we use to inform parents, researchers and students about the various studies we conducted.

_____ YES, I give my permission for the UCR Childhood Cognition Lab to use video or photos of my child on the University of California, Riverside website.

_____ NO, I do not give my permission for the UCR Childhood Cognition Lab to use vide or photos of my child.

_____

_____

Print name Child's name

_____

Signature

_____

Date

Demographic & Media Questions

Child's name:_____**Date of birth** (dd/mm/yy): ____/___/_____
Child's Gender: M F

1. How many older and younger siblings does your child have that live in the same house as your child?

____ Older siblings (gender and age of older siblings: _____)

____ Younger siblings (gender and age of younger siblings: _____)

2. How would you describe your child's ethnic background or race? Check all that apply:

____ White ____ Black ____ Native American
____ Hispanic/Latino ____ Asian ____ Other: _____
____ Don't know ____ Decline to answer

3. What is the primary language your child speaks? _____

3b. If your child speaks other languages, which languages? _____

Activities.
Please complete the following questions as accurately and honestly as possible.
These will help us understand your child's experiences using video games.
You always have the option to choose not to answer a question; just check "DK (don't know)" or "Decline to answer".

1. Please check which of the following active video games you have at home
_____Nintendo Wii Active _____Nintendo Wii Fit
_____Nintendo Wii Sports _____Microsoft Kinect
_____ Sony Eye Toy _____Dance Dance Revolution
Other: _____

2. Please check which of the following active video games your child has ever played
_____Nintendo Wii Active _____Nintendo Wii Fit
_____Nintendo Wii Sports _____Microsoft Kinect
_____ Sony Eye Toy _____Dance Dance Revolution
Other:_____

3. How much does your child like to play non-active/regular computer or video games?
__A whole lot __A lot __Somewhat __Not much __Not at all __Not applicable

4. How much does your child like to play physically active video games, like Wii Fit, Wii Sport or DDR?

__A whole lot __A lot __Somewhat __Not much __Not at all __Not applicable

5. How much does your child like to play sports?
__A whole lot __A lot __Somewhat __Not much __Not at all __Not applicable

6. How much does your child like to exercise or do any type of physical activity?
__A whole lot __A lot __Somewhat __Not much __Not at all __Not applicable

7. How much does your child like to dance or do aerobics?
__A whole lot __A lot __Somewhat __Not much __Not at all __Not applicable

8. What are your child's favorite video or computer games to play?
_____

9. What are your child's favorite sports, exercise or physically active activities?_____

Time in Activities. Respond to the following questions based on a typical week during the school year.

10. How many days does your child *spend time in structured extracurricular activities* (for example, dance classes, sports)? _____

10a. On these days, how much time does your child generally spend in structured extracurricular activities?

__Less than ½ hour __½ hour to an hour __1 to 1 ½ hours __1 ½ to 2 hours __2 to 2 ½ hours __2 ½ to 3 hours __3 to 3 ½ hours __3 ½ to 4 hours __4 to 4 ½ hours __Over 4 ½ hours

10b. Please list activities: _____

11. How many days does your child *watch television or DVDs*? _____

11a. On these days, how much time does your child generally spend watching television or DVDs?

__Less than ½ hour __½ hour to an hour __1 to 1 ½ hours __1 ½ to 2 hours __2 to 2 ½ hours __2 ½ to 3 hours __3 to 3 ½ hours __3 ½ to 4 hours __4 to 4 ½ hours __Over 4 ½ hours

12. How many days does your child *play video games*? _____

12a. On these days, how much time does your child generally spend playing any type of video games?

__Less than ½ __½ hour __1 to 1 ½ __1 ½ to 2 __2 to 2 ½ __2 ½ to 3 __3 to 3 ½ __3 ½ to 4 __4 to 4 ½ __Over 4 ½

hour	to an hour	hours	hours	hours	hours	hours	hours	hours	hours

12b. On these days, how much time does your child play any physically active video games?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

12c. On these days, how much time does your child play Wii Fit?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

12d. On these days, how much time does your child play Dance Dance Revolution or Just Dance?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

12e. On these days, how much time does your child play any other Wii games

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

12f. On these days, how much time does your child play regular video games (not active)

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

13. How many days does your child *play computer games*? _____

13a. On these days, how much time does your child generally spend playing on the computer?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

14. How many days does your child *play on the Internet*? _____

14a. On these days, how much time does your child generally spend *playing on social networking sites*?

__Less than ½ hour
__½ hour to an hour
__1 to 1 ½ hours
__1 ½ to 2 hours
__2 to 2 ½ hours
__2 ½ to 3 hours
__3 to 3 ½ hours
__3 ½ to 4 hours
__4 to 4 ½ hours
__Over 4 ½ hours

14b. On these days, how much time does your child generally spend *playing online games*?

__Less than ½ hour
__½ hour to an hour
__1 to 1 ½ hours
__1 ½ to 2 hours
__2 to 2 ½ hours
__2 ½ to 3 hours
__3 to 3 ½ hours
__3 ½ to 4 hours
__4 to 4 ½ hours
__Over 4 ½ hours

14c. On these days, how much time does your child generally spend *watching online videos*?

__Less than ½ hour
__½ hour to an hour
__1 to 1 ½ hours
__1 ½ to 2 hours
__2 to 2 ½ hours
__2 ½ to 3 hours
__3 to 3 ½ hours
__3 ½ to 4 hours
__4 to 4 ½ hours
__Over 4 ½ hours

15. How many days does your child *play handheld video games*? _____

15a. On these days, how much time does your child generally spend playing on the handheld video game?

__Less than ½ hour
__½ hour to an hour
__1 to 1 ½ hours
__1 ½ to 2 hours
__2 to 2 ½ hours
__2 ½ to 3 hours
__3 to 3 ½ hours
__3 ½ to 4 hours
__4 to 4 ½ hours
__Over 4 ½ hours

16. How many days does your child *play with a working cell phone*? _____

16a. Is this cell phone an iPhone, Android, or other touchscreen phone? Yes No

16b. On these days, how much time does your child generally spend playing with a cell phone?

__Less than ½ hour
__½ hour to an hour
__1 to 1 ½ hours
__1 ½ to 2 hours
__2 to 2 ½ hours
__2 ½ to 3 hours
__3 to 3 ½ hours
__3 ½ to 4 hours
__4 to 4 ½ hours
__Over 4 ½ hours

17. How many days does your child *play with an iPad or tablet*? _____

17a. On these days, how much time does your child generally spend playing with an iPad or tablet?

