THE EFFECT OF AN ACUTE BOUT OF PHYSICAL ACTIVITY ON INHIBITORY CONTROL IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER

By

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PUBLIC ABSTRACT

THE EFFECT OF AN ACUTE BOUT OF PHYSICAL ACTIVITY ON INHIBITORY CONTROL IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER.

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Given the growing prevalence of autism spectrum disorder (ASD) in the U.S., many researchers have dedicated their work to improving the quality of life for this population through the reduction in ASD symptoms. Interestingly, a growing body of research has suggested these symptoms may be related to aspects of cognitive function that have been shown to be affected by short-bouts of physical activity. Therefore, this study sought to explore the effects of short duration physical activity on cognitive function in individuals with ASD. For this study, 18 individuals with ASD and 18 typically developing (TD) individuals completed a computer task to assess cognitive function before and after either walking on a treadmill or sitting while reading. Findings from the study indicated that participants with ASD had poorer response accuracy to the task when compared to their TD peers. Additionally, prior to the walking condition, participants with ASD responded slower on average when compared to their performance prior to the reading condition. Although there is evidence supporting a difference between those with ASD and their TD peers in cognitive function, it is still unclear what role physical activity may play in addressing this difference. However, this study does provide an initial foundation for future research in this area by providing insight for study designs and feasibility in this area of research.

ABSTRACT

THE EFFECT OF AN ACUTE BOUT OF PHYSICAL ACTIVITY ON INHIBITORY CONTROL IN INDIVIDUALS WITH AUTISM SPECTRUM DISORDER.

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Concomitant with the increased prevalence of autism spectrum disorder (ASD) over the last two decades, interest in enhancing individual quality of life for those diagnosed by reducing ASD-related symptomologies has grown. Although evidence has suggested these symptomologies may be linked with deficits in inhibitory control and a growing body of literature has indicated benefits in inhibitory control associated with acute physical activity, the extent to which physical activity may influence inhibition in individuals with ASD is not well understood. Accordingly, the aim of this investigation was to examine the effects of an acute bout of aerobic physical activity on task performance indices of inhibitory control in individuals with ASD. Using a within-subjects crossover design, 18 individuals with ASD and 18 typically developing individuals were assessed for differences in task performance (reaction time and response accuracy) in response to a modified Eriksen flanker task prior to and 10-minutes following a 20-minute bout of aerobic exercise or seated reading across multiple, counterbalanced, sessions. Results showed a significant difference between groups for overall response accuracy with individuals with ASD displaying poorer response accuracy. Slower reaction time was also observed between rest and exercise conditions at pretest, specific to the ASD group. No significant differences were observed, however, at posttest or from pre- to posttest for either group based on mode. Despite evidence supporting differences between groups based on task performance, it remains unclear if, and to what degree, physical activity may influence interference control in individuals diagnosed with ASD. However, the findings of

this study do provide evidence for feasibility and insight regarding study design, establishing the framework for future research.

I would like to dedicate this dissertation to my mother and sister. I owe much of who I am today to the two of you. Mom – You have consistently displayed hard work, dedication, and compassion in both your personal and professional lives. While you set the bar high, your example has given me something to consistently strive for. I consider myself lucky to have had such a wonderful role model, and privileged to have built the relationship we share today. Meghan – Seeing the passion you have for your work and the influence you have on your students' lives is truly inspiring. I hope my work can one day effect the lives of others the way you have affected so many. Thank you both for the constant support, encouragement, and shoulder to lean on. I could not have done this without either of you.

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KEY TO ABBREVIATIONS

ADHD	Attention Deficit/Hyperactivity Disorder
ADOS-2	Autism Diagnostic Observation Schedule
ANOVA	Analysis of Variance
ASD	Autism Spectrum Disorder
CDC	Centers for Disease Control and Prevention
DSM-5	Diagnostic and Statistical Manual of Mental Disorders – 5th edition
HHD	Health History Demographic
HR	Heart Rate
NCLB	No Child Left Behind Act of 2001
PAR-Q	Physical Activity Readiness Questionnaire
RT	Reaction time
SCQ	Social Communication Questionnaire
SES	Socioeconomic Status
SNAP-IV	Swanson, Nolan, and Pelham Questionnaire – 4th edition
TD	Typically Developing
VO_2	Aerobic Capacity
VO_{2max}	Maximum Aerobic Capacity
WASI-II	Wechsler Abbreviated Scale of Intelligence – 2nd edition

CHAPTER 1

Introduction

Recent estimates from the Autism and Developmental Disabilities Monitoring Network suggest that 1 in 68 children are diagnosed with an Autism Spectrum Disorder (ASD; Baio, 2014; Christensen et al., 2016). This pervasive developmental disorder is often identified by impairments in social and communicative interaction, and restrictive or repetitive behaviors (American Psychiatric Association, 2013). While the etiology of this disorder is still unclear and there exists a wide spectrum of symptom expression (Volkmar, Cook, Pomeroy, Realmuto, & Tanguay, 1999), evidence suggests a possible link between the underlying symptomologies of ASD and deficits in cognitive function — particularly in areas related to cognitive control (Hill, 2004; Hughes, Russell, & Robbins, 1994; Ozonoff & Jensen, 1999). Interestingly, such impairments in cognition mirror those aspects of cognition that are enhanced following a bout of physical activity. Specifically, a growing body of evidence in both typically and atypically developing children has observed that 20-minutes of moderate intensity aerobic physical activity can improve behavioral task performance in response to cognitive control related tasks (Drollette et al., 2014; Drollette, Shishido, Pontifex, & Hillman, 2012; Hillman, Pontifex, et al., 2009; Pontifex, Saliba, Raine, Picchietti, & Hillman, 2013). Thus, given that individuals with ASD exhibit core deficits in the same aspects of cognition that are enhanced following participation in a single bout of physical activity, investigation of the extent to which a single dose of physical activity may serve to influence the cognition of individuals with ASD may inform evidence based recommendations for clinical practice and educational policy within this population.

Cognitive control — a term used synonymously with executive function — refers to a set of computational processes involved in the scheduling, selection, maintenance, and coordination of high-order cognitive functions (Hillman, Erickson, & Kramer, 2008; Pontifex et al., 2011; Rogers & Monsell, 1995). These processes regulate an individual's goal-directed interactions with the environment (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Voss et al., 2011). Cognitive control is collectively comprised of three core cognitive processes: working memory, cognitive flexibility, and inhibition (Diamond, 2012; Miyake et al., 2000). Of these core processes, evidence suggests that individual's with ASD, children in particular, exhibit distinct impairments related to inhibition (Christ, Kester, Bodner, & Miles, 2011; Kana, Keller, Minshew, & Just, 2007). This component process has been identified as particularly important within developing populations as it relates to the ability to suppress a pre-potent action-schema/override an on-going response as well as gate out task irrelevant environmental information (Barkley, 1997; Davidson, Amso, Anderson, & Diamond, 2006). Interestingly, evidence suggests that the impairment in inhibition evident in children with ASD appears to be specific to the interference component of inhibition (Adams & Jarrold, 2012; Christ, Holt, White, & Green, 2007; Keehn, Lincoln, Müller, & Townsend, 2010). That is, Adams and Jarrold (2012), employed a sample of 15 children with diagnosed ASD and 15 match-control typically developing children to specifically test the extent to which ASD-related impairments in inhibition generalized across inhibitory control domains. In response to a modified flanker task, children with ASD demonstrated poorer response accuracy when interference control demands were the greatest, relative to the match-control children; whereas no differences between groups were observed relative to performance on a stop-signal task which provided an index of inhibiting of action (Adams & Jarrold, 2012). These findings, among others (Adams & Jarrold, 2009; Lopez, Lincoln, Ozonoff, & Lai, 2005; Ozonoff & Jensen, 1999), have suggested that the deficits in inhibitory control for children with ASD do not generalize across inhibition domains, but rather are specific to managing task irrelevant information. As complex social interactions often rely on subtle social and physical cues amid a multitude of other potentially irrelevant factors (Hanley et al., 2014), this deficit in managing interference to focus on relevant indicators may in part underlie ASD related symptomologies in social interactions. With research indicating enhancements in interference control following a single bout of physical activity (Drollette et al., 2014; Hillman, Pontifex, et al., 2009; Pontifex et al., 2013), such that preadolescent children are able to more effectively distinguish relevant task information amongst a set of irrelevant stimuli, physical activity may be a means to reduce symptomologies related to social impairments in children with ASD. Acute bouts of physical activity have been shown to have a beneficial influence on interference control (Hillman et al., 2006; Hillman, Pontifex, et al., 2009; Pontifex & Hillman, 2007), with research indicating that a bout of aerobic physical activity lasting at least 20-minutes can enhance performance on tasks requiring aspects of interference control (Drollette et al., 2014; Hillman, Pontifex, et al., 2009; Pontifex et al., 2013). Specifically, in an initial investigation of the influence of a single bout of physical activity on interference aspects of inhibitory control in preadolescent children, Hillman and colleagues (2009) observed that following a single 20-minute bout of moderate-intensity physical activity, children demonstrated greater performance relative to following a similar duration of seated reading. Such bouts of moderate intensity aerobic physical activity have also been found to enhance interference related aspects of inhibitory control in children with Attention Deficit/Hyperactivity Disorder (ADHD). Utilizing a sample of 20 preadolescent children suspected or diagnosed with ADHD, and 20 match-control children, Pontifex and colleagues (2013) assessed the effect of a 20-minute aerobic exercise condition relative to 20-minutes of seated reading on behavioral performance in response to a modified flanker task. Findings from this investigation indicated that all participants experienced benefits as indexed by greater response accuracy following acute exercise relative to reading, with those diagnosed with ADHD also experiencing additional physical activity related enhancements in regulatory adjustments in behavior as indexed by greater slowing of reaction time on trials immediately following an erroneous response. Such generalized enhancements, with selective benefits for children with ADHD, taken together with the high comorbidity/dual diagnosis associated with ADHD and ASD (American Psychiatric Association, 2013), suggest that these bouts of physical activity may provide a means of enhancing interference control in children with ASD.

Despite evidence indicating a positive effect of a bout of physical activity on interference control in preadolescent populations, an overarching limitation of this literature base to date is the experimental designs used to determine the effect of physical activity on cognition (Lambourne & Tomporowski, 2010). That is, evidence in this area is drawn from studies which have, to-date, relied on within-subjects experimental designs which assessed differences in cognition following exercise relative to following a seated control condition with the experimental conditions occurring on separate days (Hillman, Pontifex, et al., 2009; Pontifex et al., 2013). Such designs are potentially problematic given evidence for day-to-day variations in neurological components associated with attentional processing (Polich & Kok, 1995), thus such differences may manifest independent of the experimental conditions. Alternatively, other investigations in this area have relied upon between-subject's experimental designs in which participants engage in cognitive testing prior to, and following an acute bout of exercise (Ferris, Williams, & Shen, 2007; Magnié et al., 2000; Nakamura, Nishimoto, Akamatu, Takahashi, & Maruyama, 1999; Yagi, Coburn, Estes, & Arruda, 1999). This method, unlike the previous, does not include a non-exercise control group, with any changes in cognition assessed from preexercise to post-exercise; rendering it difficult to distinguish effects related to exercise from those associated with exposure to the task (Pontifex, Parks, Henning, & Kamijo, 2015). Therefore, in effort to better assess the effects of physical activity within this study, a within-subjects repeated measures design will be implemented utilizing both exercise and control experimental conditions as well as pre-posttest assessments.

CHAPTER 2

Review of Literature

Autism Spectrum Disorder

Over the last two decades, Autism Spectrum Disorder (ASD) has been identified as one of the fastest growing developmental disorders in the United States, with a growing impact not only on the quality of life for individuals diagnosed but also on family and caregivers who work with them. To better understand the effects of ASD on not only the individuals diagnosed with the disorder, but also those who care for them, the Center for Disease Control and Prevention (CDC) developed the Autism and Developmental Disabilities Monitoring Network in 2000 (Baio, 2014; Centers for Disease Control and Prevention, 2016; Christensen et al., 2016). This network helped to elucidate the current prevalence of the disorder, with 1 in 68 children diagnosed in the United States (U.S.), indicating an increase in the U.S. of 29% since 2008, 64% since 2006, and 123% since 2002 (Baio, 2014). It is believed that this increase in prevalence is due primarily to improved diagnostic criteria and awareness, as the cause for this disorder is still unknown with a large number of cases identified as idiopathic (Schaaf & Zoghbi, 2011). In accordance with this increase in diagnosis of ASD in the last decade, concerns as to how these individuals may be assisted and treated has also grown. With many individuals receiving assistance from caregivers and family members, estimated lifetime costs for those supporting an individual with ASD can be as high as $2.4 million (Buescher, Cidav, Knapp, & Mandell, 2014). Ranging from behavioral and speech therapies, to pharmacological treatments, these strategies have placed a large financial and psychological demand on the individuals diagnosed with ASD and their families. While the economic cost is high, it is also important to recognize the time constraints and social pressures experienced by these individuals and their families, with a number of researchers identifying that caregivers for individuals with ASD exhibit greater levels of stress, anxiety, and depression when compared with parents of typically developing children and those with other developmental disorders (Abbeduto et al., 2004; Hastings & Johnson, 2001; L. E. Smith, Seltzer, Tager-Flusberg, Greenberg, & Carter, 2008). As such, interest in non-pharmaceutical strategies to address cognitive related issues associated with the disorder have grown, with many focusing on ways to help with social interaction and suppression of stereotypical behavioral patterns (Koenig et al., 2010).

Autism Spectrum Disorder (ASD) comprises a set of developmental disabilities identified through the Diagnostic and Statistical Manual of Mental Disorders – 5th edition (DSM-5) by impairments across two domains of functioning (American Psychiatric Association, 2013). Identified as a pervasive disorder, individuals diagnosed with ASD exhibit deficits in restrictive or repetitive patterns of behavior and/or interests, and social and communicative interactions (American Psychiatric Association, 2013). Recently adopted by the DSM-5, the phrase "spectrum disorder" is now used to reflect the wide range of behaviors and symptom expressions associated with the disorder (Volkmar et al., 1999). In accordance with the myriad of ways in which this disorder may present, it has become increasingly important to promote a greater understanding of the disorder among the general populace in hopes of providing a more inclusive and available community environment to those diagnosed with ASD and their families. One setting in which this need has become more evident is within the classroom. For instance, restrictive and repetitive behaviors (RRBs) may present in many ways (i.e., utterances, repetitive use of objects, unusual or all-consuming interests, and compulsive, rigid, ritualistic behaviors), each of which can affect not only the learning process for the child in the classroom (along with learning process for their peers), but may also impact their social interaction with their peers.

Deficits associated with social interaction are commonly observed among individuals diagnosed with ASD, and often present as behaviors such as: impaired social reciprocity, perspective taking, and nonverbal communication; as well as difficulties building flexibly appropriate social relationships (Williams White, Keonig, & Scahill, 2007). Much like the impairments associated with RRBs, these deficits may also manifest in a variety of ways (i.e., failure to acquire any speech, a need for alternative communication methods, use of stereotyped speech, echolalia, and/or simply having difficulty following typical rules of conversation; American Psychiatric Association, 2013), with each having the potential to substantially contribute to the challenges an individual with ASD faces when attempting to assimilate into a classroom environment. While a variety of treatment methods and behavioral strategies are implemented to help address these deficits and help those with ASD in the classroom, the varying nature of how the disorder presents with each diagnosis has made addressing these deficits increasingly difficult.

With concerns related to this disorder continuing to rise, many researchers have attempted to address the underlying mechanisms related to this disorder, yet the etiology remains elusive. Current suggestions for the causes of the disorder have involved many different avenues including genetics (Huguet, Ey, & Bourgeron, 2013) and pharmacology (Christensen et al., 2013; Strömland, Nordin, Miller, Akerström, & Gillberg, 1994), however due to the inability to isolate a direct cause for the disorder many researchers have begun to focus on identifying the underlying factors contributing to the disorder and ways to address them. Understanding that each case of ASD is unique is important, as each treatment approach must be tailored to the individual and family involved. Due to the complexities of the disorder and its currently unknown etiology, these treatments should be considered a long-term commitment for the individual to experience optimal results from the intervention, but not as a cure. For many, these interventions mean working with a treatment team (i.e., physician, counselor, therapists [speech, behavior, physical, occupational], psychologist, etc.) throughout their life, utilizing pharmacological (i.e., Selective Serotonin Reuptake Inhibitors and Antipsychotics) and non-pharmacological treatments (i.e., Applied Behavioral Analysis [Dunlap, Kern-Dunlap, Clarke, & Robbins, 1991; Virués-Ortega, 2010], Pivotal Response Treatment [Koegel & Kern Koegel, 2006; Lei & Ventola, 2017], Verbal Behavior [Sundberg & Michael, 2001], Early Start Denver Model [Smith, Rogers, & Dawson, 2008], and Relationship Development Intervention [Gutstein & Sheely, 2002]). While each of these methods addresses specific symptomologies associated with the disorder, a growing number of research studies have suggested that these symptomologies may be related to deficits in cognitive control (Hill, 2004; Hughes et al., 1994; Ozonoff & Jensen, 1999) consequently providing an alternative avenue to address impairments associated with ASD.