__Less than ½ hour
__½ hour to an hour
__1 to 1 ½ hours
__1 ½ to 2 hours
__2 to 2 ½ hours
__2 ½ to 3 hours
__3 to 3 ½ hours
__3 ½ to 4 hours
__4 to 4 ½ hours
__Over 4 ½ hours

18. How many days does your child *listen to music*? _____

18a. On these days, how much time does your child generally spend listening to music?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

19. How many days does your child *spend time reading*? _____

19a. On these days, how much time does your child generally spend reading?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

20. How many days does your child spend time *playing outside*? _____

20a. On these days, how much time does your child generally spend playing outside?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

21.How many days does your child spend time *exercising or playing sports*? _____

21a. On these days, how much time does your child generally spend exercising or playing sports?

__Less than ½ hour	__½ hour to an hour	__1 to 1 ½ hours	__1 ½ to 2 hours	__2 to 2 ½ hours	__2 ½ to 3 hours	__3 to 3 ½ hours	__3 ½ to 4 hours	__4 to 4 ½ hours	__Over 4 ½ hours

22. What are your child's top 3 favorite activities of those listed above?

1st favorite: _____

2nd favorite: _____

3rd favorite: _____

23. Is there another activity that your child really likes that we haven't asked about?

Specific Video Games. Think about the specific types of video games your child plays to answer the following questions. If you do not know put "IDK"

24. How many days does your child spend time *playing video games with sports themes, like Wii Sports*? _____

24a. On these days, how much time does your child generally spend playing sports video games?

__Less than ½ hour | __½ hour to an hour | __1 to 1 ½ hours | __1 ½ to 2 hours | __2 to 2 ½ hours | __2 ½ to 3 hours | __3 to 3 ½ hours | __3 ½ to 4 hours | __4 to 4 ½ hours | __Over 4 ½ hours

25. How many days does your child spend time *playing video games with strategic life simulation, like the Sims*? _____

25a. On these days, how much time does your child generally spend playing *strategic life simulatio*n video games?

__Less than ½ hour | __½ hour to an hour | __1 to 1 ½ hours | __1 ½ to 2 hours | __2 to 2 ½ hours | __2 ½ to 3 hours | __3 to 3 ½ hours | __3 ½ to 4 hours | __4 to 4 ½ hours | __Over 4 ½ hours

26. How many days does your child spend time *playing video games with puzzles, like the Tetris*? _____

26a. On these days, how much time does your child generally spend playing *puzzle* video games?

__Less than ½ hour | __½ hour to an hour | __1 to 1 ½ hours | __1 ½ to 2 hours | __2 to 2 ½ hours | __2 ½ to 3 hours | __3 to 3 ½ hours | __3 ½ to 4 hours | __4 to 4 ½ hours | __Over 4 ½ hours

27. How many days does your child spend time *playing video games with racing, like Mario Kart*? _____

27a. On these days, how much time does your child generally spend playing *racing* video games?

__Less than ½ hour | __½ hour to an hour | __1 to 1 ½ hours | __1 ½ to 2 hours | __2 to 2 ½ hours | __2 ½ to 3 hours | __3 to 3 ½ hours | __3 ½ to 4 hours | __4 to 4 ½ hours | __Over 4 ½ hours

28. How many days does your child spend time *playing first person shooter video, like Call of Duty*? _

28a. On these days, how much time does your child generally spend playing *first person shooter* video games?

__Less than ½ hour | __½ hour to an hour | __1 to 1 ½ hours | __1 ½ to 2 hours | __2 to 2 ½ hours | __2 ½ to 3 hours | __3 to 3 ½ hours | __3 ½ to 4 hours | __4 to 4 ½ hours | __Over 4 ½ hours

29. How many days does your child spend time *playing video games with adventure quests, like the Mario Brothers or World of Warcraft*? _____

29a. On these days, how much time does your child generally spend playing *adventure quest* video games?

__Less | __½ | __1 to | __1 ½ | __2 to | __2 ½ | __3 to | __3 ½ | __4 to | __Over

than ½ hour	hour to an hour	1 ½ hours	to 2 hours	2 ½ hours	to 3 hours	3 ½ hours	to 4 hours	4 ½ hours	4 ½ hours

30. What does your child usually do when they have a **choice about how to spend their free time?**

__Almost always choose activities like TV, reading, listening to music, or computers	__ Usually choose activities like TV, reading, listening to music, or computers	__Just as likely to choose active as inactive recreation	__Usually choose activities like bicycling, dancing, outdoor games or active sports	__ Almost always choose activities like bicycling, dancing, outdoor games or active sports

31. How do you rate **your child's athletic coordination**, compared to other children of the same age and gender?

__Much less coordinated	__Somewhat less coordinated	__About the same	__Somewhat more coordinated	__Much more coordinated

32. How do you rate **your child's physical activity**, compared to other children at the same age and gender?

__Much less than others	__Somewhat less than others	__About the same	__Somewhat more than others	__Much more than others

Media Rules:

33a. Do you have rules about how much television your child can watch?
Yes No

33b. Do you have rules about what television shows your child can watch?
Yes No

33c. If you have rules related to television use, please describe.

34a. Do you have rules about how much time your child can spend playing video games? Yes No

34b. Do you have rules about what video games your child can play? Yes No

34c. If you have rules related to video games, please describe.

35a. Do you have rules about how much time your child can spend on a computer?
Yes No

35b. Do you have rules about what your child can play while on the computer?
Yes No

35c. If you have rules related to computer use, please describe.

36a. Do you have rules about how much time your child can spend using a cell phone?
Yes No

36b. Do you have rules about what your child can play while using a cell phone?
Yes No

36c. If you have rules related to cell phone use, please describe.

37a. Do you have rules about how much time your child can spend on an iPad/tablet?
Yes No

37b. Do you have rules about what your child can play while on an iPad or tablet?
Yes No

37c. If you have rules related to iPad or tablet use, please describe.

Medical Information

38. Does your child have any health conditions that make physical activity or exercise difficult?
Yes No
If Yes please explain:

39. Does your child have any limitations or restrictions when it comes to physical activity or exercise?
Yes No
If Yes please explain:

40. Does your child have asthma? Yes No
If Yes: Does your child take an inhaler? Yes No
How often does your child take an inhaler?

41. Does your child have allergies? Yes No
If Yes: Does your child take medication to relieve symptoms? Yes No

42. Does your child have diabetes? Yes No
If Yes: Does your child take medication to relieve symptoms? Yes No

43. Does your child have ADD/ADHD? Yes No
If Yes: Does your child take medication? Yes No
Which medication?
What is your child's schedule for medication?

44. Does your child take any other medications that would be important for us to know?

Questions about you: Finally we have a few questions about you and your household.

45. What is your relationship to the child in this survey?
__Mother __Father __Aunt __Uncle __Grandmother _Grandfather Other:

46. Which adults live in the same house as the child? (Check all that apply.)
__Mother __Father __Aunt __Uncle __Grandmother _Grandfather Other:

47. What is your gender? F M 48. What is your age? _____

49. Please check the option that most accurately reflects *your current employment*:
__Full-time __Part-time __Student __Home-maker __Retired __Disabled __ Not employed __Decline to answer

50. Please check the option that most accurately reflects *your current relationship status*:
__Married __Live-in partner __Divorced __Separated __Widowed __Single __Decline to answer

51. Please check the option that most accurately reflects *your husband/wife/partner's current employment*:
__Full-time __Part-time __Student __Home-maker __Retired __Disabled __ Not employed __Decline to answer

52. What is the last grade you completed in school?

__	__	__	__	__	__	__
Did not complete high school	High school diploma or GED	Some college/ vocational school	Associates degree	Bachelor's degree	Advanced degree	Decline to answer

53. What is the last grade *your husband/wife/partner* completed in school?

__	__	__	__	__	__	__
Did not complete high school	High school diploma or GED	Some college/ vocational school	Associates degree	Bachelor's degree	Advanced degree	Decline to answer

54. What was your household income last month? _____
55. What is your average household income in a year? _____

56. How would you describe your ethnic background or race? Check all that apply:
White _____ Black _____ Native American____ Asian _____
Hispanic/Latino _____ Other: _____ Don't know _____

57. We would like to ask you about your cultural/ethnic identity (the culture you feel the most sense of belonging to). Please rate the strength of you cultural identification with the following cultures by circling the appropriate number from the scales below.

	Very Weak	Weak	Some what Weak	Some what Strong	Strong	Very Strong
US American (North American)	1	2	3	4	5	6
Other:	1	2	3	4	5	6

58. What is the primary language spoken in your household? _____

58a. If another language is frequently spoken, which other language? _____

59. Have you ever participated in a different study in the Childhood Cognition Lab at UCR? If so, which ones? (Please check all that apply.)

__Watching Baby Einstein __Playing with My First Computer

__The TV show about reading

__Watching Sid the Science Kid and Little Bill

59a.Did you participate with the child involved in the current study or a different child?

___Same child in current study ___Different child from current study

Child Behavior Questionnaire

On the next pages you will see a set of statements that describe children's reactions to a number of situations. We would like you to tell us what your child's reaction is likely to be in those situations. There are of course no "correct" ways of reacting; children differ widely in their reactions, and it is these differences we are trying to learn about. Please read each statement and decide whether it is a "true" or "untrue" description of your child's reaction within the past six months. Use the following scale to indicate how well a statement describes your child:

Circle #	If the statement is:
l	extremely untrue of your child
2	quite untrue of your child
3	slightly untrue of your child
4	neither true nor false of your child
5	slightly true of your child
6	quite true of your child
7	extremely true of your child

If you cannot answer one of the items because you have never seen the child in that situation, for example, if the statement is about the child's reaction to your singing and you have never sung to your child, then circle NA (not applicable). Please be sure to circle a number or NA for every item.

1	**2**	**3**	**4**	**5**	**6**	**7**	**NA**
extremely untrue	**quite untrue**	**slightly untrue**	**neither true nor untrue**	**slightly true**	**quite true**	**extremely true**	**not applicable**

My child:

1. Seems always in a big hurry to get from one place to another (1).
   l 2 3 4 5 6 7 NA
2. Gets angry when told s/he has to go to bed (2).
   l 2 3 4 5 6 7 NA
3. Likes going down high slides or other adventurous activities (4).
   l 2 3 4 5 6 7 NA
4. Usually rushes into an activity without thinking about it (7).
   l 2 3 4 5 6 7 NA
5. Likes to play so wild and recklessly that s/he might get hurt (10).
   l 2 3 4 5 6 7 NA

6. Tends to run rather than walk from room to room (12).
   1 2 3 4 5 6 7 NA
7. Has temper tantrums when s/he doesn't get what s/he wants (14).
   1 2 3 4 5 6 7 NA
8. When practicing an activity, has a hard time keeping her/his mind on it (16).
   1 2 3 4 5 6 7 NA
9. When outside, often sits quietly (18).
   1 2 3 4 5 6 7 NA
10. Will move from one task to another without completing any of them (21).
   1 2 3 4 5 6 7 NA
11. Moves about actively (runs, climbs, jumps) when playing in the house (22).
   1 2 3 4 5 6 7 NA
12. Enjoys taking warm baths (26).
   1 2 3 4 5 6 7 NA
13. Often rushes into new situations (28).
   1 2 3 4 5 6 7 NA
14. Gets quite frustrated when prevented from doing something s/he wants to do (30).
   1 2 3 4 5 6 7 NA
15. Enjoys activities such as being chased, spun around by the arms, etc. (33).
   1 2 3 4 5 6 7 NA
16. Takes a long time in approaching new situations (36).
   1 2 3 4 5 6 7 NA
17. Can wait before entering into new activities if s/he is asked to (38).
   1 2 3 4 5 6 7 NA
18. Enjoys "snuggling up" next to a parent or babysitter (39).
   1 2 3 4 5 6 7 NA
19. Gets angry when s/he can't find something s/he wants to play with (40).
   1 2 3 4 5 6 7 NA
20. Is slow and unhurried in deciding what to do next (43).
   1 2 3 4 5 6 7 NA
21. Prepares for trips and outings by planning things s/he will need (45).
   1 2 3 4 5 6 7 NA
22. Prefers quiet activities to active games (50).
   1 2 3 4 5 6 7 NA
23. Tends to say the first thing that comes to mind, without stopping to think about it (51).
   1 2 3 4 5 6 7 NA
24. Has trouble sitting still when s/he is told to (at movies, church, etc.) (53).
   1 2 3 4 5 6 7 NA
25. Enjoys just being talked to (57).
   1 2 3 4 5 6 7 NA
26. Rarely gets upset when told s/he has to go to bed (61).
   1 2 3 4 5 6 7 NA
27. When drawing or coloring in a book, shows strong concentration (62).
   1 2 3 4 5 6 7 NA
28. Enjoys looking at picture books (65).