Cognitive Control

Cognitive control, also referred to as executive function or executive control, is a term used to reference the underlying set of higher-order, cognitive processes associated with the regulation of goal-directed interactions within the environment (Botvinick et al., 2001; Meyer & Kieras, 1997; Voss et al., 2011). Comprised of three core cognitive processes (i.e., inhibition, working memory, and cognitive flexibility; Diamond, 2006)), cognitive control is involved with scheduling, selection, maintenance, and coordination of processes underlying an individual's perception, memory, and behaviors (Botvinick et al., 2001; Hillman et al., 2008; Miyake et al., 2000; Pontifex et al., 2011). Although each of these core processes plays an integral role in an individual's decision making, and perceptions of the world, inhibition has received a great deal of attention within the literature, particularly with respect to research involving acute physical activity (Hillman et al., 2006; Hillman, Snook, & Jerome, 2003; Hillman, Buck, Themanson, Pontifex, & Castelli, 2009; Pontifex & Hillman, 2007). Cognitive psychologists have theorized that inhibition is composed of related, but distinct subprocesses (Nigg, 2000) each playing a part in an individual's ability to override impulsive responses. To date, researchers have been able to distinguish subtypes of inhibition allowing for a more thorough examination of how this overarching process operates (Friedman & Miyake, 2004; Nigg, 2000). Inhibition is commonly separated into prepotent response inhibition (i.e., the ability to suppress a dominate response in order to respond with a less potent response) and interference control (i.e., the ability to ignore irrelevant information within the stimulus environment; Barkley, 1997; Friedman & Miyake, 2004; Geurts, van den Bergh, & Ruzzano, 2014; Miyake & Friedman, 2012), with various paradigms used to examine each.

Of the paradigms utilized to assess inhibition processes of cognitive control, the Eriksen flanker task (Eriksen & Eriksen, 1974) is commonly used due to its ability to elicit interference control. In order to successfully complete this task, participants are required to respond to a centrally presented target stimulus flanked by task irrelevant stimuli with the congruence of the target stimulus and flanking stimuli manipulated to elicit response interference. During a congruent stimuli presentation (i.e., <<<<< or PPPPP), the centrally presented target stimulus and the lateral flanking stimuli are uniform. As this presentation array does not require interference control, task performance commonly results in faster and more accurate responses when compared to the incongruent stimuli presentation (i.e., <<><< or PPRPP). The incongruent array utilizes opposing action-schemas for the target and flanking stimuli, eliciting both an incorrect response to the flanking stimuli and a correct response to the target stimuli (Eriksen & Eriksen, 1974; Pontifex et al., 2015). Due to the additional interference presented during this stimulus condition, participants are required to gate out the irrelevant task information in order to engage in a correct response (Spencer & Coles, 1999). While conceptually this paradigm appears simplistic, it is because of this straightforward approach that this task has been adapted and modified to fit many diverse needs. Through the modification of the stimuli presented (e.g., letters, arrows, fish; Eriksen & Eriksen, 1974; Hillman et al., 2003; Pontifex et al., 2013), researchers have been able to adapt the task to meet their needs for various participant populations and examine a variety of outcome measures. However, it is important to note that when examining these varying populations, selection of outcome measures to explore is an important consideration. While reaction time can be used to explore the timing for response selection within most populations, children have been shown to exhibit impulsiveness when selecting a response that may result in consistency of reaction time across each condition (congruent and incongruent; Christakou et al., 2009; Davidson et al., 2006; Drollette et al., 2014). Therefore, response accuracy measures may provide more accurate, insight into the ability to inhibit the flanking stimuli given the population of interest (Davidson et al., 2006; Drollette et al., 2014).

Cognitive Control Characteristics in Individuals with ASD

As we have acquired more information pertinent to our understanding of the core cognitive control aspects, application of this knowledge to new populations has increased exponentially. In particular, interest toward individuals diagnosed with developmental disabilities, such as ASD, has grown due to the similarities between the symptomologies associated with diagnoses and the core cognitive processes. Through this work, one proposed explanation for a potential underlying mechanism associated with ASD symptomologies has been based on impairment in the aspects of cognitive control (Hill, 2004; Hughes et al., 1994;

Ozonoff & Jensen, 1999). Within this population, deficits associated with cognitive flexibility (see Hill, 2004 for review), working memory (Luna et al., 2002; Luna, Doll, Hegedus, Minshew, & Sweeney, 2007) and inhibition (Christ et al., 2007; Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004; Ozonoff, Strayer, McMahon, & Filloux, 1994) have all been documented. Findings relative to cognitive flexibility and working memory impairment have been supported through extensive assessment of structural, metabolic, and neurotransmitter abnormalities associated with the prefrontal cortex (PFC; Chugani et al., 1997; Ohnishi et al., 2000; Salmond, De Haan, Friston, Gadian, & Vargha-Khadem, 2003), a region of the brain associated with higher-order cognitive processing, such as cognitive control, and has shown delayed development in individuals diagnosed with ASD (Zilbovicius et al., 1995). As evidence to substantiate the findings for deficits in cognitive control and working memory remains consistent, research exploring inhibition within the population has been debated.

Although the aspect of inhibition has yielded mixed findings with regard to individuals with ASD, it has also been consistently suggested as the link for ASD symptomologies due to the impaired ability of individuals with ASD to suppress unwanted behaviors (Langen, Durston, Kas, van Engeland, & Staal, 2011). Additionally, individuals with ASD struggle to inhibit extraneous semantic information during conversation often strictly interpreting language, conveying a potential influence of inhibitory control on social and communicative interaction (Geurts et al., 2014; Hughes, 2001). While the notion that inhibition may underlie ASD symptomologies is prevalent, the inconsistencies within the literature have complicated our understanding of inhibitory control within an ASD population. However, it is because of these inconsistencies that researchers have begun separating inhibition into prepotent response inhibition and interference control when investigating this research question. An example of this can be seen in Christ et al.'s, 2007 and 2011 work utilizing a flanker paradigm to assess interference control, and a Go/No-Go task to assess inhibition of prepotent responses. Findings from this study indicated that individuals with ASD experience impaired interference control, but have intact prepotent response inhibition when compared to a control population. While there are studies suggesting that interference control remains intact for individuals diagnosed with ASD (Brian, Tipper, Weaver, & Bryson, 2003; Ozonoff & Strayer, 1997, p. 200; Ozonoff et al., 1994; Pennington & Ozonoff, 1996), research has shown that when utilizing tasks that require the individual to manage task irrelevant information (such as the Flanker paradigm) the deficits observed for inhibition appear specific to the interference control domain (Adams & Jarrold, 2012; Keehn et al., 2010; Lopez et al., 2005). Interestingly, the deficits observed in interference control for individuals with ASD mirror the aspects of cognitive control that have shown transient enhancements following an acute bout of physical activity (Drollette et al., 2014; Hillman, Buck, et al., 2009; Pontifex et al., 2013), suggesting a potential for physical activity to improve interference control performance and reduce symptomologies in individuals with ASD.

Physical Activity Trends in Individuals with ASD

While research exploring the effects of physical activity on aspects of cognitive control are still fairly contemporary, the benefits of physical activity associated with overall health have been well documented. The Centers for Disease Control and Prevention (U.S. Department of Health and Human Services, 2008) have reported that participating in 150 minutes per week of physical activity at a moderate-to-vigorous intensity level can help to reduce risk of cardiovascular disease, type II diabetes, obesity, some forms of cancer, and improve mental health. Current guidelines also recommend that youth between the ages of 6 and 17 years old should engage in at least 60 minutes of physical activity daily, including aerobic, resistance, and bone-strengthening activities (U.S. Department of Health and Human Services, 2008). Despite this knowledge, estimates indicate that 1 in 5 adults and approximately 21% of youth in the U.S. meet these recommendations (U.S. Department of Health and Human Services, 2008). In response to this trend, there has been an increased emphasis placed on motivation and adherence to physical activity by researchers in many fields. However, while public health officials have attempted to implement the findings from this research, it has become evident that activity patterns associated with various populations, such as individuals diagnosed with developmental disabilities, differ from the general public. Preliminary research has shown these individuals may exhibit an increased sedentary lifestyle when compared to their typically developing peers (Draheim, Williams, & McCubbin, 2002; Todd & Reid, 2006), with individuals diagnosed with ASD exhibiting a significant decline in physical activity participation with age (MacDonald, Esposito, & Ulrich, 2011; Pan, 2008; Pan & Frey, 2006). This increased sedentary behavior not only places these individuals in a high-risk category for the aforementioned health concerns, but also suggests an even greater need to explore motivation for activity in these groups, as well as, garner a better understanding for the perceived barriers to physical activity these individuals are facing.

One barrier to physical activity often cited throughout the ASD literature is related to impairments in the areas of fine and gross motor skills, commonly presenting as delayed or atypical motor patterns (Lloyd, MacDonald, & Lord, 2013; Ozonoff et al., 2008; Staples & Reid, 2010). Over the course of an individual's life there are a number of milestones associated with skill development that each person will experience. Progression through these milestones is a fairly set continuum with most deviations from the standard trajectory occurring through changes in the onset and endpoints with each milestone. Individuals diagnosed with ASD tend to fall behind the standard trajectory early in life, and with age may experience an exponential increase in delays due to the compounding nature of the milestone progression (Lloyd et al., 2013). When considering the critical role these motor milestones play in the acquisition and utilization of complex motor skills associated with physical activity (i.e., kicking a soccer ball, throwing, catching, etc.) it is understandable that this population struggles to maintain an active lifestyle when compared to their typically developing peers. Exacerbating this issue further, exposure to these activities and practice at home, a playground, or during physical education classes is often used to address these delays, however these settings tend to introduce additional barriers for children with ASD potentially effecting the ability for these individuals to overcome motor deficits.

Beyond improving physical activity engagement and motor delays, research focusing on the effects of physical activity within this population have also had promising results related to some of the symptomologies commonly associated with ASD. When individuals diagnosed with ASD are observed in the playground and physical education environments, concerns affiliated with deficits observed in social and communicative interaction are often cited in the literature. In an unstructured setting utilizing free play activity, such as recess, research has shown that individuals diagnosed with ASD tend to exhibit lower levels of engagement in physical activity compared to their TD peers (Pan, 2008). Similar findings have also been observed in the playground environment, where the ASD population gravitate toward individualized activities such as isolated play (playing by oneself), parallel play (playing near a peer, but not interacting), and observation (watching other's play while they remain inactive). With regard to physical activity, this form of isolation can be beneficial as it helps to eliminate issues associated with non-verbal communication and feeling misunderstood while attempting to complete the activity

(Pan, 2009). Yet, as most physical activities individuals participate in at recess and on the playground, involve group participation, children with ASD who disengage from their peers may be isolated from these activities due to their difficulties with social interaction (Pan & Frey, 2006), and find themselves physically inactive as a result. Contrary to this dynamic, physical education classes appear to provide a greater level of opportunity for social engagement allowing individuals with ASD to become more active (Pan, 2008). It has been suggested that the change in environment, particularly the transition to a structured setting, could be directly related to the change in participation level. As the different environments present with varying levels of peer acceptance, fear of exclusion, social engagement, and other negative social and behavioral perceptions, individuals with ASD may not perceive an equal opportunity for involvement between the settings (Pan, 2008, 2009; Pan, Tsai, Chu, & Hsieh, 2011). For instance, in the instructor-led environment of a physical education classroom, a pre-determined social and communicative framework (i.e., kids are automatically involved and part of the team) may optimize the opportunity for individuals with ASD to interact with peers and engage in greater amounts of physical activity. Consistent with these findings, Pan (2010) conceptually expanded this approach from the physical education environment to a group exercise setting (aquatics) over the course of 10-weeks. Results from this study indicate improved social skills following completion of the exercise protocol among 16 children with ASD. However, in a similar study conducted by Fragala-Pinkham, Haley, & O'Neil (2011) over the course of 14-weeks, no differences were observed between the control group (n = 5) and those diagnosed with ASD (n = 7). Although results have been mixed, further research exploring potential benefits of physical activity on social and communicative interaction within this population is necessary as concerns related to statistical power within the samples and potential confounds (i.e., repeated socialization opportunities through chronic intervention protocols) may have influenced the findings present in existing literature.

Research exploring the effects of physical activity on repetitive and restrictive behaviors has been encouraging, with many of the studies focusing on improvements in classroom etiquette and unwanted behaviors. This area of study has shown that when individuals with ASD engage in physical activity, stereotypic behaviors often associated with repetitive and restrictive behaviors seen in the classroom improve (Elliott, Dobbin, Rose, & Soper, 1994; Kern, Koegel, & Dunlap, 1984; Kern, Koegel, Dyer, Blew, & Fenton, 1982). Of particular concern within this literature, though, is the variation in physical activity modalities and the varying study designs. Within the small number of studies that have explored this effect, majority have utilized an aerobic bout of physical activity within the study design (i.e., jogging; Kern et al., 1984, 1982; Levinson & Reid, 1993). This approach is consistent with physical activity based research, however as each of these studies utilizes an observational analytic cohort design, findings from these analyses are informative but require further exploration. Alternatively, the few studies implementing an experimental crossover design are well powered and controlled, however the physical activity modalities include martial arts (Bahrami, Movahedi, Marandi, & Abedi, 2012; Movahedi, Bahrami, Marandi, & Abedi, 2013) and horseback riding (Bass, Duchowny, & Llabre, 2009; Gabriels et al., 2012) potentially complicating the generalizability of the data to the academic setting. In spite of these concerns, all but one study (Oriel, George, Peckus, & Semon, 2011) exploring this area has observed a positive effect of physical activity on stereotypic behaviors, suggesting that increased physical activity participation may lead to potential reductions in unwanted behaviors in daily life as well as within the classroom. Unfortunately, regardless of the benefits associated with physical activity, individuals with ASD who have overcome many of the barriers limiting their participation are still often unable to engage in physical activity as current educational practices have reduced or eliminated physical activity options in favor of increased instructional time within the classroom (Pan, 2008).

Acute Physical Activity Influences on Physical and Cognitive Health

Concomitant with recent societal trends indicating an increase in sedentary behavior, and the rise in obesity for both children and adults within the U.S. (Finkelstein et al., 2012; Ogden, Carroll, Kit, & Flegal, 2014), interest in finding ways to combat these adverse health behaviors/characteristics has grown. Experts have suggested for the first time in 200 years, that younger generations may face shorter life expectancies relative to their parents and grandparents (Olshansky et al., 2005). Given the well-established links between physical activity and many serious health conditions (i.e., cardiovascular disease, obesity, some forms of cancer, diabetes, metabolic syndrome; U.S. Department of Health and Human Services, 2008; Yanovski & Yanovski, 2011) that may play a role in this diminished life expectancy, researchers have sought ways to promote and encourage a physically active lifestyle. Particular interest has been given to the school environment for children and young adults, as the restrictions of the environment (i.e., confined to desk, limited activity time, approximately 30% of a day [7-8 hours] spent in this setting) may inadvertently foster sedentary behaviors. Therefore, advocates for increased physical activity in children, adolescents, and young adults have focused their efforts on the school environment, suggesting policy changes that would provide greater opportunity to become active throughout the school day (H. Wechsler, Devereaux, Davis, & Collins, 2000). These changes in policy, however, have been met with resistance, with school administrators/educational policy makers often citing concerns about allocating time of objectives outside of the classroom that may impact a child's academic performance (Dwyer, Sallis, Blizzard, Lazarus, & Dean, 2001; Shephard, 1997).

While these concerns are understandable, given the increased pressures placed on school officials and teachers through initiatives like the 2001 No Child Left Behind Act (NCLB), one can conclude that these concerns for a negative impact on academic performance appear unfounded based on current literature in the field (Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Dills, Morgan, & Rotthoff, 2011; Dollman, Boshoff, & Dodd, 2006; Eveland-Sayers, Farley, Fuller, Morgan, & Caputo, 2009; Fisher et al., 2011; Grissom, 2005; Keita Kamijo et al., 2012; Li, Dai, Jackson, & Zhang, 2008; Pontifex et al., 2011). The NCLB Act has focused on increasing accountability standards for teachers and school's relative to reading and mathematics performance within the classroom, resulting in 44% of schools reporting decreases in non-academic subjects in order to increase classroom time dedicated to math and reading (McMurrer & Kober, 2007). This method of selectively dedicating time to specific academic material at the expense of others may be counterintuitive, however, as programs implementing social, emotional and physical development appear to be the most effective (Diamond, 2010). In particular, researchers have shown that when including recess within the school day, classroom behavior and on-task performance significantly improve (Jarrett et al., 1998), and this added activity during the day can also translate to increased physical activity outside of the school day (Dale, Corbin, & Dale, 2000). Unfortunately, despite the growing body of evidence supporting the health and classroom benefits of physical activity, the decline in physical activity opportunities throughout the school setting continues. However, with recent evidence suggesting that engagement in a single-bout of physical activity may serve to benefit cognitive function (particularly cognitive control; Drollette et al., 2014, 2012; Hillman, Pontifex, et al., 2009; Pontifex et al., 2013), researchers have potentially forged a new link between the cognitive learning process and physical activity suggesting that a short-bout of activity (such as recess or PE) may not only improve overall health and classroom behavior, but it may improve the way in which our brain functions to learn material within the classroom.