1 2 3 4 5 6 7 NA

29. Is good at following instructions (67).
1 2 3 4 5 6 7 NA
30. Likes to go high and fast when pushed on a swing (69).
1 2 3 4 5 6 7 NA
31. When building or putting something together, becomes very involved in what s/he is doing, and works for long periods (71).
1 2 3 4 5 6 7 NA
32. Likes being sung to (72).
1 2 3 4 5 6 7 NA
33. Approaches places s/he has been told are dangerous slowly and cautiously (73).
1 2 3 4 5 6 7 NA
34. Likes the sound of words, such as nursery rhymes (76).
1 2 3 4 5 6 7 NA
35. Dislikes rough and rowdy games (78).
1 2 3 4 5 6 7 NA
36. Can easily stop an activity when s/he is told "no" (81).
1 2 3 4 5 6 7 NA
37. Is among the last children to try out a new activity (82).
1 2 3 4 5 6 7 NA
38. Is easily distracted when listening to a story (84).
1 2 3 4 5 6 7 NA
39. Is full of energy, even in the evening (85).
1 2 3 4 5 6 7 NA
40. Enjoys sitting on parent's lap (86).
1 2 3 4 5 6 7 NA
41. Gets angry when called in from play before s/he is ready to quit (87).
1 2 3 4 5 6 7 NA
42. Enjoys riding a tricycle or bicycle fast and recklessly (88).
1 2 3 4 5 6 7 NA
43. Sometimes becomes absorbed in a picture book and looks at it for a long time (89).
1 2 3 4 5 6 7 NA
44. Likes to sit quietly and watch people do things (93).
1 2 3 4 5 6 7 NA
45. Enjoys gentle rhythmic activities, such as rocking or swaying (94).
1 2 3 4 5 6 7 NA

The PAD Parental Attitudes Scales*

Your Name _____ Your Gender: M F
Your Child's Name _____
Your Child's Gender: M F Your Child's Age _____
Your Child's Birthday _____ Today's Date _____

Please answer the attached questionnaire for one of your children. If you have more than one child, be sure to focus all your answers on the one child whose name you have written above. Be sure to answer the questions independently, that is, without consulting your spouse or a friend.

You may agree or disagree in different degrees with each statement. Highest agreement is +4; highest disagreement is –4. And, when you cannot agree or disagree with a statement, simply answer with a zero. Use the other numbers on the scale to show more moderate feelings in each direction.

Record you numerical answer to each statement in the space provided preceding the statement.

+4 = very strong agreement
+3 = strong agreement
+2 = moderate agreement
+1 = slight agreement
0 = neither agreement nor disagreement
-1 = slight disagreement
-2 = moderate disagreement
-3 = strong disagreement
-4 = very strong disagreement

_____ 1. Taking a few minutes to just be with my child helps me relax.

_____ 2. Children become too excited if they watch horror shows.

_____ 3. My child must try every food I serve.

_____ 4. I thought that children were supposed to be much happier than my child has turned out to be.

_____ 5. I leave my child with a lot of different people, so he gets used to change.

_____ 6. I try not to insist that my child always obey me.

_____ 7. I never regret having a child.

_____ 8. It doesn't bother me to have unexpected visitors drop in.

_____ 9. I enjoy showing the latest pictures of my child to my friends.

_____ 10. I don't think a fast-paced and busy home life is good for a child.

_____ 11. I don't think my child should have special manners for adults.

_____ 12. It's hard to be stuck at home with a child.

_____ 13. My child should be aware that what I say goes.

_____ 14. It is important to talk to babies even though they can't talk back.

_____ 15. I don't tolerate temper tantrums.

_____ 16. I like to be with my child.

_____ 17. I don't believe in catering to my child's demands.

_____ 18. I find it really irritating when all other women can talk about is their children.

_____ 19. I prefer to stay home rather than have my child exposed to more than one or two baby sitters.

_____ 20. I feel my child knows what is best for him.

_____ 21. My child often upsets me.

_____ 22. It is important that a child experience highly emotional encounters between his parents.

_____ 23. I think my child should comply with all my requests.

_____ 24. Having a child to care for is a lot of fun.

_____ 25. My child should learn to put his toys away after using them.

_____ 26. It is very interesting to spend time watching my child.

_____ 27. I don't like my child to be exposed to too many surprises.

_____ 28. Parents should not back down once they have told the child not to do something.

_____ 29. I look forward to the time when my child requires less care and attention from me.

_____ 30. My child can make the decision not to eat a food he really dislikes.

_____ 31. When I have free time, I'd rather be with my child than read a book.

_____ 32. A noisy home is bad for a child.

_____ 33. It is important for a child to have a fixed bedtime.

_____ 34. I find myself wondering if my child will ever grow up.

_____ 35. I want my child to have lots of children to play with.

_____ 36. I don't like to place a lot of rules on my child.

_____ 37. I really enjoy talking about my child.

_____ 38. I try to keep my child away from situations that may be overly exciting.

_____ 39. Having a child has been a very large burden for me.

_____ 40. One of the worst things a parent can do is insist that the child obey their every command.

_____ 41. When I have finished my day's work, I need time away from my child.

_____ 42. I make sure that my child sees as many different people as possible.

_____ 43. I have tried to teach my child early who makes the decisions in our family.

_____ 44. Staying at home with a child is more boring than I thought it would be.

_____ 45. My child should have the right to choose to stay up late occasionally.

_____ 46. It makes me happy just to think of the time my child and I spend together.

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THANK YOU SO MUCH FOR YOUR TIME ON THESE SURVEYS!