To date the literature exploring the effects of physical activity on cognitive health has primarily focused on a chronic approach due to the physical activity guidelines given through public health recommendations (U.S. Department of Health and Human Services, 2008). These guidelines, while beneficial and informative, often emphasize the habituation of physical activity into a chronic lifelong behavior, which for many is not maintainable and may discourage physical activity engagement (Okun et al., 2003). Therefore, recent studies have deviated from the utilization of intervention strategies to assess chronic cognitive benefits, to focus on single-bouts of physical activity (i.e. acute physical activity), with many researchers suggesting that the chronic benefits observed in the literature may represent a culmination of improvements incurred through several individual physical activity bouts. It is important to note, however, that the mode and intensity of these acute bouts is crucial for our understanding of physical activity benefits on cognition. Currently, aerobic-based physical activity has been the primary mode of physical activity utilized within the literature (Hillman, Pontifex, et al., 2009; Pontifex et al., 2015; Pontifex et al., 2013), with few studies exploring the effects of resistance training (Chang, Pan, Chen, Tsai, & Huang, 2012; Kao, Westfall, Parks, Pontifex, & Hillman, 2017; Lachman, Neupert, Bertrand, & Jette, 2006) and coordination exercises. The reasoning for this approach has relied on the understanding that continuous treadmill- or cycle-based activities allow the researcher to control the intensity of the exercise and maintain a steady-state of activity.

However, as researchers have expanded practices to other modalities, similar benefits have been reported in areas such as resistance training (Kao et al., 2017). These findings, while promising, must also be approach cautiously as the authors utilized a circuit training approach to the resistance training condition, potentially altering the basis of the activity from anaerobic to aerobic in nature. However, we cannot conclude that simply participating in aerobic based activity will lead to benefits in cognitive function, as research has indicated that intensity level may moderate the effects of physical activity on cognition, with moderate-to-vigorous activity levels yielding the greatest change compared to light and vigorous intensities (Chang et al., 2012; Hillman, Kamijo, & Pontifex, 2012; Lambourne & Tomporowski, 2010).

Presently, the most commonly explored component of cognitive control relative to physical activity has been the aspect of inhibition (Hillman, Buck, et al., 2009; Hillman et al., 2003; Kamijo et al., 2009; Pontifex et al., 2015, 2013). In an early study, Hillman and colleagues (2009) implemented a 20-minute bout of moderate intensity treadmill walking to assess changes in performance on a modified flanker task relative to a seated rest condition. Findings from this study indicated that following physical activity children exhibited greater response accuracy when compared to seated rest, suggesting that participation in a single-bout of moderate aerobic physical activity may improve a child's ability to effectively gate out irrelevant information. Interestingly, in a separate study by Drollette et al. (2014), similar findings relative to response accuracy were found indicating that aerobic physical activity may have a particular influence of this outcome measure. However, within this study, participants were separated based on flanker performance during their seated rest condition into high and low performing groups, with the effect of physical activity on response accuracy only manifesting within the low performing group. These findings suggest that the benefits associated with inhibitory control may differentially impact individuals based on who needs it the most. This assertion has provided retroactive support for studies exploring these effects in populations diagnosed with developmental disabilities, such as ADHD. Due to the similarities between ADHD symptomologies and inhibitory control aspects influenced via physical activity, Pontifex and colleagues (2013) sought to investigate if similar effects on inhibition may be observed within a preadolescent population diagnosed with ADHD. Comparing between a 20-minute aerobic physical activity condition and a 20-minute seated reading condition, researchers identified that following the acute physical activity condition individuals in their typically developing group and those with ADHD shown improved response accuracy. However, while research in this area has been promising, in order to better understand the influence of physical activity on inhibition, further investigations within other participant populations is needed. Accordingly, with the known deficits in inhibitory control associated with ASD, this population may be uniquely qualified to experience these benefits

Purpose

Evidence suggests that children with ASD exhibit cognitive deficits related to interference control, an aspect of cognition that is positively influenced by a single bout of aerobic physical activity. Therefore, this study explores the influence of an acute bout of moderate intensity aerobic activity on cognition in children with ASD. This study will focus on how single bouts of physical activity may result in variations in behavioral indices of interference control. Utilizing a well-controlled design including age-matched typically developing control participants and a reading control condition, results from this study will elucidate the influence of physical activity on interference control in children, and to what extent this relationship may translate to the deficits in interference control observed in children with ASD.

Rationale

A number of research studies have continued to highlight the growing struggle faced by children with ASD. With many of these individuals participating in a variety of treatment techniques (i.e., pharmacological, behavioral, social, and educational), the cost and time constraints can be overwhelming. As physical activity may provide a cost-effective and relatively low time demand, particularly in a population that has a high prevalence of sedentary behaviors, the inclusion of activity may help address these concerns. Therefore, the proposed study explores the relationship between cognitive control processes, specifically the interference control component of inhibition, and a single bout of aerobic physical activity in both typically developing preadolescent children and children with ASD. Evidence of a meaningful relationship between activity and interference control in children with ASD, may provide insight into an alternative method for improving classroom performance and cognitive health, as well as a complementary non-pharmaceutical option aiding children diagnosed with ASD.

Hypotheses

The purpose of this investigation was to determine the effects of a single bout of physical activity on behavioral indices of cognition for children with ASD during performance of a task requiring variable amounts of inhibition, specifically interference control. Accordingly, given prior research in this area the following specific hypothesis are proposed:

1. Prior to the experimental conditions, it was predicted that children with ASD would manifest with poorer response accuracy relative to typically developing children; indicating impairments in interference aspects of inhibitory control.

2. Relative to seated reading, it was predicted that a single bout of physical activity would enhance response accuracy for both children with ASD and typically developing children, indicating that aerobic physical activity is beneficial to behavioral indices of interference control.
3. Relative to typically developing children, participation in a single bout of physical activity would result in selectively greater improvements in response accuracy for children with ASD, such that differences between groups would no longer be apparent following physical activity.

CHAPTER 3

Methodology

The relationship between a single bout of aerobic physical activity and modulations in cognitive control in children with ASD was investigated. A sample of individuals with ASD and typically developing peers were recruited from the Greater Mid-Michigan area. Each participant completed an assessment of inhibitory aspects of cognitive control prior to and following 20 minutes of aerobic physical activity and 20 minutes of seated reading.

Participants and Recruitment

A sample of 18 individuals diagnosed with ASD (0 female) and 18 typically developing individuals (4 female) were recruited to participate. The participant sample was predominately male, as the ratio of ASD diagnoses for males and females is 5:1 (Baio, 2014). The average age for participants in the ASD group was 12.7 ± 1.0 years old, while the TD group had an average age of 12.3 ± 1.1 years. Children with ASD were recruited from the general community population based upon a clinical diagnosis along the autism spectrum. Recruitment took place through: 1) fliers posted throughout the greater Mid-Michigan area (see Appendices H & J), 2) e-mail correspondence with parents and families of potential participants (see Appendices I & K), 3) support from health care professionals who specialize in ASD treatment, and 4) support from regional organizations who work to connect parents, inform the community, and help children diagnosed with ASD. Clinical status was verified using the Autism Diagnostic Observation Schedule-2nd Edition (ADOS-2). Participants over the age of 18 provided written consent prior to beginning the study, and participants under the age of 18 provided written assent along with written consent from their parent or legal guardian in accordance with the Human Research Protection Program at Michigan State University.

Exclusionary criteria.

Inclusionary criteria for all participants, as well as specific inclusionary criteria for ASD and typically developing participants are provided in Table 3.1. Non-consent of the individual or a child's guardian resulted in the participant being excluded from the investigation. Any participant who was not capable of performing exercise based on the Physical Activity Readiness Questionnaire (PAR-Q; Thomas, Reading, & Shephard, 1992) was excluded for their safety. Similarly, all participants had normal or corrected-to-normal vision. Any potential participant with an ASD diagnosis who was non-verbal was also excluded from the study. Intelligence quotient, assessed using the Wechsler Abbreviated Scale of Intelligence – Version 2 (WASI-II; Wechsler, 2011), and pubertal timing, measured using the modified Tanner Staging Scales (Taylor et al., 2001), were also obtained as cognition has been found to be sensitive to these factors (Davies, Segalowitz, & Gavin, 2004). While not used for exclusionary criteria, these factors were assessed as potentially confounding variables within the statistical model.

Power Analysis

A sensitivity analysis was conducted using G*Power 3.1.2 (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the relative effects that would be possible to observe given the present experimental design. To provide a conservative assessment, a participant attrition rate of approximately 30% was assumed across multiple days of testing. Thus, given a sample size of 18 participants per group and beta of .20 (i.e., 80% power), the present design theoretically has sufficient sensitivity to detect multivariate repeated measures within-factors effects exceeding f = 0.207, between-factors effects exceeding f = 0.38 (assuming correlation between repeated measures ≥ 0.5), and interactions exceeding f = 0.585. For post-hoc comparisons, assuming a two-sided alpha, the design has sufficient sensitivity to detect t-test differences exceeding d =

0.48 for dependent means and $d = 0.96$ for independent means. Within the context of the acute physical activity and cognition literature, a previous investigation conducted by Pontifex et al. (2013) observed acute physical activity induced modulations in inhibitory control in typically developing children and children with ADHD with an effect size in excess of $d = 0.9$. Similarly, effect sizes for ASD related impairments in inhibitory control have been observed to exceed $d = 1.0$ (Christ et al., 2007). Thus, even with such an attrition rate, this design should provide sufficient sensitivity to address the aims of the present investigation.

Table 3.1.

Inclusion Criteria for Participant Acceptance into the Current Project

Inclusion Criteria for All Participants	
1. 5–25 years of age.	
2. Physically capable of performing exercise based on the PAR-Q.	
3. Normal or corrected-to-normal vision.	
Inclusion Criteria for ASD participants	**Inclusion Criteria TD participants**
1. Verified clinical status using the ADOS.	1. Free of ASD diagnosis
2. Verbal	2. SNAP-IV ADHD-Inattention subscale average score below 1.78
	3. SNAP-IV ADHD-Hyperactivity/Impulsivity subscale average score below 1.44
	4. SNAP-IV ADHD-Combined subscale average score below 1.67

Note: Physical Activity Readiness Questionnaire – PAR-Q

Cognitive Control Task

To assess inhibitory aspects of cognitive control, participants completed a modified version of the Eriksen flanker task (Eriksen & Eriksen, 1974). This task requires participants to attend to a centrally presented target fish amid either congruous or incongruous flanking fish (see

Figure 3.1), with the goal of responding based on the directionality of the target stimuli. The incongruent stimuli (when the target faces opposite the direction of the flanking stimuli), relative to the congruent stimuli (when all stimuli face the same direction) requires greater amounts of interference control to inhibit the activation of the incorrect action schemas elicited by the flanking stimuli, in order to over-ride this response pattern to execute correct response (Spencer & Coles, 1999). Participants completed two blocks of 156 trials, presented with equiprobable congruency and directionality. The block of trials was restarted if participants exhibited performance below 50% correct or exhibited a high rate of impulsive responses (TD: Rest-Pretest = 2, Rest-Posttest = 0, Exercise-Pretest = 2, Exercise-Posttest = 3; ASD: Rest-Pretest = 2, Rest-Posttest = 2, Exercise-Pretest = 5, Exercise-Posttest = 3). The stimuli were 3 cm tall yellow goldfish, presented focally for 200 ms on a blue background with an inter-trial interval equally distributed between 1500 ms, 1600 ms, and 1700 ms. Utilization of this task allowed for the assessment of a number of behavioral performance indices. Primary analysis utilized reaction time (RT; i.e., time in ms from the presentation of the stimulus) and response accuracy (i.e., number of correct and error responses) measures in addition to interference score measures (incongruent minus congruent trials). Stimulus presentation, timing, and measurement of behavioral response time and accuracy was controlled using PsychoPy, 1.81 (Peirce, 2009).

Experimental Conditions

Participants complete two experimental conditions in the study, a 20-minute walk on a treadmill and 20-minutes of seated reading. In the exercise condition, the first 4-minutes of the condition were utilized as a warm up for the activity. During this warm-up, participants would begin by walking at a slow pace at a 1.0% grade with the speed and grade of the treadmill increased incrementally until heart rate reached 65% of the participants age-predicted heart rate max (i.e., 220-age). Upon reaching the 65% threshold, the speed and grade of the treadmill remained unchanged until the end of the condition. During the session, participants were able to interact with the research staff, however no other activities were provided during this time. The rest condition similarly lasted for 20-minutes with participants given the option of reading either a book of their choice from a selection of age-appropriate books, or bringing a book from home to read. During this time, participants were given a desk to sit at where they were able to complete the reading task on their own. Research staff sat with the children during this time, and had minimal interaction. Throughout each condition, heart rate, rate of perceived exertion (assessed with the OMNI scale), and feeling scale were assessed every 2-minutes; with speed and grade of the treadmill also measured at the same intervals during the exercise condition.

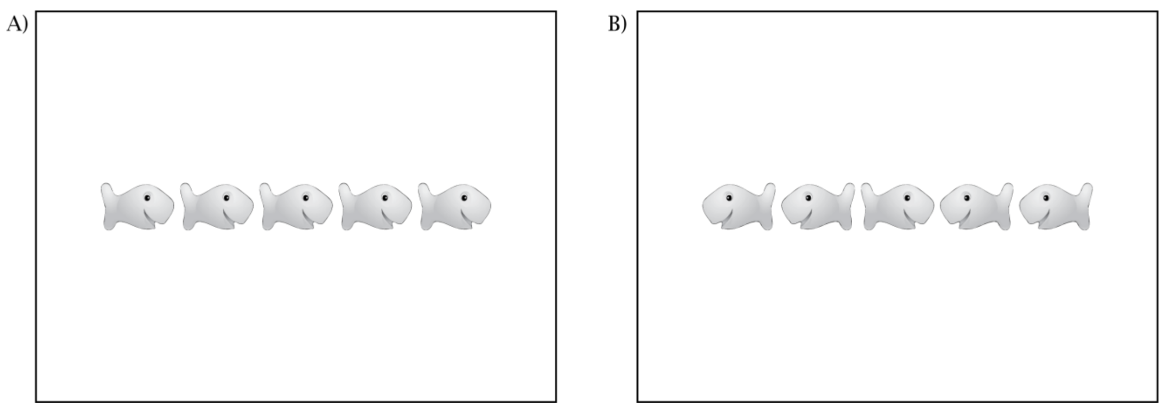

Figure 3.1. Illustration of the congruent (A) and incongruent (B) goldfish stimuli used in the modified flanker task.

Procedure

A within-subjects repeated measures design was utilized for this study, during which participants were asked to visit the lab for three separate sessions occurring on three different days. Session 1 was approximately 2-hours in duration, while sessions 2 and 3 were approximately 1.5 hours in duration. On the first day, participants and parents completed all paperwork, including; informed consent, informed assent, health history demographics (HHD), physical activity readiness questionnaire (PAR-Q), the SNAP-IV Rating Scale for Attention-Deficit/Hyperactivity Disorder (ADHD), the Social Communication Questionnaire (SCQ), the modified Tanner Staging Scales for current pubertal staging, and the Wechsler Abbreviated Scale of Intelligence – Version 2. Initial participant recruitment included 22 participants with ASD, and 21 TD participants. At this stage, 2 potential participants with ASD were dropped from the study as one was non-verbal, and the other had photosensitive epilepsy that may have been impacted by the cognitive task. All recruited members of the TD group completed the 1st session.

Following completion of the paperwork, participants in the ASD group — based on prior diagnosis — were assessed using the Autism Diagnostic Observation Schedule – 2nd edition (ADOS-2) as an added measure of classification and severity of their diagnosis. All ADOS-2 assessments were conducted by trained, clinically reliable researchers. Upon completion of the questionnaires and the ADOS-2 assessment (only for ASD group), participants completed a practice set of each of the experimental procedures that will be used for the study. This practice included a brief exposure to the modified flanker task, including one practice block consisting of 20 trials and one full block of 156 trials.