Appendix D

Exercise Protocol

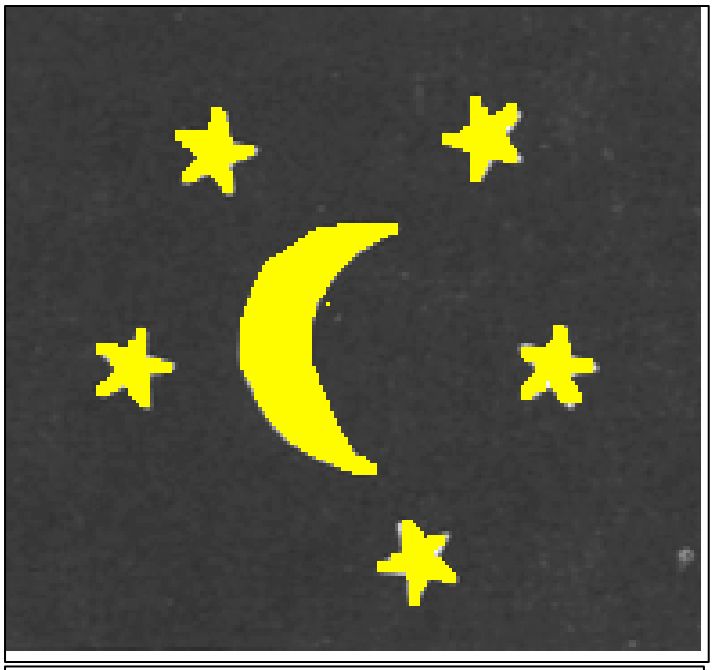
Demo List

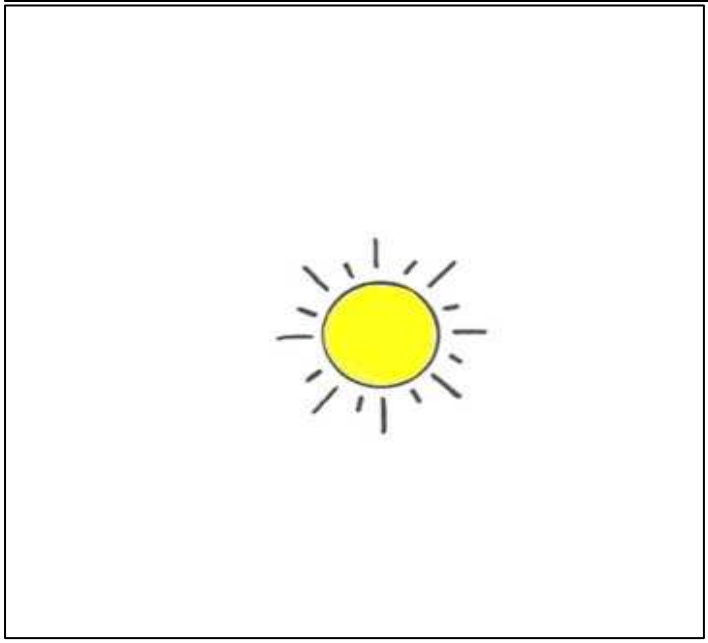
- Marching in Place
- Hopping
- Side Stepping Left to Right
- Stepping Forward and Back
- Feet In Feet Out
- Feet In Feet Forward Back (Hop)
- Step to the Right (Right foot then Left)
- Step to the Left (Left foot then Right)
- Step Forward (Right foot then Left)
- Step Backwards (Right foot then Left)
- Hop Left (1 or 2 footed hop)
- Hop Right(1 or 2 footed hop)
- Hop forward (1 or 2 footed hop) x
- Hop back (1 or 2 footed hop) x
- Hop in a Circle
- Step Right to Step Up left foot (Reverse)
- Step Right to Step Down left foot (Reverse) xx
- Step Left to Up right foot (Reverse) xx
- Step Left to Down right foot (Reverse)

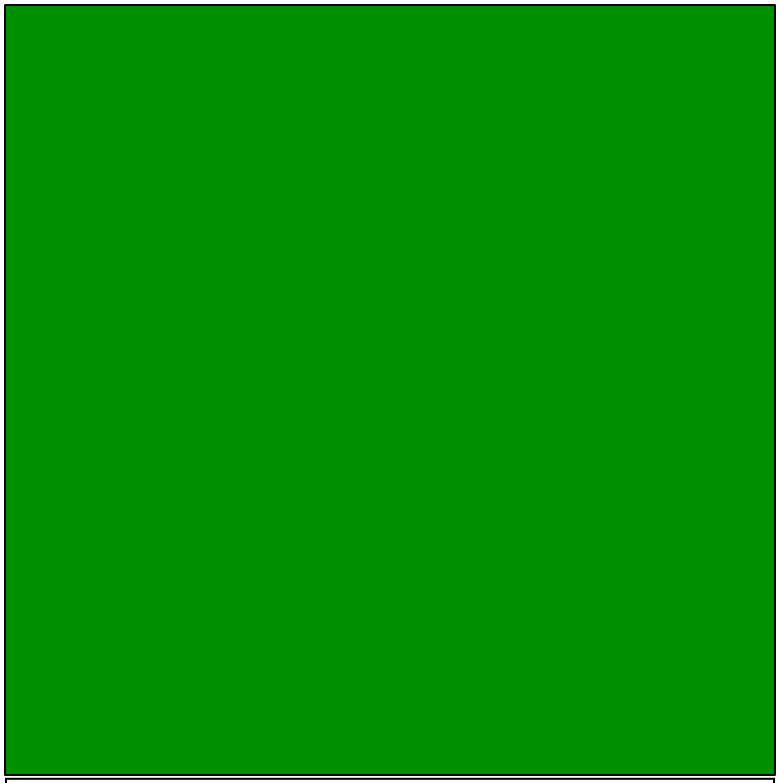
Exercise	Time	Recorded Time	Number of steps	Notes
1. Demo	2:18			
2. Marching in Place, Feet in Feet Out	1:35			
3. Hop in a Circle, Marching in Place	1:35			
4. Stepping Forward and Back, Step to the Right (both feet over), Step to the Left (both feet over)	1:37			
5. Step Right to Step Up left foot, Marching in Place, Step Left to Down right foot	1:35			
6. Marching in Place, Left foot step 3 times, March in place, Right foot step 3 times	1:42			
7. Hop Left, Step Backwards, Hop Right, Step Forward	1:34			
8. Step to the Left, Hopping, Step to the Right	1:32			
9. Step Left to Up right foot, Step Right to Step Down left foot	1:48			
10. Feet in Feet Out, Marching in Place, Feet In Feet Forward Back (Hop), Marching in Place	1:34			
11. Stepping Forward and Back (sidestep), Stepping left to right (sidestep)	1:38			
12. Step Right to Step Up left foot, Marching in Place	1:42			
13. Step Forward, Hop Right, Step Back, Hop Left	1:39			