Participants were then counter-balanced into two different session orders, with some participants receiving the reading session on the second day and the aerobic physical activity session on the third day. The alternative order had participants receiving the aerobic physical activity session on the second day and the reading session on the third day. Consistency between time of day for each session was attempted with an average difference in session start time of 0.1 hours (± 2.4 hours). During each visit, heart rate (HR) was measured at 2-minute intervals throughout the entire session using a Polar heart rate monitor (Polar WearLink®+ 31, Polar Electro, Finland). Prior to the start of the testing on each day, participants were provided with a block of 20 practice trials of the flanker task. Participants were then asked to complete the flanker task prior to and 10 minutes following each experimental session. The experimental conditions consisted of 20 minutes of either seated reading or aerobic physical activity on a motor-driven treadmill at an intensity between 65% and 75% of their age predicted maximum heart rate (Pontifex et al., 2013). The final sample included 18 participants in each group, with an 81.8% and 85.7% attrition rate for the ASD and TD groups, respectively. Prior to beginning the 2^{nd} session, one member of the ASD group withdrew from the study, and two members of the TD group withdrew from participation. Prior to the 3^{rd} session, one member of each group withdrew from participation. Upon completion of the study, participants were compensated monetarily at a rate of $10 per hour for all time completed in the study.

Statistical Analysis

Statistical analysis was conducted using PASW Statistics, 24.0 (IBM, Armonk, NY) using the Greenhouse-Geisser statistic with subsidiary univariate ANOVAs and Bonferroni corrected *t*-tests for post-hoc comparisons. The family-wise alpha level was set at 0.05, with effect sizes reported using partial-eta squared and Cohen's *d* based on the appropriate corrections for between-subjects (d_s) and repeated measures (d_{rm}). Prior to hypothesis testing, preliminary analyses were conducted to ensure that the ASD and typically developing groups did not significantly differ on any factors known to influence cognitive function in this age group (e.g., SES, age, pubertal timing, IQ, etc.). Analysis of task performance measures (median RT and response accuracy) was conducted separately using a 2 (Group: ASD, TD) × 2 (Mode: Reading, Exercise) × 2 (Time: Pre-test, Post-test) × 2 (Congruency: Congruent, Incongruent) multivariate repeated measures ANOVA. Secondary analyses examined task performance interference scores (Incongruent minus Congruent trials) using a 2 (Group: ASD, TD) × 2 (Mode: Reading, Exercise) × 2 (Time: Pre-test, Post-test) multivariate repeated measures ANOVA. To ensure that any potential findings were not masked by differences in pre-test performance, analyses were also conducted replicating the models listed above but collapsing Time into a change score (Post-test minus Pre-test; Pontifex et al., 2015).

CHAPTER 4

Results

Participant Characteristics

Participant demographics and clinical status confirmation statistics for the ASD group are provided in Table 6.1 (Appendix P). Initial analyses of demographic variables between groups indicated a significant difference for IQ, t (34) = 2.6, p = 0.014, d_s = 0.87, 95% CI_d [0.18, 1.55]. As a result, analyses were conducted including IQ as a covariate to examine if IQ related to any task performance variables within the multivariate repeated measures ANOVA models. Findings revealed no significant interactions with mode (p's $\geq$ 0.063); therefore, all further analyses were collapsed for IQ. No other significant differences were identified for age, pubertal timing, or socioeconomic status (SES), t's (34) $\leq$ 1.8, p's $\geq$ 0.075, d_s's $\leq$ 0.61, 95% CI_d [-0.06, 1.28]. Clinical status confirmation for the ASD group, separated by ADOS module, are available in Table 6.2 (Appendix P). Findings also revealed no significant differences between groups for HR across either condition, t's (33) $\leq$ 1.7, p's $\geq$ 0.097, d_s's $\leq$ 0.58, 95% CI_d [-0.10, 1.25] (Figure 6.13; Appendix Q). Finally, preliminary analysis revealed no significant difference between groups for session order, $\chi^2_{(1, N = 36)}$ = 2.857, p = 0.091, therefore all subsequent analyses were collapsed across session order.

Task Performance

Reaction time.

Analysis revealed a main effect of Congruency, with incongruent trials (486.4 ± 21.6 ms) exhibiting longer RT latency when compared to congruent trials (458.6 ± 21.2 ms), $F_{(1, 34)}$ = 59.1, p < 0.001, η_p^2 = 0.64. A Group x Mode x Time interaction was also observed for RT latency, $F_{(1, 34)}$ = 4.7, p = 0.038, η_p^2 = 0.12. Decomposition of this interaction revealed faster reaction time at rest (465.2 ± 145.3 ms) relative to exercise (497.3 ± 148.7 ms) only at pretest for the ASD group, t (17) = 2.6, $p = 0.017$, $d_{rm} = 0.22$, 95% CI_d [0.04, 0.39] (Figure 6.14; Appendix Q). No significant differences were observed at posttest or from pre- to posttest for either group, $F's_{(1, 34)} \leq 2.8$, $p's \geq 0.1$, η_p^2's ≤ 0.14.

Response accuracy.

Analysis of response accuracy revealed a main effect of Group, with poorer overall response accuracy for the ASD group (70.6 ± 3.7 %) relative to their TD counterparts (82.0 ± 3.7 %), $F_{(1, 34)} = 4.8$, $p = 0.035$, $\eta_p^2 = 0.13$. Additionally, a main effect of Congruency, $F_{(1, 34)} = 24.2$, $p < 0.001$, $\eta_p^2 = 0.42$, was observed with lower response accuracy for the incongruent trials (70.2 ± 3.1 %) relative to congruent trials (82.5 ± 2.6 %) (Figure 6.15; Appendix Q).

Interference scores.

Analysis for interference scores associated with the flanker task (incongruent trials minus congruent trials) revealed no significant findings for either mean RT latency (Figure 6.16a; Appendix Q), $F's_{(1, 34)} \leq 1.1$, $p's \geq 0.3$, η_p^2's ≤ 0.03, or response accuracy (Figure 6.16b; Appendix Q), $F's_{(1, 34)} \leq 2.2$, $p's \geq 0.1$, η_p^2's ≤ 0.06.

Change scores.

Analysis of change in performance from Pretest to Posttest revealed a Group x Mode interaction for mean RT latency, $F_{(1, 34)} = 4.7$, $p = 0.038$, $\eta_p^2 = 0.12$. Decomposition of this interaction manifested no statistically significant findings for either Group, $t's$ (34) ≤ 1.6, $p's \geq 0.1$, $d_{rm} \leq 0.26$, 95% CI_d [-0.07, 0.59], or Mode, $t's$ (17) ≤ 0.8, $p's \geq 0.4$, $d_s \leq 0.28$, 95% CI_d [-0.38, 0.93]. No statistically significant findings were observed for change in response accuracy from Pretest to Posttest, $F's_{(1, 34)} \leq 0.8$, $p's \geq 0.4$, η_p^2's ≤ 0.02.

CHAPTER 5

Discussion

Currently, only one other study has attempted to assess the effects of physical activity on cognitive function in individuals with ASD, in which researchers observed improved performance relative to working memory (Digit Span Tasks) and trending effects for inhibition (Stroop Task; Anderson-Hanley, Tureck, & Schneiderman, 2011). However, this study is the first to utilize an acute aerobic exercise based paradigm to specifically explore modulations in behavioral indices of interference control before-and-after completion of the experimental conditions. Findings replicate previous work indicating poorer response accuracy relative to a modified flanker task for individuals diagnosed with ASD, compared to their typically developing matched-controls (Adams & Jarrold, 2012; Keehn et al., 2010; Lopez et al., 2005) Additionally, the physical activity condition showed no detrimental effects on interference control for either group, corresponding with previous acute physical activity literature and supporting the initial hypothesis for this study (Hillman, Pontifex, et al., 2009; Pontifex et al., 2013; Drollette et al., 2012; Drollette et al, 2014). However, contrary to the remaining hypotheses for this project, physical activity did not enhance task performance measures of interference control in either group. This outcome may be the result of several factors including: 1) the physical activity intensity, 2) the study design, 3) small observed effect sizes, and 4) sensitivity of outcome measures. While it is still unclear if acute aerobic physical activity may have an impact on interference control in individuals with ASD, given this is the first venture to explore this line of work valuable insight has been obtained that may help to strengthen future work within this area.

Task Performance

Flanker task check.

Prior research has shown changes in task performance specific to reaction time and response accuracy when completing incongruent trials of the modified flanker task relative to the congruent trials (Eriksen & Eriksen, 1974; Hillman et al., 2003; Pontifex et al., 2013). Specifically, slower reaction time was observed for the incongruent trials relative to the congruent trials, indicating an increase in processing time during trials requiring a greater level of interference control (Eriksen & Eriksen, 1974; Spencer & Coles, 1999). Poorer response accuracy was also present for incongruent trials relative to congruent for both groups, suggesting increased difficulty ignoring task irrelevant information corresponding with elevated stimuli interference during incongruent trials (Spencer & Coles, 1999). While these findings are standard for this task, they do serve as a practical check for the effective implementation of the task.

Reaction time.

Within this investigation, individuals with ASD displayed decreased reaction time latency at pretest during their exercise session relative to their rest session. While this finding is not unique to the physical activity and cognition research, it has helped to elucidate some methodological limitations of the current study that should be rectified in future work, particularly when to disclose experimental condition assignment to participants. Transparency of session order was maintained with parents in order to help them better prepare the children for either the exercise session (i.e., wear sneakers and work out clothing to session) or the reading session (i.e., ensure the participant brought reading material to the session if desired). However, this approach may have had an adverse effect on the findings as many parents appeared to heavily emphasize the physical activity component with their child in hopes of preparing them for the treadmill on the day they were to complete the exercise condition. As a result, when the children entered the lab they were prepared to immediately begin the treadmill activity, leading to a high number of impulsive responses during the cognitive task as they attempted to 'get to the fun part'. In order to rectify these responses, the task was restarted, and they were informed why we had to begin the task again. As the research team would instruct them to answer as accurately and quickly as possible, participants may have emphasized accuracy over response time, thus accounting for the observed reduction in reaction time during the pretest exercise condition.

Future studies may consider altering the task utilized for the control condition, changing from a seated reading protocol to an active control. During an active control condition, participants would engage in an extremely low-intensity exercise intensity (i.e., walking on a treadmill at 0.5 mph and zero percent grade) designed to avoid a meaningful increase in physiological exertion. Addition of this design as a control condition would provide equal opportunity for participants to engage in a treadmill based condition during either testing session, therefore helping to alleviate any bias toward a particular condition based solely on the inclusion of treadmill-based activity. Further, as it is feasible to rapidly process a participant's pretest performance, a pseudo-randomization for session order based on pretest performance during the initial session may be utilized to eliminate pretest differences between conditions in later analyses.

Response accuracy.

Modulations of response accuracy performance have been a consistent finding throughout the physical activity and cognition literature, specifically for children (Drollette et al., 2014;

Drollette et al., 2012; Hillman et al., 2003; Pontifex et al., 2013). It has been suggested that within a preadolescent population measurements of reaction time may demonstrate a maintenance effect across congruency types due to a predisposition to impulsive responses (Christakou et al., 2009), whereas adults tend to favor increased accuracy over speed and will therefore slow their responses during the more challenging trial types (Davidson et al., 2006; Drollette et al., 2014). Therefore, response accuracy has often been identified as a more reliable indicator of physical activity influences on cognition in children. In accordance with previous research, it was hypothesized in this study that individuals with ASD would present with poorer response accuracy overall relative to their typically developing peers. This hypothesis was supported within the data, adding to a well-established literature based examining differences in cognitive control for individuals with ASD. However, no physical activity related effects were observed, suggesting that for this population, physical activity may not influence inhibitory control, a finding inconsistent with similar research in typically developing individuals and other populations with developmental disorders. The data does, however, trend in accordance with previous literature and replicate results for the TD group when assessed using planned contrast comparisons designed to replicate posttest comparisons utilized in previous research (t (17) = -2.5, p = 0.021, d_{rm} = 0.23, 95% CI_d [0.03, 0.43]). This trend and consistency with other study designs, indicate that while findings are not significant there may be underlying components that are contributing to this lack of a finding. One possibility is that this discrepancy may be the result of intensity utilized within each experimental condition. Research has established that, much like the inverted-U perspective, modulations in cognition are at their greatest following moderate-to-vigorous activity (assessed through heart rate based intensity for exercise), with diminished effects for cognitive control at vigorous and low intensity levels (Bender &

McGlynn, 1976; Davey, 1973; Hillman et al., 2012; Weingarten & Alexander, 1970). Utilizing this principle, this study aimed to have participants complete the exercise condition between 65% and 75% of their age-predicted heart rate max. However, upon analysis of heart rate intensities following exercise both groups fell below that threshold (TD: 62.4 ± 0.8%; ASD: 62.1 ± 1.1%). While the groups are not significantly below the lower bound associated with moderate intensity activity, the fact that they are outside of this range may influence the potential for physical activity influences on interference control. Additionally, the TD sample does present with above average IQ (112.7 ± 17.0) potentially effecting performance on the cognitive task in which participants may have experienced a ceiling effect between pretest and posttest for each experimental condition.

Interference & change scores.

Although a congruency effect was observed for reaction time and response accuracy, secondary analysis of interference scores collapsed across congruencies yielded no statistically significant effects. As interference scores are intended to reflect the time difference needed for handling the added interference of an incongruent trial and the ability to effectively manage that interference in order to initiate a correct response (Buck, Hillman, & Castelli, 2008), this finding would suggest that regardless of group, experimental condition, and time point participants experienced no improvements, and just as important no detriments, to the regulation of these processes. Similar findings were also found when controlling for change from pre-to posttest. In this analysis, the change score is intended to represent the improvement (or deterioration) of a particular variable with the goal in this study of determining if the changes observed for each condition varied within and between the groups. Results from this assessment indicated that neither condition within the groups, or conditions between the groups varied significantly from one another.

Practical Implications

Although this study provided limited statistical insight into the effects of acute physical activity on interference control, the contribution of this work to the field is strongly rooted in the conceptual significance of the overall methodology. Research exploring the cognitive abilities of those diagnosed with ASD has often been seen as challenging, and improbable, due to the various possible expression of the disorder for each individual (Smith et al., 2007). This has resulted in a limited body of research to explore, and within that scope, an inconsistent usage of cognitive tasks across studies and low sample sizes. These limitations of the research area are not to be discredited, however, as these outcomes clearly reflect the struggles of working with an ASD population. It is understandable, given these challenges, that to date this is only the second project to explore this research question (Anderson-Hanley et al., 2011), and the first to implement this treadmill-based design using modernized tasks for interference control. Germane to the contributions of the project, however, is the support for feasible implementation of the study design within an ASD population. With much of the research examining physical activity in those with ASD utilizing alternative activity programs (i.e., karate, horseback riding, rock climbing, swimming, and anaerobic training; (Scharoun, Wright, Robertson-Wilson, Fletcher, & Bryden, 2017), the practicality of utilizing a treadmill modality for this study was concerning (although this is the common mode of physical activity used within the physical activity and cognition literature). However, participants displayed high competency for completing the walking task, indicating that inclusion of treadmill-based activities within this area of study is possible. In addition to the mode of activity utilized, there have been concerns regarding the effect to which known fine motor deficits in individuals with ASD may impact performance on the cognitive task (Provost, Lopez, & Heimerl, 2006). While fine motor skills were not assessed in this study, the impact of these deficits in relation to the cognitive task can be observed through reaction time latency. Therefore, as no between-group effects were observed for reaction time ($F_{(1, 34)} = 0.2$, $p = 0.7$, $\eta_p^2 = 0.01$), use of this cognitive task format does not appear to be influenced by fine motor deficits for individuals with ASD. However, further examination of this matter is needed in order to fully elucidate if, and to what extent, fine motor impairment in individuals with ASD may affect their ability to perform the required movements to complete the cognitive task.

Additionally, while the use of multi-day studies when working with individuals with diagnosed ASD is not uncommon, the study design utilized within this project provided beneficial insight into recruitment, participant attrition and participant interest. In recent years the use of a repeated measures within-subjects design has been suggested as the default study design for exploring physical activity effects on cognitive function. This design structure is beneficial in that it accounts for individual variability in the model and includes a control comparison (Pontifex et al., 2015), however it may be unsuitable for this population. While the overall time commitment for the study was ~4 hours (spread across three sessions), the added burden of attending multiple sessions was difficult for many families. Due to other commitments, such as school, therapy (behavioral, physical, occupational, and speech), work, and family, it was often difficult for families to identify multiple time gaps within their rigorous schedules. To overcome this burden on the participant and their families, many of the successful multi-day research studies have altered this challenge into a researcher burden by taking the study out of the lab and to the participants (MacDonald et al., 2012; Reynolds, Pitchford, Hauck, Ketcheson, & Ulrich, 2016). Alternatively, a between-subject's pre-posttest design over a single laboratory session (Ferris et al., 2007; Magnié et al., 2000; Nakamura et al., 1999; Yagi et al., 1999) may also help to ease this participant load. Ultimately, the inclusion of either approach may be beneficial in future work in order to ensure low participant burden and ample sample size for detecting effects on cognition.

Limitations & Future Directions

The primary goal of the study was to elucidate the potential effects of acute aerobic physical activity on the interference aspect of inhibitory control within individuals diagnosed with ASD. While there were subtle findings associated with the results of this endeavor, the project did ultimately fail to find significant effects of physical activity on interference control in either group studied. Such a finding may be driven by a number of factors, most notably the age range of the participants. Although participants were matched based on age, the range of participant age varied from 6.8 to 22.2 years old. With research indicating that age may act to moderate the performance of individuals on various cognitive control tasks (Hillman et al., 2008), and that deficits associated with cognitive control may diminish with age among individuals with ASD (Happé, Booth, Charlton, & Hughes, 2006), inclusion of such a broad age range may act to mask potential effects of physical activity on cognition. Additionally, this age range encompasses a time of significant physical and cognitive development that may impact the neurological processing and physiological capabilities for an individual (Petersen, 1988). Future research should narrow the age gap by separating groups into young adults, adolescents, and preadolescents in order to help minimize the effect of this potential confound.

Another contributing factor may be associated with the low heart rate intensities observed in this study during the exercise condition. As discussed above, heart rate intensity provides a relatively easy index for assessing the potential benefits of physical activity on cognitive control (Chang et al., 2012; Hillman et al., 2012; Lambourne & Tomporowski, 2010), however within this study both groups fell below the moderate intensity classification associated with the greatest modulation in cognition. The failure to meet this minimum threshold may result from two distinct factors: 1) inclusion of an aerobically fit population overall, 2) intensity thresholds based on age-predicted HR maximum (220 minus age), and 3) concerns for participant safety. Without measures of aerobic fitness, it is difficult to discern the impact of the first possible factor, however participant level of physical activity involvement was included within the health history demographic survey. Participants (or their parents) reported that on average they engaged in 2 hours of physical activity per day, with the minimum report indicating at least 1 hour per day. While these findings may seem insignificant, based on these reports this sample of participants is at least meeting, and with many exceeding, the physical activity guidelines suggested for kids. This conclusion would suggest that these individuals may be aerobically fit, thus impacting their heart rate based intensity levels. As this study did not perform a standard assessment for maximum aerobic capacity (VO_{2max}) in which maximum HR can be obtained directly, an age-predicted HR max was utilized to determine HR intensity levels. This method of determining intensity level, known as the zero to peak method (Karvonen & Vuorimaa, 1988), is a common protocol used throughout physical activity literature, however there are disadvantages that could have impacted the ability for the participants in this study to reach the minimum HR intensity threshold. In particular, inclusion of age-predicted HR max in this method inherently adds a large amount of standard error to the outcome as it does not account for individual variability between participants. Additionally, because this overall method does not account for variability in cardiac responses between individuals it is possible that the HR intensity thresholds used do not accurately reflect the levels of the participants due to their fitness level.

The concerns for participant safety stem from this potential impact on heart rate based intensity level, as participants significantly varied in the speed and grade used during the exercise condition. Of particular interest was a significant decrease in speed and grade observed within the ASD group while completing the exercise condition. Participants in this group often utilized a varied gait pattern when walking on the treadmill that would result in a smaller stride length and a greater frequency of steps. This observation is consistent with gait based research in children with ASD (see Kindregan, Gallagher, & Gormley, 2015 for review), as children with ASD have reduced range of motion in the ankle and knee joints. Interestingly, this altered gait would result in a heart rate just at the 65% threshold, however with adjustments to the workload their heart rate would exhibit little variation. In spite of this limited increase in heart rate, workload was often left steady after this mild fluctuation due to researcher concern for participant safety and the observed gait pattern. Future research may find that implementing an alternative mode of exercise, such as a cycle ergometer may allow for improved heart rate measure of intensity. However, as riding a standard two-wheel bicycle is a motor skill that individuals with ASD often struggle with (MacDonald et al., 2012; Reynolds et al., 2016), this mode may demonstrate alternative motor difficulties, therefore an alternative to adjusting mode of activity may be to alter the measure of intensity (i.e., Aerobic Capacity [VO_2] and/or Lactate Threshold).

A final contributing factor to the outcomes from this study may be the overall sample size. With research indicating moderate-to-large effect sizes (0.4 to 0.9) relative to the effects of acute exercise on aspects of cognitive control, a conservative estimate (0.5) was utilized for *a* *priori* power analyses to determine sample size for this investigation. With an observed effect size for response accuracy of 0.33 in the TD group and 0.16 for the ASD group, this preliminary appraisal is a clear overestimation. Therefore, the study overall may simply be underpowered given the small effect sizes observed, suggested that future work in this area may need a larger sample size in order to observe effects within individuals diagnosed with ASD compared to previous work in other populations.

Conclusion

Interventions examining the effects of physical activity on cognitive control in individuals with ASD are rare, and relatively new concepts. The current study utilized an acute aerobic physical activity paradigm shown to influence the interference aspect of inhibition, in an attempt to better understand the potential for cognitive improvement within the ASD population. Despite finding support for impaired interference control in individuals with ASD compared to their typically developing matched-controls, an effect for physical activity was not observed, therefore it remains unclear at this time if, and to what degree, physical activity may influence cognition in individuals diagnosed with ASD.

With respect to the limitations of this project, there are still a number of future directions to explore. While inhibition has been the core aspect of cognitive control linked to ASD symptomologies, examining the effect of physical activity on other components of cognitive control may be beneficial. This study opted to focus on inhibition, specifically interference control, as previous research has observed deficits in inhibition for those with ASD and acute aerobic physical activity has been shown to modulate this aspect of cognition. Results from this study suggest that it may be possible that physical activity does not affect inhibition within this population. However, individuals with ASD have also been observed to present with additional deficits in set-shifting and working memory. As physical activity has been shown to affect these aspects of cognitive control, exploration into the modulations of these components in response to physical activity may provide greater insight into the effects of physical activity on cognitive control within individuals with ASD. Additionally, behavioral measures of cognitive control may not be sensitive enough measures to truly elucidate the influence of physical activity. Therefore, future research should consider implementing neuroimaging techniques, such as electroencephalographic measures of event-related potentials to assess neuroelectric indices of inhibition and functional magnetic resonance imaging to measure changes in activity throughout different regions of the brain, to assess the effects of physical activity on brain function relative to cognitive control.

Despite the limitations of this study, the overall contribution for future work is still significant. As this is only the second study to explore the effects of acute physical activity on cognition in individuals with ASD, identification of the various methodological limitations observed throughout this study should serve to greatly strengthen the overall design of future projects. The addition of observed effects sizes for this population relative to physical activity influences on cognition, will also help to ensure ample power for future studies; thus, helping to bolster the literature base as a whole. Finally, support for the feasibility of the current protocols within this population will hopefully provide the means for other researchers to begin exploring this area. As this line of research has the potential to impact public health issues relative to childhood inactivity, educational policy, and overall quality of life for individuals diagnosed with ASD, these contributions may provide a foundation for future work within this area.

APPENDICES

Appendix A: IRB Approval Letter

MICHIGAN STATE UNIVERSITY

Revision Application Approval

March 30, 2017

To: Matthew Pontifex
27P IM Sports Circle
East Lansing, MI 48824-1049

Re: **IRB# 12-062** Category: EXPEDITED 4,7
Revision Approval Date: March 29, 2017
Project Expiration Date: December 6, 2017

Title: Examining the influence of single bouts of aerobic exercise on specific attentional networks

The Institutional Review Board has completed their review of your project. I am pleased to advise you that **the revision has been approved.**

This revision includes changes to the assent/consent form, eligibility criteria, and the sample size.

The review by the committee has found that your revision is consistent with the continued protection of the rights and welfare of human subjects, and meets the requirements of MSU's Federal Wide Assurance and the Federal Guidelines (45 CFR 46 and 21 CFR Part 50). The protection of human subjects in research is a partnership between the IRB and the investigators. We look forward to working with you as we both fulfill our responsibilities.

Renewals: IRB approval is valid until the expiration date listed above. If you are continuing your project, you must submit an ***Application for Renewal*** application at least one month before expiration. If the project is completed, please submit an ***Application for Permanent Closure.***

Revisions: The IRB must review any changes in the project, prior to initiation of the change. Please submit an ***Application for Revision*** to have your changes reviewed. If changes are made at the time of renewal, please include an ***Application for Revision*** with the renewal application.

Problems: If issues should arise during the conduct of the research, such as unanticipated problems, adverse events, or any problem that may increase the risk to the human subjects, notify the IRB office promptly. Forms are available to report these issues.

Please use the IRB number listed above on any forms submitted which relate to this project, or on any correspondence with the IRB office.

If we can be of further assistance, please contact us at 517-355-2180 or via email at IRB@msu.edu. Thank you for your cooperation.

c: Andrew Parks, Jason Moser, Anthony Delli Paoli, Natalie Berger, Janet Hauck

Office of Regulatory Affairs
Human Research Protection Programs

Biomedical & Health Institutional Review Board (BIRB)

Community Research Institutional Review Board (CRIRB)

Social Science Behavioral/Education Institutional Review Board (SIRB)

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Fax: (517) 432-4503
Email: irb@msu.edu
www.hrpp.msu.edu

MSU is an affirmative-action, equal-opportunity employer.

Figure 6.1. Copy of IRB approval letter.

Appendix B: Dissertation Funding Sources

Dissertation Funding Sources

1. **Dissertation Completion Fellowship - 2017**
   College of Education, Michigan State University
   Funded - $7,000
   Use: Study coordinator assistantship support

2. **Summer Research Renewable Fellowship – 2015/2016**
   College of Education, Michigan State University
   Funded - $12,000
   Use: Study coordinator assistantship support

3. **Research Practicum/Research Development Fellowship - 2013**
   Department of Kinesiology, Michigan State University
   Funded - $3,340
   Use: Participant compensation and supplies

Not Funded

1. **Research Practicum/Research Development Fellowship – 2014**
   Department of Kinesiology, Michigan State University
   Unfunded - $4,000

Appendix C: Informed Assent – Age 5-7

Participant Information and Assent Form - Age 5-7

"Examining the Influence of Single Bouts of Aerobic Exercise on Specific Attentional Networks."

HBCL
Health Behaviors & Cognition Laboratory
Michigan State University

Investigators Directing Research:

Drew Parks, M.S., Doctoral Student, Department of Kinesiology, Michigan State University, 38 IM Sports Circle, East Lansing, MI 48824-1049, (517) 353-0892, parksa51@msu.edu

Matthew B. Pontifex, Ph.D., Assistant Professor, Department of Kinesiology, Michigan State University, 126E IM Sports Circle, East Lansing, MI 48824-1049, (517) 432-5105, pontifex@msu.edu, http://education.msu.edu/kin/hbcl

Child Assent Script

This study is to help us understand how being active can influence how your brain works. On the first day (today) you will be asked to play some games and activities. The next two times you come in, we will ask you to play some games on the computer while we record your brain activity with special fabric caps. We will then ask you to either: sit and watch a movie or walk on a treadmill and watch a movie. After that, we will have you play the games on the computer again. The only people who will know about what you say and do in the study will be the people in charge of the study and your parents or guardians. Writing your name on this page means that this part of the page was read to you or read by you and that you agree to be in the study. If you decide to quit the study, all you have to do is tell the person in charge.

Child's Signature: ______________________________________

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Figure 6.2. Informed assent paperwork for children 5 to 7 years old.

Appendix D: Informed Assent – Age 8-12

Participant Information and Assent Form – Age 8-12

"Examining the Influence of Single Bouts of Aerobic Exercise on Specific Attentional Networks."

HBCL
Health Behaviors & Cognition Laboratory
Michigan State University

Investigators Directing Research:

Drew Parks, M.S., Doctoral Student, Department of Kinesiology, Michigan State University, 38 IM Sports Circle, East Lansing, MI 48824-1049, (517) 353-0892, email@msu.edu

Matthew B. Pontifex, Ph.D., Assistant Professor, Department of Kinesiology, Michigan State University, 126E IM Sports Circle, East Lansing, MI 48824-1049, (517) 432-5105, pontifex@msu.edu, http://education.msu.edu/kin/hbcl

You are being asked to participate in a research study. You will be asked to sign this form if you agree to be a part of the study. We will also ask your parent or guardian to sign a form to make sure that they agree for you to be a part of the study. This form will tell you about the purpose, risks, and benefits of this research study. You should decide if you want to be a part of the study only after you understand what you will be asked to do.

Purpose of the Research

This study is to help us understand how being active can influence how your brain works.

What You Will Do

You will be asked to come into the lab today and two other days. Today you will be asked to do the things below for about 90 minutes:

- Questionnaires – You will be asked to fill out some forms. These forms ask about your: readiness to exercise, health history and demographic information, and which hand you like to use. We will also ask you questions to make sure that you understand what we are asking you to do. This should take about 20-30 minutes.
- Observational Assessment – You will be asked to do some puzzles, storytelling games, and pretend play games. This should take about 30-45 minutes.
- Cognitive Task Practice – You will get to see and play some computer games that we will use in the study. These games ask you to respond when you view certain shapes and symbols. This should take about 5-10 minutes.

On the other days, you will be asked to do the things below:

- Experimental Conditions – You will be asked to walk on a treadmill or sit for 20 minutes. We will also ask you to wear a heart rate monitor (Polar WearLink+ 31, Polar Electro, Finland) so that we know how hard your heart is working. We will also have a movie playing so that you do not get bored.
- Cognitive Tasks – Before and after the treadmill, you will be asked to play some computer games. This should take 10-20 minutes.
- Electroencephalographic (EEG) Profile – During the computer games, we will record signals given off by your brain. We will do this using a stretchy cap (Neuroscan Quik-Cap, Neuro, Inc., El Paso, TX). The cap does not hurt but we will fill the sensors in it with some salt based gel. This gel washes out with warm soapy water. This should take about 15-20 minutes to set up before you play the computer games for the first time. This is only for research and is not a clinical test.

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17 . This version supersedes all previous versions. IRB # 12-062.

Figure 6.3. Informed assent paperwork for children 8 to 12 years old.

Figure 6.3 (cont'd).

Privacy and Confidentiality

The only people who will know about what you say and do in the study will be the people in charge of the study and your parents or guardians. Unless required by law, all data will be kept private and will not link back to you in any way.

Your Rights to Participate, Say No, or Withdraw

The choice to be a part of the study is up to you. You or your parent/guardian may at any time and without penalty:

1. Refuse to be a part of the study.
2. Change your mind about being in the study.
3. Choose to skip a question or activity.

Please tell the research staff if you are thinking about stopping or deciding to stop, so that they can tell you how to do so safely.

Costs and Compensation for Participation

To thank you for your time, you will be paid $10 for finishing the first session and $15 for the other two sessions of the study. If you finish all three days of the study, we will pay you an additional $10 (for a total of up to $50). Should you or your parent/guardian decide to stop being a part of the study, you will still be paid for the time you attended.

Potential Benefits

There is no direct benefit to being in this study. We hope that what we learn from this study will help us understand how exercise and the brain are linked. These findings may help you to choose to be more active.

Potential Risks

If you chose to be in the study, you might feel some itchy skin where the sensors sat on your head. You may also get a headache from wearing the stretchy cap. If you do not normally exercise there is a chance of minor injury and/or pain after using the treadmill. If you experience any such negative feelings, please inform the research staff. You should also know that you will wash your hair with warm soapy water to remove the gel that is used during testing.

Documentation of Informed Assent

Before you agree to be a part of the study, please make sure that you:

- Are aware of what you will be asked to do.
- Give your consent by choice.
- Know that you can choose to stop at any time.

Your signature below means that you are choosing to be a part of this research study.

Signature: ____ Date: ______________________

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17 . This version supersedes all previous versions. IRB # 12-062.

Appendix E: Informed Assent – Age 13-17

Participant Information and Assent Form - Age 13-17

"Examining the Influence of Single Bouts of Aerobic Exercise on Specific Attentional Networks."

HBCL
Health Behaviors & Cognition Laboratory
Michigan State University

Investigators Directing Research:

Drew Parks, M.S., Doctoral Student, Department of Kinesiology, Michigan State University, 38 IM Sports Circle, East Lansing, MI 48824-1049, (517) 353-0892, email@msu.edu

Matthew B. Pontifex, Ph.D., Assistant Professor, Department of Kinesiology, Michigan State University, 126E IM Sports Circle, East Lansing, MI 48824-1049, (517) 432-5105, pontifex@msu.edu, http://education.msu.edu/kin/hbcl

You are being asked to participate in a research study. You will be asked to sign this form if you agree to be a part of the study. We will also ask your parent or guardian to sign a form to make sure that they agree for you to be a part of the study. This form will tell you about the purpose, risks, and benefits of this research study. You should decide if you want to be a part of the study only after you understand what you will be asked to do.