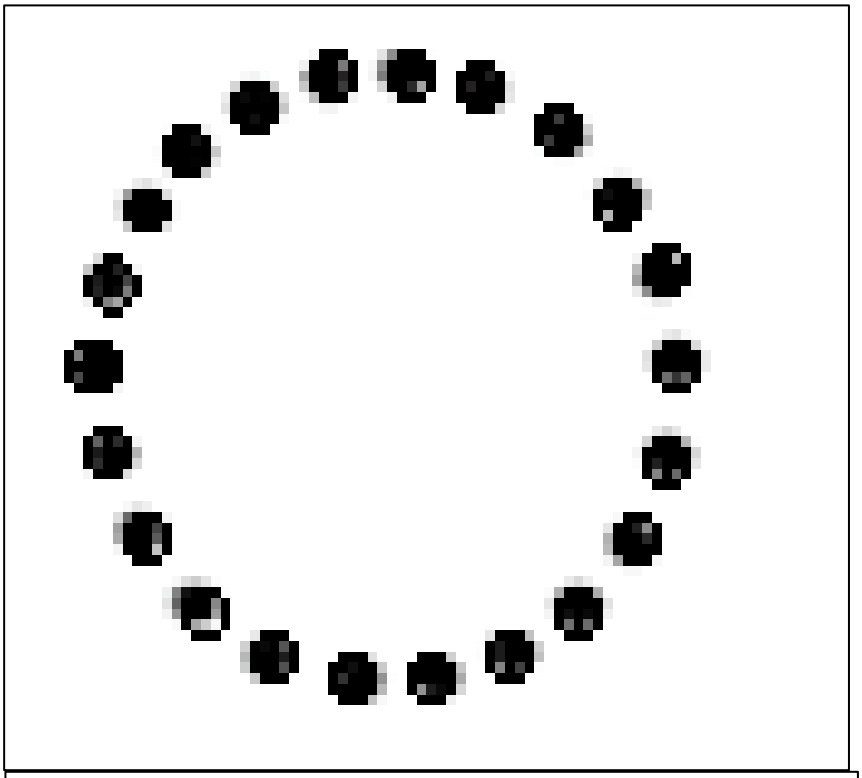
Appendix E
Executive Functioning Tasks

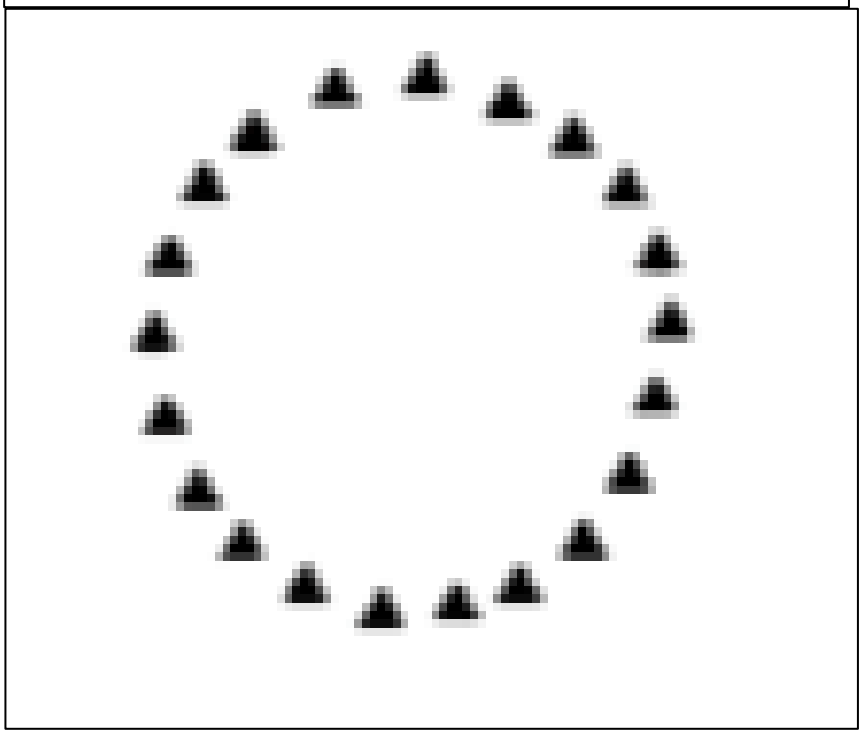
Stroop Tasks

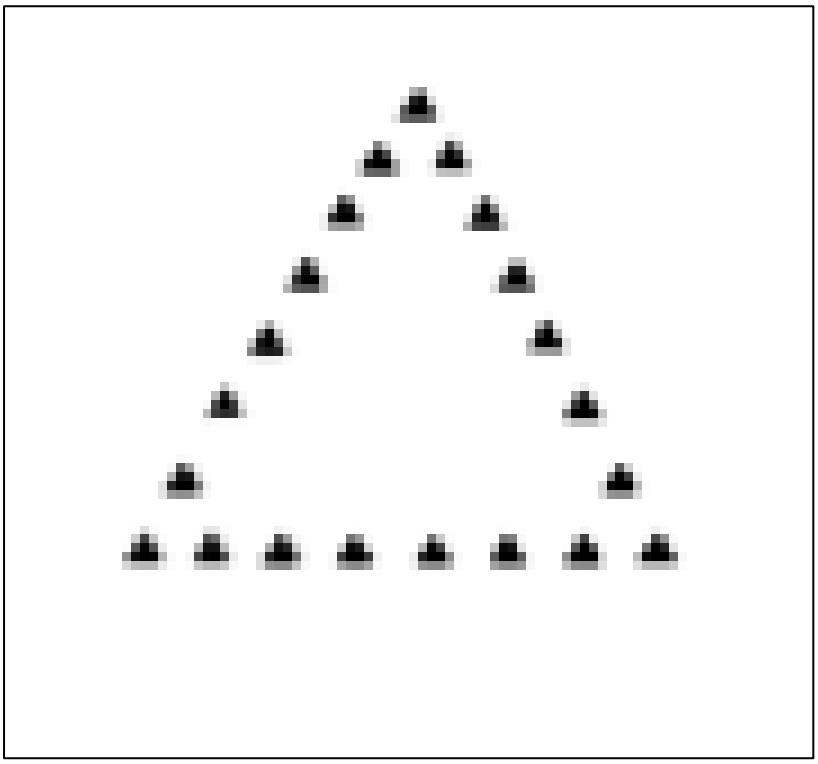


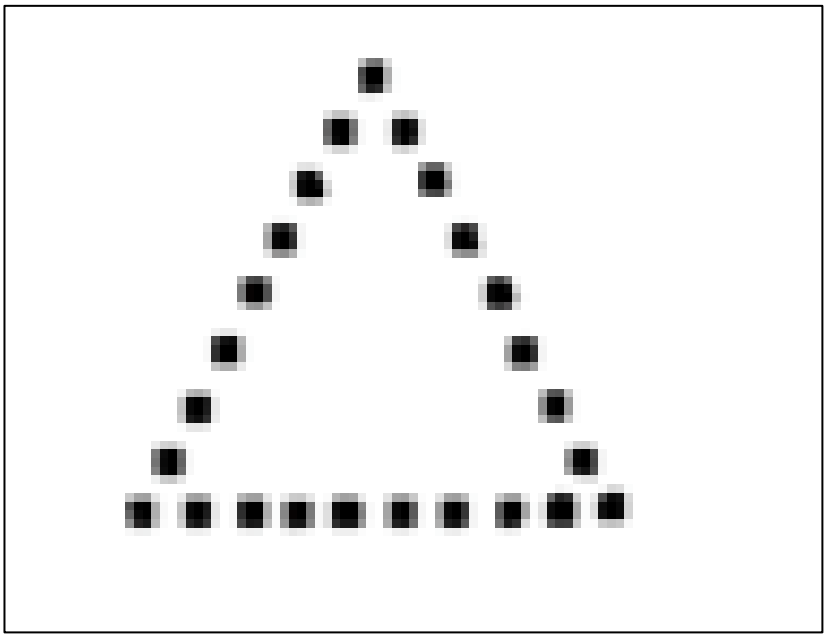


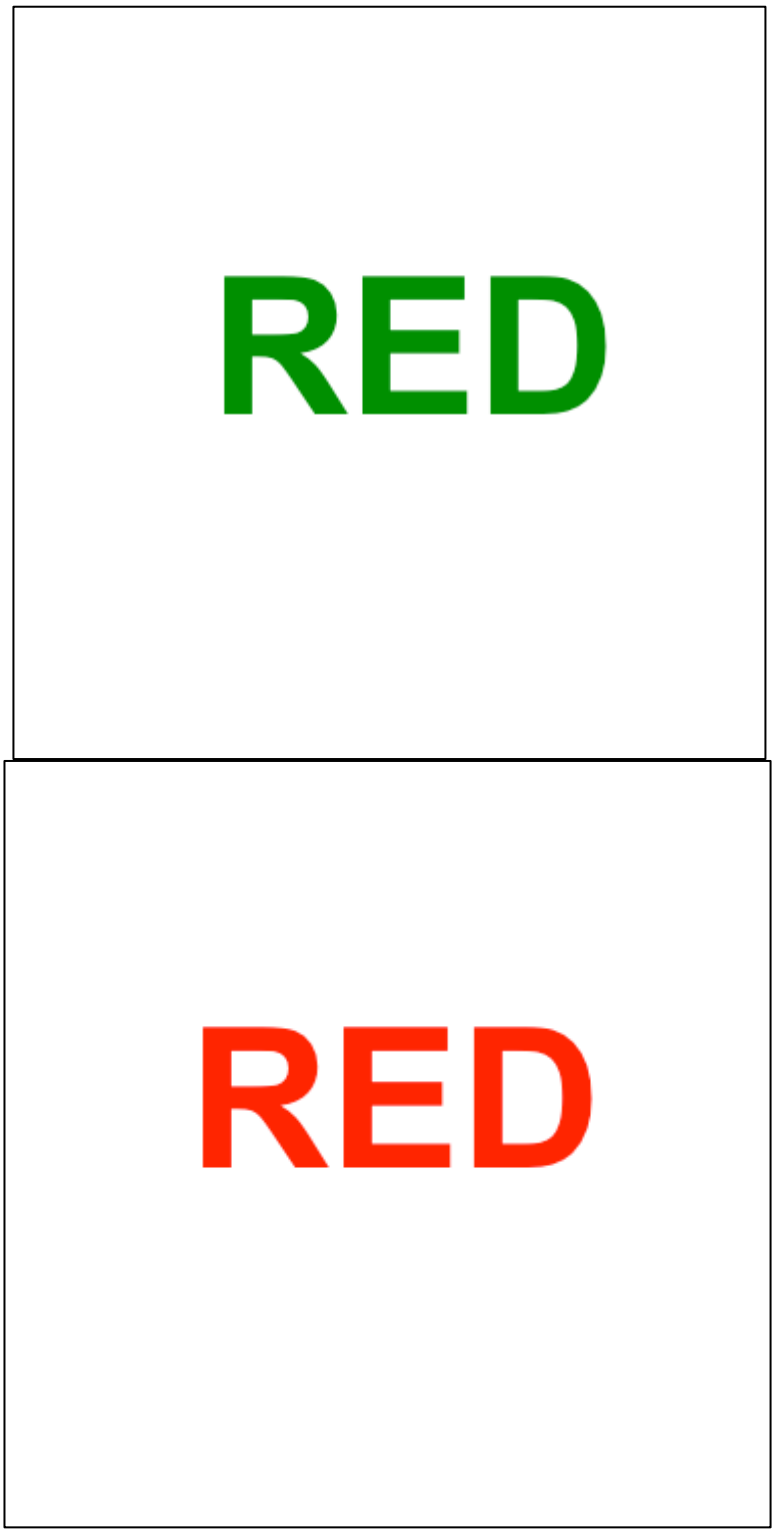


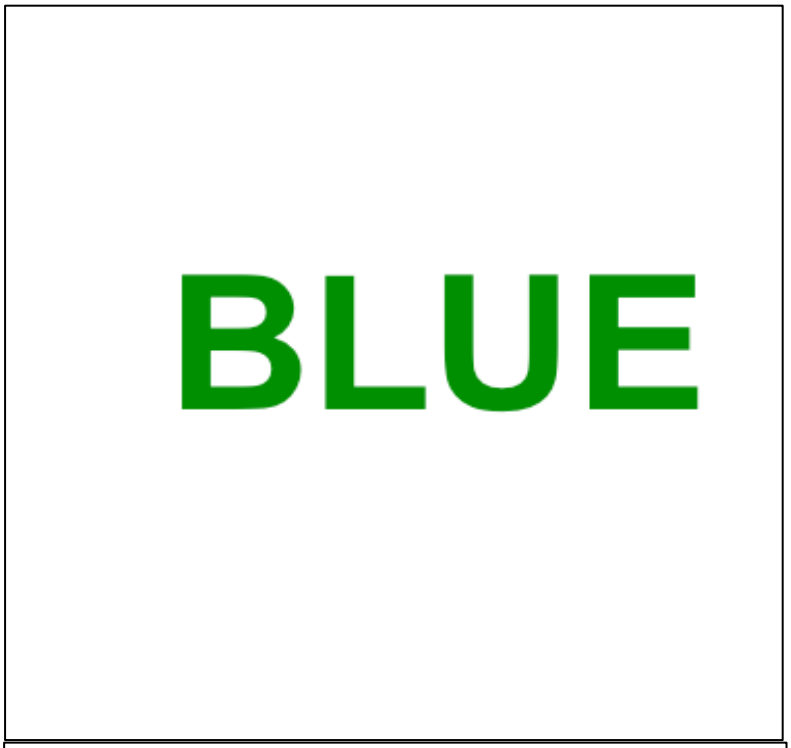


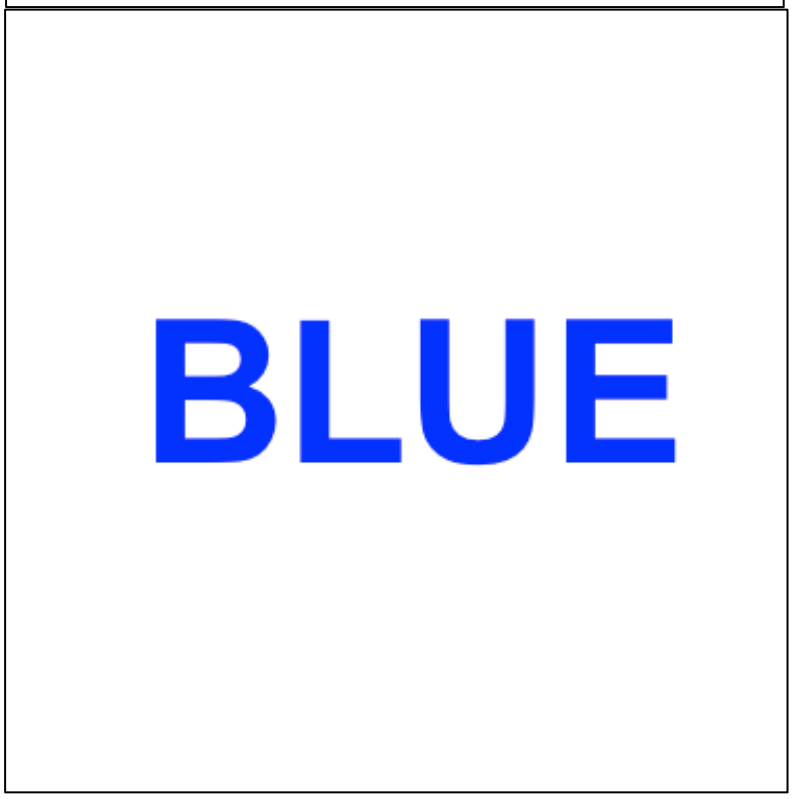







RED
RED


BLUE

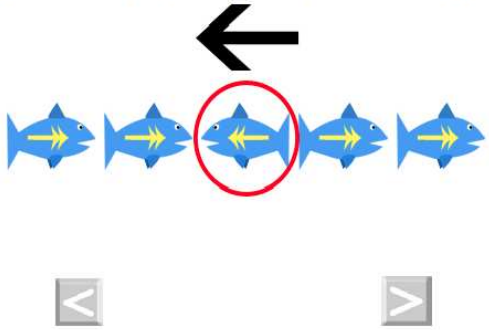

BLUE

Flanker Task

Block 1: Single Middle Focus

The next screen has the caption "**When the fish are BLUE the hungry fish is in the MIDDLE! Feed the MIDDLE fish by pressing where it's facing. Here, the middle fish is facing this way!**" (The arrow is pointing left.)

Experimenter says "In this game you get to feed the hungry fish! The hungry fish is in the middle, feed the middle fish by pressing where it's facing!" See the middle fish is facing this way so you press this button."