Purpose of the Research

The goal of this study is to see how physical activity may alter attention in typically developing individuals and individuals with Autism Spectrum Disorder. By being a part of the study, you will be helping us to understand the benefits of an active life.

What You Will Do

You will be asked to come into the lab today and two other days. Today you will be asked to do the things below for about 90 minutes:

- Questionnaires – You will be asked to fill out some forms. These forms ask about your: readiness to exercise, health history and demographic information, and which hand you like to use. We will also ask you questions to make sure that you understand what we are asking you to do. This should take about 20-30 minutes.
- Observational Assessment – You will be asked to do some puzzles, storytelling games, and pretend play games. This should take about 30-45 minutes.
- Cognitive Task Practice – You will get to see and play some computer games that we will use in the study. These games ask you to respond when you view certain shapes and symbols. This should take about 5-10 minutes.

On the other days, you will be asked to do the things below:

- Experimental Conditions – You will be asked to walk on a treadmill or sit for 20 minutes. We will also ask you to wear a heart rate monitor (Polar WearLink+ 31, Polar Electro, Finland) so that we know how hard your heart is working. We will also have a movie playing so that you do not get bored.
- Cognitive Tasks – Before and after the treadmill, you will be asked to play some computer games. This should take 10-20 minutes.
- Electroencephalographic (EEG) Profile – During the computer games, we will record signals given off by your brain. We will do this using a stretchy cap (Neuroscan Quik-Cap, Neuro, Inc., El Paso, TX). The cap does not hurt but we will fill the sensors in it with some salt based gel. This gel washes out with warm soapy water. This should take about 15-20 minutes to set up before you play the computer games for the first time. This is only for research and is not a clinical test.

Privacy and Confidentiality

Any responses or information you provide will be kept private. All data will be coded and grouped with data from other participants. Once the study is finished, your data will not link back to you in any way. All records will be kept for at least 3 years after the end of the study in a locked secure location and your confidentiality will be protected to the maximum extent of the law. Government representatives, when

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Figure 6.4. Informed assent paperwork for children 13 to 17 years old.

Figure 6.4 (cont'd).

required by law, and the Michigan State University Human Research Protection Program may deem it necessary to look at and/or copy your information. No personal information will be used if the results of this study are presented. All data from this study will be used for research only, not for the diagnosis of any disorder.

Your Rights to Participate, Say No, or Withdraw

The choice to be a part of the study is up to you. You or your parent/guardian may at any time and without penalty:

1. Refuse to be a part of the study.
2. Change your mind about being in the study.
3. Choose to skip a question or activity.

Please tell the research staff if you are thinking about stopping or deciding to stop, so that they can tell you how to do so safely.

Costs and Compensation for Participation

There are no costs to be in this study. To thank you for your time, you will be compensated $10 for finishing the first session and $15 for the other two sessions of the study. If you finish all three days of the study, we will compensate you an additional $10 (for a total of up to $50). Should you or your parent/guardian decide to stop being a part of the study, you will still be compensated to the next half-hour for the time you attended.

Potential Benefits

There is no direct benefit to being in this study. We hope that what we learn from this study will help us understand how exercise and the brain are linked. These findings may help you to choose to be more active.

Potential Risks

Everything used in the study has been used before in educational and research settings involving humans. Nothing is new, untested, or of questionable safety for the health and well-being of humans. If you chose to be in the study, you might feel some itchy skin where the sensors sat on your head. You may also get a headache from wearing the stretchy cap. If you experience any such negative feelings, please inform the research staff. You should also know that you will wash your hair with warm soapy water to remove the gel that is used during testing.

You should also know that if you do not normally exercise there is a chance of minor injury and/or pain after using the treadmill. However, we do not anticipate any major injuries to occur. Should you become injured due to exercising, we encourage you to notify the research staff and to consult your physician if necessary. There is also a very slim chance that sudden death or cardiac issues can occur while exercising. This is very rare and the benefits of exercise are known to outweigh the risks. We have made these risks smaller by our screening and inclusion/exclusion criteria. We will also make sure that you understand how to safely use the treadmill.

Your Rights to Get Help if Injured

If you are injured as a result of being in this study, Michigan State University will assist you in obtaining emergency care for the research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. Any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University will not provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. If at any time, day or night, you experience adverse physical symptoms, you should immediately contact your personal physician or emergency personnel (i.e., dial 911).

Contact Information

If at any time, either now or later, you have concerns or questions about this study, please contact the researcher, Dr. Matthew B. Pontifex (517-432-5105, pontifex@msu.edu), who is responsible for this study.

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17 . This version supersedes all previous versions. IRB # 12-062.

Figure 6.4 (cont'd).

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail: irb@msu.edu or regular mail at 408 W. Circle Drive, Room 207 Olds Hall, MSU, East Lansing, MI 48824.

Documentation of Informed Assent

Before you agree to be a part of the study, please make sure that you:

- Are aware of what you will be asked to do.
- Give your consent by choice.
- Know that you can choose to stop at any time.

Your signature below means that you are choosing to be a part of this research study.

Signature: _______________________________________ Date: ______________________

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17 . This version supersedes all previous versions. IRB # 12-062.

Appendix F: Informed Consent – Age 18+

Participant Information and Consent Form – Age 18+

"Examining the Influence of Single Bouts of Aerobic Exercise on Specific Attentional Networks."

Investigators Directing Research:

Drew Parks, M.S., Doctoral Student, Department of Kinesiology, Michigan State University, 38 IM Sports Circle, East Lansing, MI 48824-1049, (517) 353-0892, email@msu.edu

Matthew B. Pontifex, Ph.D., Assistant Professor, Department of Kinesiology, Michigan State University, 126E IM Sports Circle, East Lansing, MI 48824-1049, (517) 432-5105, pontifex@msu.edu, http://education.msu.edu/kin/hbcl

You are being asked to participate in a research study. You will be asked to sign this form if you agree to be a part of the study. This form will tell you about the purpose, risks, and benefits of this research study. You should decide if you want to be a part of the study only after you understand what you will be asked to do.

Purpose of the Research

The goal of this study is to see how physical activity may alter attention in typically developing individuals and individuals with Autism Spectrum Disorder. By being a part of the study, you will be helping us to understand the benefits of an active life.

What You Will Do

You will be asked to come into the lab today and two other days. Today you will be asked to do the things below for about 90 minutes:

- Questionnaires – You will be asked to fill out some forms. These forms ask about your: readiness to exercise, health history and demographic information, and which hand you like to use. We will also ask you questions to make sure that you understand what we are asking you to do. This should take about 20-30 minutes.
- Observational Assessment – You will be asked to do some puzzles, storytelling games, and pretend play games. This should take about 30-45 minutes.
- Cognitive Task Practice – You will get to see and play some computer games that we will use in the study. These games ask you to respond when you view certain shapes and symbols. This should take about 5-10 minutes.

On the other days, you will be asked to do the things below:

- Experimental Conditions – You will be asked to walk on a treadmill or sit for 20 minutes. We will also ask you to wear a heart rate monitor (Polar WearLink+ 31, Polar Electro, Finland) so that we know how hard your heart is working. We will also have a movie playing so that you do not get bored.
- Cognitive Tasks – Before and after the treadmill, you will be asked to play some computer games. This should take 10-20 minutes.
- Electroencephalographic (EEG) Profile – During the computer games, we will record signals given off by your brain. We will do this using a stretchy cap (Neuroscan Quik-Cap, Neuro, Inc., El Paso, TX). The cap does not hurt but we will fill the sensors in it with some salt based gel. This gel washes out with warm soapy water. This should take about 15-20 minutes to set up before you play the computer games for the first time. This is only for research and is not a clinical test.

Privacy and Confidentiality

Any responses or information you provide will be kept private. All data will be coded and grouped with data from other participants. Once the study is finished, your data will not link back to you in any way. All records will be kept for at least 3 years after the end of the study in a

Figure 6.5. Informed consent paperwork for adults 18 years old and older.

Figure 6.5 (cont'd).

locked secure location and your confidentiality will be protected to the maximum extent of the law. Government representatives, when required by law, and the Michigan State University Human Research Protection Program may deem it necessary to look at and/or copy your information. No personal information will be used if the results of this study are presented. All data from this study will be used for research only, not for the diagnosis of any disorder.

Your Rights to Participate, Say No, or Withdraw

The choice to be a part of the study is up to you. You may at any time and without penalty:

1. Refuse to be a part of the study.
2. Change your mind about being in the study.
3. Choose to skip a question or activity.

Please tell the research staff if you are thinking about stopping or deciding to stop, so that they can tell you how to do so safely.

Costs and Compensation for Participation

There are no costs to be in this study. To thank you for your time, you will be compensated $10 for finishing the first session and $15 for the other two sessions of the study. If you finish all three days of the study, we will compensate you an additional $10 (for a total of up to $50). Should you decide to stop being a part of the study, you will still be compensated to the next half-hour for the time you attended.

Potential Benefits

There is no direct benefit to being in this study. We hope that what we learn from this study will help us understand how exercise and the brain are linked. These findings may help you to choose to be more active.

Potential Risks

Everything used in the study has been used before in educational and research settings involving humans. Nothing is new, untested, or of questionable safety for the health and well-being of humans. If you chose to be in the study, you might feel some itchy skin where the sensors sat on your head. You may also get a headache from wearing the stretchy cap. If you experience any such negative feelings, please inform the research staff. You should also know that you will wash your hair with warm soapy water to remove the gel that is used during testing.

You should also know that if you do not normally exercise there is a chance of minor injury and/or pain after using the treadmill. However, we do not anticipate any major injuries to occur. Should you become injured due to exercising, we encourage you to notify the research staff and to consult your physician if necessary. There is also a very slim chance that sudden death or cardiac issues can occur while exercising. This is very rare and the benefits of exercise are known to outweigh the risks. We have made these risks smaller by our screening and inclusion/exclusion criteria. We will also make sure that you understand how to safely use the treadmill.

Your Rights to Get Help if Injured

If you are injured as a result of being in this study, Michigan State University will assist you in obtaining emergency care for the research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. Any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University will not provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. If at any time, day or night, you experience adverse physical symptoms, you should immediately contact your personal physician or emergency personnel (i.e., dial 911).

Contact Information

If at any time, either now or later, you have concerns or questions about this study, please contact the researcher, Dr. Matthew B. Pontifex (517-432-5105, pontifex@msu.edu), who is responsible for this study.

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Figure 6.5 (cont'd)

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail: irb@msu.edu or regular mail at 408 W. Circle Drive, Room 207 Olds Hall, MSU, East Lansing, MI 48824.

Documentation of Informed Consent

Before you agree to be a part of the study, please make sure that you:

- Are aware of what you will be asked to do.
- Give your consent by choice.
- Know that you can choose to stop at any time.

Your signature below means that you are choosing to be a part of this research study.

Signature: _______________________________________ Date: ______________________

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Appendix G: Informed Consent - Parent

Participant Information and Consent Form - Parent

"Examining the Influence of Single Bouts of Aerobic Exercise on Specific Attentional Networks."

HBCL
Health Behaviors & Cognition Laboratory
Michigan State University

Investigators Directing Research:

Drew Parks, M.S., Doctoral Student, Department of Kinesiology, Michigan State University, 38 IM Sports Circle, East Lansing, MI 48824-1049, (517) 353-0892, parksa51@msu.edu

Matthew B. Pontifex, Ph.D., Assistant Professor, Department of Kinesiology, Michigan State University, 126E IM Sports Circle, East Lansing, MI 48824-1049, (517) 432-5105, pontifex@msu.edu, http://education.msu.edu/kin/hbcl

Your child is being asked to participate in a research study. If you and your child agree to participate in this study, you will be asked to sign this informed consent document. Informed consent is a written agreement that you sign indicating a willingness to have your child participate in this research. We will also obtain assent from your child if they are interested in participating. This informative document will tell you about the purpose, risks, and benefits of this research study. You should consent only after you have been given all the necessary information and have decided that you wish for your child to participate.

Purpose of the Research

The main goal of this research study is to determine how a single bout of physical activity may influence attention in typically developing children and children with Autism Spectrum Disorder. By participating in this research you will be helping to increase our understanding of the potential cognitive benefits of an active lifestyle.

What You Will Do

If you should agree to participate, you and your child will be asked to come into the lab on three separate days (including today). Today you and your child will be asked to complete the following tests and procedures which should take approximately 60 to 90 minutes to complete:

- Questionnaires – After completing this informed consent, you will be asked to complete a series of questionnaires. These questionnaires will assess your child's: readiness to exercise, health history and demographic characteristics, pubertal status, and clinical characteristics. Your child will also be asked a series of questions to assess their hand preference and screen their level of intelligence. This should take approximately 20-30 minutes to complete and will only be done the first time you come into the lab.
- Observational Assessment – Your child will be presented with various activities (such as puzzles, storytelling, and pretend play) during which time an experimenter will provide your child with a series of prompts and environmental cues to evaluate how they communicate and interact with the activities. This should take approximately 30-45 minutes to complete and will only be done the first time you come into the lab.
- Cognitive Task Practice – Your child will be provided the opportunity to see and practice several visual computer-based games that will be used on the other days that you come into the lab. These games will require your child to view shapes and symbols and respond to specific stimuli. These games will intentionally vary how the demands of the task making them more difficult by presenting conflicting information or varying the memory demands. These games will take approximately 5-10 minutes to demonstrate.

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Figure 6.6. Informed consent paperwork for parents of children under 18 years old.

Figure 6.6 (cont'd).

On the following two days you come into the lab, your child will be asked to complete the following tests and procedures which should take approximately 90 minutes to complete.

- Experimental Conditions – Each day that you come into the lab, your child will be asked to participate in a different type of activity. The activities each last for 20 minutes during which time your child will be asked to either: sit while watching a movie or walk on a treadmill while watching a movie. During each session, we will ask your child to wear a heart rate monitor (Polar WearLink+ 31, Polar Electro, Finland) so that we can measure how hard their heart is working.

- Cognitive Tasks – Immediately prior to and after each experimental condition, your child will be asked to complete several visual computer-based games. These games will take approximately 10-20 minutes to complete before the experimental conditions and 10 to 20 minutes after, depending on how many rest breaks your child would like to take.

- Electroencephalographic (EEG) Profile – Immediately prior to and after each experimental condition, we will record the electrical activity given off by your child's brain while they perform the cognitive tasks. We will do this using sensors located within a lycra cap (Neuroscan Quik-Cap, Neuro, Inc., El Paso, TX) placed on your child's head. The sensors are painless and simply record the electrical signals naturally produced by the body. It will be necessary to fill each sensor with some salt-based gel. This takes approximately 15 to 20 minutes to set up before the experimental condition and this gel washes out with warm soapy water. The electroencephalographic profile is not a clinical assessment. This means that the procedure is not designed to assess any conditions your child has, nor reveal any clinically relevant neurological problems. Rather, it is intended only for research purposes.

Privacy and Confidentiality

Confidentiality is assured for all participants with regard to any responses and information you provide. All data collected will be numerically coded and grouped with data from other participants. Approximately 50 participants will be recruited for this study. Therefore, no individual data will be identifiable once the study is complete. All records will be kept for a minimum of 3 years after the end of the study in a locked secure location and your confidentiality will be protected to the maximum extent of the law. However, government representatives, when required by law, and the Michigan State University Human Research Protection Program may deem it necessary to look at and/or copy your information. Names and other personal information will not be used if the results of this study are published or presented at scientific meetings. All data obtained from this study will be used for research purposes only, not for the diagnosis of any disorder.

Your Rights to Participate, Say No, or Withdraw

Participation in this project is entirely voluntary. You or your child may at any time and without penalty: 1) refuse to participate, 2) withdraw your participation, and/or 3) skip a question or activity should you or your child feel uncomfortable, wish not to answer, or wish not to engage in the activity. Please inform the research staff if you or your child is thinking about stopping or deciding to stop, so that they can tell you how to do so safely.

Costs and Compensation for Participation

There are no anticipated costs for participating in this study, as we will provide the necessary equipment and study materials. However, as with other University related activities; any costs associated with parking will be your responsibility. As an incentive, and appreciation for contributing your time to this study, your child will be compensated $10 for completing the first session and $15 a session for the other two days of the experiment. Upon completing all three days of testing we will also compensate your child an additional $10 (for a total of $50 upon completion of all testing). Should you or your child decide to withdraw participation prior to the completion of the experiment, you will still be compensated to the next half-hour for the time you attended.

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Figure 6.6 (cont'd).

Potential Benefits

If you and your child agree to take part in this study, there may not be any direct benefit. We hope that the information learned from this study will contribute to gaining further insight into the relationship between exercise and cognition. These findings may also have implications for lifestyle factors that relate to improved cognitive health across the lifespan, and may provide a rationale for your child to be active.

Potential Risks

All procedures, techniques, equipment, and measures to be used in the study are routinely used in educational and research settings involving humans. No individual methodological element is new, untested, or of questionable safety for the health and general well being of humans. You should be aware that as a result of your child's participation in this study, they may experience some minor skin irritation from the application of the sensors at the recording sites. Although occurring only in rare instances, your child may experience a headache from wearing the electrode cap. If your child experiences any such negative sensations please inform the research staff. You should also know that you will need to wash their hair with warm soapy water to completely remove the gel that is used during EEG testing.

It is also necessary to inform you that when individuals who have been sedentary engage in exercise, there is a chance of incurring minor injury and most certainly some discomfort due to the intensified use of major muscle groups that have not received a great deal of use recently. Although the exercise portion of this study is of moderate intensity, it is possible that they could be injured or experience discomfort as a result of engaging in exercise. However, we do not anticipate any major injuries to occur. Should your child become injured due to exercising, we encourage you to notify the research staff and to consult your physician if necessary. There is also a very slim chance that sudden death or cardiac irregularities can occur while exercising. As noted, this is very rare and the benefits of exercise are known to outweigh the risks. We have also minimized these risks through screening and inclusion/exclusion criteria. However, we strongly suggest that you and your child pay close attention to all safety instructions as your child is oriented to the equipment.

Your Rights to Get Help if Injured

If your child is injured as a result of their participation in this research project, Michigan State University will assist you in obtaining emergency care, if necessary, for the research related injuries. If you have insurance for medical care, your insurance carrier will be billed in the ordinary manner. As with any medical insurance, any costs that are not covered or in excess of what are paid by your insurance, including deductibles, will be your responsibility. The University's policy is not to provide financial compensation for lost wages, disability, pain or discomfort, unless required by law to do so. This does not mean that you are giving up any legal rights you may have. If at any time, day or night, your child experiences adverse physical symptoms, you should immediately contact your personal physician or emergency personnel (i.e., dial 911).

Contact Information

If at any time, either now or later, you have concerns or questions about this study, such as scientific issues, how to do any part of it, or to report an injury, please contact the researcher, Dr. Matthew B. Pontifex (517-432-5105, pontifex@msu.edu), who is responsible for this study.

If you have questions or concerns about your role and rights as a research participant, would like to obtain information or offer input, or would like to register a complaint about this study, you may contact, anonymously if you wish, the Michigan State University's Human Research Protection Program at 517-355-2180, Fax 517-432-4503, or e-mail: irb@msu.edu or regular mail at 408 W. Circle Drive, Room 207 Olds Hall, MSU, East Lansing, MI 48824.

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Figure 6.6 (cont'd).

Documentation of Informed Consent

Before you agree to participate, please ensure that you:

- Are aware of what you and your child will be asked to do.
- Give your consent voluntarily.
- Know that you can withdraw your consent at any time.

Your signature below means that you voluntarily agree for your child to participate in this research study.

Signature: _______________________________________ Date: ______________________

Child Participant's Name: _______________________________________
Please Print

This consent form was approved by a Michigan State University Institutional Review Board. Approved 3/29/17 – valid through 12/6/17. This version supersedes all previous versions. IRB # 12-062.

Appendix H: Recruitment Flyer for Individuals with ASD

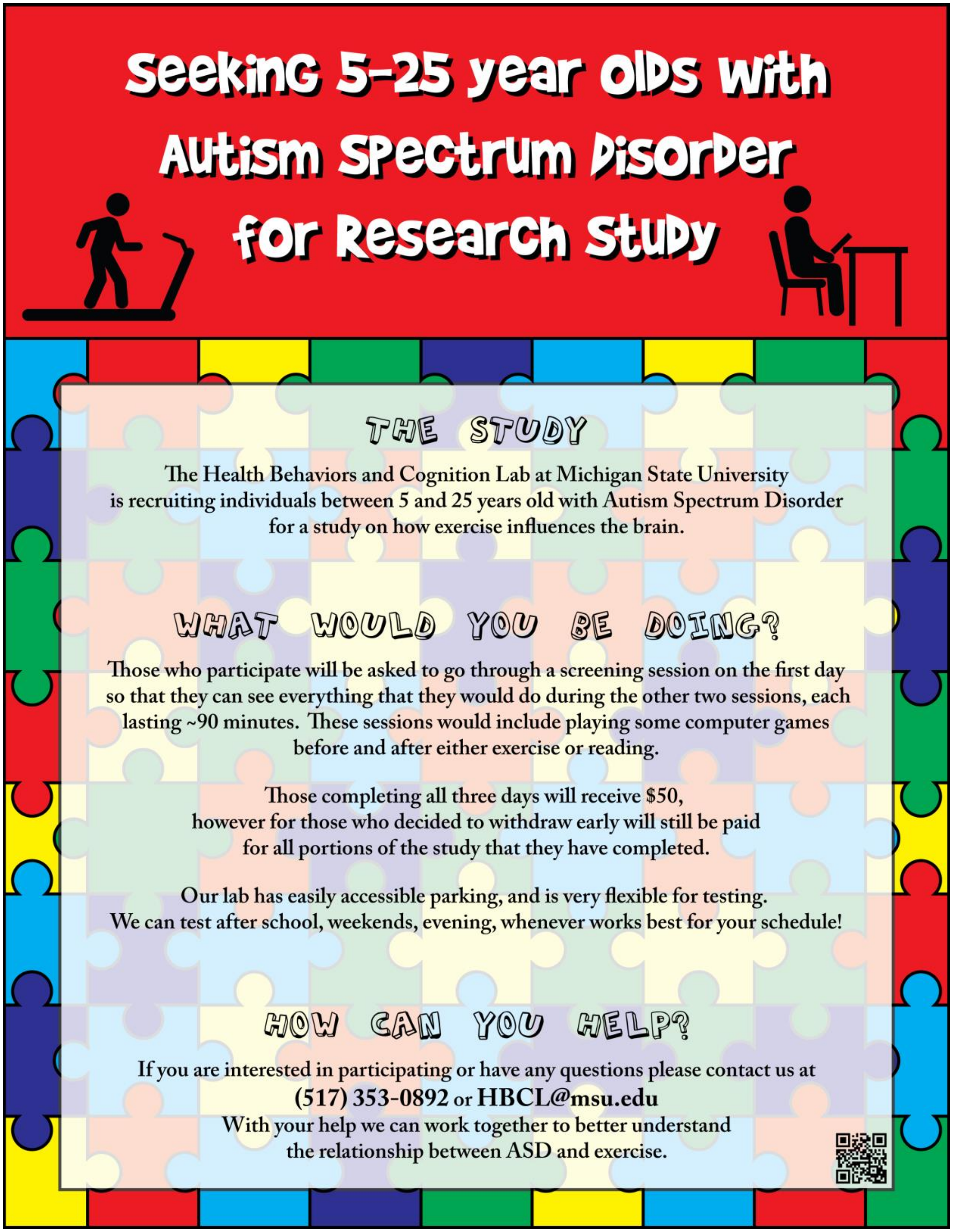

Figure 6.7. Recruitment flyer for individuals with ASD.

Appendix I: Recruitment Email for Individuals with ASD

Subject: Research Study for Individuals with Autism Spectrum Disorder (Age 5-25)

Email
Hello,

The Health Behaviors and Cognition Lab at Michigan State University is **recruiting Individuals with Autism Spectrum Disorder aged 5-25** who are interested in helping us study the link between cognition and exercise.

Where does this study take place?
Participation takes place at Michigan State University, with easily accessible parking.

What will you be asked to do?
Individuals who participate will be asked to go through a screening session on the first day. Those who qualify will be asked to participate in two additional sessions where we will have you either walk on a treadmill or rest while reading a book. Participants will also be asked to play some brief computerized games before and after the reading or activity. Each session lasts 60 to 90 minutes and can be done whenever works best for your schedule (after school, evenings, weekends, early-out school days, we will make it work!).

How will you be compensated?
Participants will be compensated $50 for completing the study (~$10/hr.)

How can we get involved?
If you are interested in participating or have any questions please contact Drew at (517) 353-0892 or HBCL@msu.edu.
With your help we can work together to better understand how healthy bodies result in healthy brains.

Drew Parks, M.S.

Doctoral Candidate **I** Graduate Assistant
Health Behaviors and Cognition Laboratory
Department of Kinesiology
Michigan State University

38 IM Sports Circle
308 W. Circle Drive
East Lansing, MI 48824
(517)433-0892 (Office/Lab)
(517)353-2944 (Fax)
http://education.msu.edu/kin/hbcl

Appendix J: Recruitment Flyer for TD Individuals

Figure 6.8. Recruitment flyer for typically developing individuals..

Appendix K: Recruitment Email for TD Individuals

Subject: Physical Activity and Cognition Study

Email
Hello,

The Health Behaviors and Cognition Lab at Michigan State University is **recruiting individuals age 14-18** who are interested in helping us study the link between cognition and exercise. Our work has recently been gaining attention on Facebook, in the New York Times, the Wall Street Journal, and was even mentioned on the Today Show; but we still need more participants for our ongoing studies.

Where does this study take place?
Participation takes place at Michigan State University, with easily accessible parking.

What will my child be asked to do?
Individuals who participate will be asked to complete two testing sessions, each approximately 60-90 minutes in duration. During the sessions participants will be asked to play some brief computerized games before and after either walking on a treadmill or reading a book. Sessions can be done whenever works best for your schedule (daytime, evenings, weekends, early-out school days, we will make it work!).

How will my child be compensated?
Children will be compensated $50 for completing the study (~$10/hr.)

How can we get involved?
If you are interested in participating or have any questions please contact Drew at (517) 353-0892 or HBCL@msu.edu.

With your help we can work together to better understand how healthy bodies result in healthy brains.

Drew Parks, M.S.

Doctoral Candidate **I** Graduate Assistant
Health Behaviors and Cognition Laboratory
Department of Kinesiology
Michigan State University

38 IM Sports Circle
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(517)433-0892 (Office/Lab)
(517)353-2944 (Fax)
http://education.msu.edu/kin/hbcl

Appendix L: SNAP-IV

The SNAP-IV Teacher and Parent Rating Scale
James M. Swanson, Ph.D., University of California, Irvine, CA 92715

Name:_______________ Gender:_________ Age:_________ Grade:_________

Ethnicity (circle one which best applies): African-American Asian Caucasian Hispanic Other_______________

Completed by:_______________ Type of Class:_______________ Class size:_______________

For each item, check the column which best describes this child:	Not At All	Just A Little	Quite A Bit	Very Much
1. Often fails to give close attention to details or makes careless mistakes in schoolwork or tasks				
2. Often has difficulty sustaining attention in tasks or play activities				
3. Often does not seem to listen when spoken to directly				
4. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties				
5. Often has difficulty organizing tasks and activities				
6. Often avoids, dislikes, or reluctantly engages in tasks requiring sustained mental effort				
7. Often loses things necessary for activities (e.g., toys, school assignments, pencils, or books)				
8. Often is distracted by extraneous stimuli				
9. Often is forgetful in daily activities				
10. Often has difficulty maintaining alertness, orienting to requests, or executing directions				
11. Often fidgets with hands or feet or squirms in seat				
12. Often leaves seat in classroom or in other situations in which remaining seated is expected				
13. Often runs about or climbs excessively in situations in which it is inappropriate				
14. Often has difficulty playing or engaging in leisure activities quietly				
15. Often is "on the go" or often acts as if "driven by a motor"				
16. Often talks excessively				
17. Often blurts out answers before questions have been completed				
18. Often has difficulty awaiting turn				
19. Often interrupts or intrudes on others (e.g., butts into conversations/games)				
20. Often has difficulty sitting still, being quiet, or inhibiting impulses in the classroom or at home				
21. Often loses temper				
22. Often argues with adults				
23. Often actively defies or refuses adult requests or rules				
24. Often deliberately does things that annoy other people				
25. Often blames others for his or her mistakes or misbehavior				
26. Often touchy or easily annoyed by others				
27 Often is angry and resentful				
28. Often is spiteful or vindictive				
29. Often is quarrelsome				
30. Often is negative, defiant, disobedient, or hostile toward authority figures				
31. Often makes noises (e.g., humming or odd sounds)				
32. Often is excitable, impulsive				
33. Often cries easily				
34. Often is uncooperative				
35. Often acts "smart"				
36. Often is restless or overactive				
37. Often disturbs other children				
38. Often changes mood quickly and drastically				
39. Often easily frustrated if demand are not met immediately				
40. Often teases other children and interferes with their activities				

Figure 6.9. SNAP-IV assessment for expression of ADHD symptoms.

Figure 6.9 (cont'd).

Check the column which best describes this child:	Not At All	Just A Little	Quite A Bit	Very Much
41. Often is aggressive to other children (e.g., picks fights or bullies)	_____	_____	_____	_____
42. Often is destructive with property of others (e.g., vandalism)	_____	_____	_____	_____
43. Often is deceitful (e.g., steals, lies, forges, copies the work of others, or "cons" others)	_____	_____	_____	_____
44. Often and seriously violates rules (e.g., is truant, runs away, or completely ignores class rules)	_____	_____	_____	_____
45. Has persistent pattern of violating the basic rights of others or major societal norms	_____	_____	_____	_____
46. Has episodes of failure to resist aggressive impulses (to assault others or to destroy property)	_____	_____	_____	_____
47. Has motor or verbal tics (sudden, rapid, recurrent, nonrhythmic motor or verbal activity)	_____	_____	_____	_____
48. Has repetitive motor behavior (e.g., hand waving, body rocking, or picking at skin)	_____	_____	_____	_____
49. Has obsessions (persistent and intrusive inappropriate ideas, thoughts, or impulses)	_____	_____	_____	_____
50. Has compulsions (repetitive behaviors or mental acts to reduce anxiety or distress)	_____	_____	_____	_____
51. Often is restless or seems keyed up or on edge	_____	_____	_____	_____
52. Often is easily fatigued	_____	_____	_____	_____
53. Often has difficulty concentrating (mind goes blank)	_____	_____	_____	_____
54. Often is irritable	_____	_____	_____	_____
55. Often has muscle tension	_____	_____	_____	_____
56. Often has excessive anxiety and worry (e.g., apprehensive expectation)	_____	_____	_____	_____
57. Often has daytime sleepiness (unintended sleeping in inappropriate situations)	_____	_____	_____	_____
58. Often has excessive emotionality and attention-seeking behavior	_____	_____	_____	_____
59. Often has need for undue admiration, grandiose behavior, or lack of empathy	_____	_____	_____	_____
60. Often has instability in relationships with others, reactive mood, and impulsivity	_____	_____	_____	_____
61 Sometimes for at least a week has inflated self esteem or grandiosity	_____	_____	_____	_____
62. Sometimes for at least a week is more talkative than usual or seems pressured to keep talking	_____	_____	_____	_____
63. Sometimes for at least a week has flight of ideas or says that thoughts are racing	_____	_____	_____	_____
64. Sometimes for at least a week has elevated, expansive or euphoric mood	_____	_____	_____	_____
65. Sometimes for at least a week is excessively involved in pleasurable but risky activities	_____	_____	_____	_____
66. Sometimes for at least 2 weeks has depressed mood (sad, hopeless, discouraged)	_____	_____	_____	_____
67. Sometimes for at least 2 weeks has irritable or cranky mood (not just when frustrated)	_____	_____	_____	_____
68. Sometimes for at least 2 weeks has markedly diminished interest or pleasure in most activities	_____	_____	_____	_____
69. Sometimes for at least 2 weeks has psychomotor agitation (even more active than usual)	_____	_____	_____	_____
70. Sometimes for at least 2 weeks has psychomotor retardation (slowed down in most activities)	_____	_____	_____	_____
71. Sometimes for at least 2 weeks is fatigued or has loss of energy	_____	_____	_____	_____
72. Sometimes for at least 2 weeks has feelings of worthlessness or excessive, inappropriate guilt	_____	_____	_____	_____
73. Sometimes for at least 2 weeks has diminished ability to think or concentrate	_____	_____	_____	_____
74. Chronic low self-esteem most of the time for at least a year	_____	_____	_____	_____
75. Chronic poor concentration or difficulty making decisions most of the time for at least a year	_____	_____	_____	_____
76. Chronic feelings of hopelessness most of the time for at least a year	_____	_____	_____	_____
77. Currently is hypervigilant (overly watchful or alert) or has exaggerated startle response	_____	_____	_____	_____
78. Currently is irritable, has anger outbursts, or has difficulty concentrating	_____	_____	_____	_____
79. Currently has an emotional (e.g., nervous, worried, hopeless, tearful) response to stress	_____	_____	_____	_____
80. Currently has a behavioral (e.g., fighting, vandalism, truancy) response to stress	_____	_____	_____	_____
81. Has difficulty getting started on classroom assignments	_____	_____	_____	_____
82. Has difficulty staying on task for an entire classroom period	_____	_____	_____	_____
83. Has problems in completion of work on classroom assignments	_____	_____	_____	_____
84. Has problems in accuracy or neatness of written work in the classroom	_____	_____	_____	_____
85. Has difficulty attending to a group classroom activity or discussion	_____	_____	_____	_____
86. Has difficulty making transitions to the next topic or classroom period	_____	_____	_____	_____
87. Has problems in interactions with peers in the classroom	_____	_____	_____	_____
88. Has problems in interactions with staff (teacher or aide)	_____	_____	_____	_____
89. Has difficulty remaining quiet according to classroom rules	_____	_____	_____	_____
90. Has difficulty staying seated according to classroom rules	_____	_____	_____	_____

Appendix M: Social Communication Questionnaire (SCQ)

Please answer circle the answer that *best describes* your child's behavior <u>over the last 3 months</u>.