The next screen has three parts. The top captions says "**Sometimes the MIDDLE fish will be all by himself! You should still press where he's facing!**"



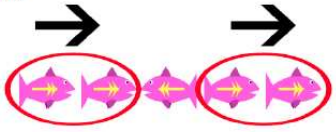
The middle caption says "**Sometimes the MIDDLE fish will have company that's going in another direction! You should still press where the middle fish is facing!**"



The bottom caption says, "**Your job is to feed the MIDDLE fish!**"

Block 2: Single Outside Focus

Then a screen with the caption "**When the fish are PINK all the OUTSIDE fish are hungry! Feed the fish on the OUTSIDE by pressing where they're facing. Here, the outside fish are facing this way.**" (Note the arrows pointing right.)



The next screen has the top caption "**Sometimes there won't be a middle fish! You should still press where the OUTSIDE fish are facing!**"



The middle caption says "**And sometimes the other fish will be going somewhere else! You should still press where the OUTSIDE fish are facing!**"



The bottom caption says "**Your job is to feed the OUTSIDE fish!**"

Block 3: Switch Focus

E) The Mixed (Blue and Pink Fish) Game.

The next screen says "**Now you're going to play the game with BOTH colors. So try really hard to remember the rules!**"

Press **enter** to advance.

A colorful screen appears with the top caption "**Blue means feed the MIDDLE! Press where the MIDDLE fish is facing!**"



The middle caption says "**Pink means feed the OUTSIDE! Press where the OUTSIDE fish are facing!**"



The bottom caption says" **Blue – MIDDLE!** **Pink – OUTSIDE!** "

Press **enter** to advance.

Go/No-Go

Example three Go trials followed by a No-Go trial