Although you may be uncertain about whether some behaviors were present or not, please answer *yes* or *no* to every question on the basis of what you think.

1. Does your child ever use odd phrases or say the same thing over and over in almost exactly the same way (either phrases that they hear other people use or ones that they make up)? .... Yes No
2. Does your child ever use socially inappropriate questions or statements? For example, does your child ever regularly ask personal questions or make personal comments at awkward times? .... Yes No
3. Does your child ever get their pronouns mixed up (e.g., saying *you* or *she/he* for *I*)? .... Yes No
4. Does your child ever use words that they seem to have invented or made up themselves; Put things in odd, indirect ways; or use metaphorical ways of saying things (e.g., Saying *hot rain* for *steam*)? .... Yes No
5. Does your child ever say the same thing over and over in exactly the same way or insist that you say the same thing over and over again? .... Yes No
6. Does your child ever have things that they seem to have to do in a very particular way or order or rituals that they insist that you go through? .... Yes No
7. Does your child ever use your hand like a tool or as if it were part of their own body (e.g., pointing with your finger or putting your hand on a doorknob to get you to open the door)? .... Yes No
8. Does your child ever have any interests that preoccupy them and might seem odd to other people (e.g., traffic lights, drainpipes, or timetables)? .... Yes No
9. Does your child ever seem to be more interested in parts of a toy or an object (e.g., spinning the wheels of a car), rather than in using the object as it was intended? .... Yes No
10. Does your child ever have any special interests that are unusual in their intensity but otherwise appropriate for their age and peer group (e.g., trains or dinosaurs)? .... Yes No
11. Does your child ever seem to be unusually interested in the sight, feel, sound, taste, or smell of things or people? .... Yes No
12. Does your child ever have any mannerisms or odd ways of moving their hands or fingers, such as flapping or moving their fingers in front of their eyes? .... Yes No
13. Does your child ever have any repetitive complicated movements of their whole body, such as spinning or bouncing up-and-down? .... Yes No
14. Does your child ever injure themselves deliberately, such as biting their arm or banging their head? .... Yes No
15. Does your child ever have any objects (*other* than a soft toy or comfort blanket) that they *have* to carry around? .... Yes No

Rutter, Bailey, & Lord (2003). SCQ

Figure 6.10. Social communication questionnaire assessment.

Figure 6.10 (cont'd).

Please answer circle the answer that *best describes* your child's behavior <u>over the last 3 months</u>.

Although you may be uncertain about whether some behaviors were present or not, please answer *yes* or *no* to every question on the basis of what you think.

16. Do you have a to and fro "conversation" with your child that involves taking turns or building on what you have said? .... Yes No
17. Does your child's facial expression usually seem appropriate to the particular situation, as far as you can tell? .... Yes No
18. Does your child have any particular friends or a best friend? .... Yes No
19. Does your child ever talk with you just to be friendly (rather than to get something)? .... Yes No
20. Does your child ever spontaneously copy you (or other people) or what you are doing (such as vacuuming, gardening, or mending things)? .... Yes No
21. Does your child ever spontaneously point at things around them just to show you things (not because they want them)? .... Yes No
22. Does your child ever use gestures, other than pointing or pulling your hand, to let you know what they want? .... Yes No
23. Does your child nod their head to indicate *yes*? .... Yes No
24. Does your child nod their head to indicate *no*? .... Yes No
25. Does your child usually look at you directly in the face when doing things with you or talking with you? .... Yes No
26. Does your child smile back if someone smiles at them? .... Yes No
27. Does your child ever show you things that interest them to engage your attention? .... Yes No
28. Does your child ever offer to share things other than food with you? .... Yes No
29. Does your child ever seem to want you to join in their enjoyment of something? .... Yes No
30. Does your child ever try to comfort you if you are sad or hurt? .... Yes No
31. If your child wants something or wants help, do they look at you and use gestures with sounds or words to get your attention? .... Yes No
32. Does your child show a normal range of facial expressions? .... Yes No
33. Does your child ever spontaneously join in and try to copy the actions in social games, such as "*the Mulberry Bush*" or "*London Bridge is Falling Down*"? .... Yes No
34. Does your child play any pretend or make-believe games? .... Yes No
35. Does your child seem interested in other children of approximately the same age whom they do not know? .... Yes No
36. Does your child respond positively when another child approaches them? .... Yes No
37. If you come into a room and start talking to your child without calling their name, do they usually look up and pay attention to you? .... Yes No
38. Does your child ever play imaginative games with another child in such a way that you can tell that each child understands what the other is pretending? .... Yes No
39. Does your child play cooperatively in games that need some form of joining in with a group of other children, such as hide-and-seek or ball games? .... Yes No

Appendix N: Physical Activity Readiness Questionnaire (PAR-Q)

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

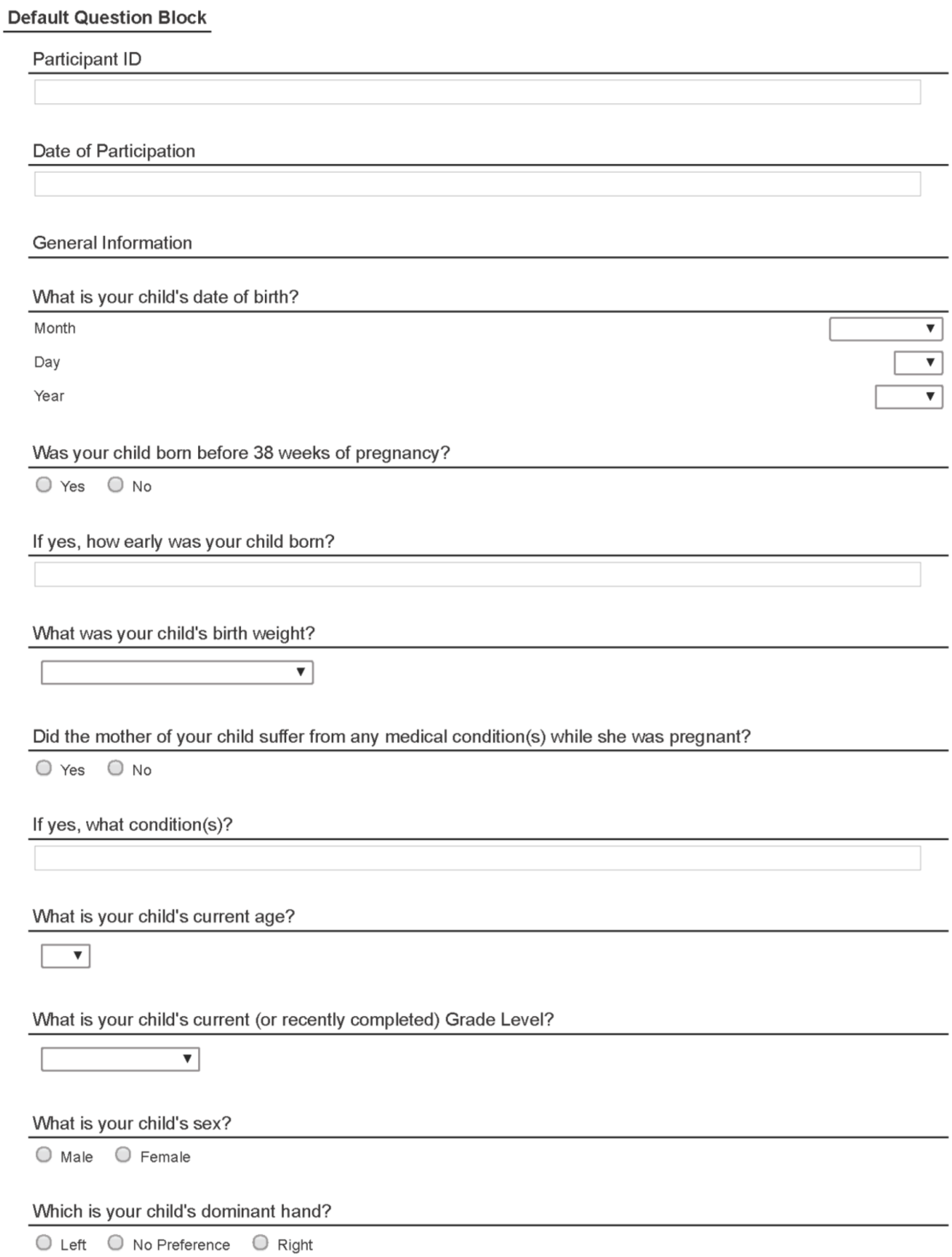
Common sense is your best guide in answering these few questions. Please read them carefully and check the ☐ Yes or ☐ No opposite the question if it applies to your child.

YES	NO	
☐	☐	1. Has your doctor ever said your child has a heart condition and that they should only do physical activity recommended by a doctor?
☐	☐	2. Does your child feel pain in their chest when they do physical activity?
☐	☐	3. In the past month, has your child had chest pain when they were NOT doing physical activity?
☐	☐	4. Does your child lose their balance because of dizziness or do they ever lose consciousness?
☐	☐	5. Does your child have a bone or joint problem that could be made worse by a change in their physical activity?
☐	☐	6. Is your child's doctor currently prescribing drugs (for example, water pills) for their blood pressure or a heart condition?
☐	☐	7. Do you know of any other reason why your child should not do physical activity?

PAR-Q (Thomas, Reading, & Shephard, 1992)

Figure 6.11. Physical activity readiness questionnaire.

Appendix O: Health History Demographic Survey



Default Question Block

Participant ID

Date of Participation

General Information

What is your child's date of birth?

Month

Day

Year

Was your child born before 38 weeks of pregnancy?

Yes No

If yes, how early was your child born?

What was your child's birth weight?

Did the mother of your child suffer from any medical condition(s) while she was pregnant?

Yes No

If yes, what condition(s)?

What is your child's current age?

What is your child's current (or recently completed) Grade Level?

What is your child's sex?

Male Female

Which is your child's dominant hand?

Left No Preference Right

Figure 6.12. Health history demographic form completed online.

Figure 6.12 (cont'd).

Is your child color blind?

○ Yes ○ No

Does your child wear contacts of glasses?

○ Yes ○ No

If yes, what is their prescription for?

[▼]

Demographics

Please answer the following questions about your child's home environment:
(If a specific question is not applicable, please skip it.)

	Yes	No
Does your child live with their biological parent(s)?	○	○
Does your child live in a single parent/guardian household?	○	○
Does your child live with their Mother or a Female Guardian?	○	○
Does your child's Mother / Female Guardian work?	○	○
Does your child live with their Father or a Male Guardian?	○	○
Does your child's Father / Male Guardian work?	○	○

What is the highest level of education obtained by your child's:
(If a specific question is not applicable, please skip it.)

Mother / Female Guardian [▼]

Father / Male Guardian [▼]

How many other children (under the age of 18) live with your child?

How old are they?

What is/are their sex(s)?

0 Males

0 Females

How many biological siblings does your child have?

Does your child receive free or reduced-price school lunch?

Figure 6.12 (cont'd).

○ Yes ○ No

Do you consider yourself to be Hispanic or Latino?
(A person of Mexican, Puerto Rican, Cuban, South or Central American, or other Spanish culture or origin, regardless of race)

○ Yes ○ No

What race/ethnicity do you consider your child?
(Select one or more options below)

- ☐ American Indian or Alaska Native: a person having origins in any of the original peoples of North and South America (including Central America) and who maintains tribal affiliation or community attachment.
- ☐ Asian: a person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam.
- ☐ Black or African American: a person having origins in any of the Black racial groups of Africa.
- ☐ Native Hawaiian or Other Pacific Islander: a person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
- ☐ White or Caucasian: a person having origins in any of the original peoples of Europe, the Middle East or North Africa.

What is your approximate gross household income?
(Income includes wages and salaries, unemployment insurance, disability payments, child support payments received, as well as any personal business, investment, or other kinds of income received routinely.)

[▼]

Activities

How many hours per week does your child spend participating in:

Musical Activities	[▼]
Religious Activities	[▼]
Sports Activities	[▼]

What Musical Activities does your child participate in?

If your child plays an instrument, what instrument(s) do they play?

What Sports Activities does your child participate in?

Figure 6.12 (cont'd).

Does your child participate in formal youth sports?

○ Yes ○ No

Has you child attended regular afterschool care outside of your home in the last year?

○ Yes ○ No

Habits

On an average day during the WEEK, how much time does your child spend:

- Watching Television ▼
- On the Computer ▼
- Playing Videogames ▼
- Being Physically Active ▼

On an average day during the WEEKEND, how much time does your child spend:

- Watching Television ▼
- On the Computer ▼
- Playing Videogames ▼
- Being Physically Active ▼

How much sleep does/did your child get:

- On an Average Week Night ▼
- On an Average Weekend Night ▼
- Last Night ▼

How many drinks of the following substances does your child consume on an average day?

- Water ▼
- Caffeinated Soft Drinks ▼
- Cups of Tea ▼

How often would you rate your child's stress level as HIGH?

Never	Rarely	Sometimes	Most of the Time	Always
○	○	○	○	○

How many hours has it been since your child last:

- Had a caffeinated substance? ▼
- Ate a meal or snack? ▼
- Last exercised? ▼

When your child last ate, what did s/he have to eat?

Figure 6.12 (cont'd).

When your child last exercised, what type of exercise did your child do?

How long did s/he exercise for?

How hard did s/he exercise?

General Health

When was the last time your child saw a doctor?

Has your child ever been diagnosed with:

	Yes	No
Any allergies?	○	○
Dyslexia?	○	○
An Attentional Disorder?	○	○
Asthma?	○	○
Epilepsy?	○	○
Diabetes?	○	○
Cancer?	○	○
Hearing Impairment?	○	○

If your child is diabetic, what type do they have?

If your child has been hospitalized within the last 6 months, please explain:

If your child has ever lost consciousness, please explain:
(i.e., was it the result of hitting their head, another form of injury, a seizure, etc.; how long were they unconscious?)

Figure 6.12 (cont'd).

Medications/Supplements

Is your child presently taking or have they taken any of the following medication within the past two months?

- ☐ Asprin, Bufferin, Anacin
- ☐ Iron or Poor Blood Medications
- ☐ Allergy Shot
- ☐ Blood Pressure Pills
- ☐ Laxatives
- ☐ Water Pills
- ☐ Cortisone
- ☐ Sleeping Pills
- ☐ Antibiotics
- ☐ Cough Medicine
- ☐ Tranquilizers
- ☐ Barbiturates
- ☐ Digitalis
- ☐ Weight Reducing Pills
- ☐ Phenobarbital
- ☐ Hormones
- ☐ Blood Thinning Pills
- ☐ Thyroid Medicine
- ☐ Insulin or Diabetic Pills
- ☐ Dilantin
- ☐ Other, please specify

Does your child take Ginkgo Biloba supplements?

○ Yes ○ No

If yes, when was the last time they took the supplement?

▼

What dose of the supplement did they take?

Does your child take Iron supplements?

○ Yes ○ No

If yes, when was the last time they took the supplement?

▼

What dose of the supplement did they take?

Does your child take any stimulants or sedatives?

○ Yes ○ No

If yes, what do they take?

Figure 6.12 (cont'd).

When was the last time they took it?

What dose of it did they take?

Cardiovascular Health

Does your child have any of the following:

	Yes	No
Pain or discomfort in the chest, neck, jaw, arms, or other areas that may be related to poor circulation?	○	○
Heartbeats or palpitations that feel more frequent or forceful than usual or feeling that their heart is beating very rapidly?	○	○
Unusual dizziness or fainting?	○	○
Shortness of breath while lying flat or a sudden difficulty in breathing that wakes them up while sleeping?	○	○
Shortness of breath at rest or with mild exertion (such as walking two blocks)?	○	○
Feeling lame or pain in the legs brought on by walking?	○	○
A known heart murmur?	○	○
Unusual fatigue with usual activities?	○	○

Has any male in your immediate family had a heart attack or sudden death before the age of 55?

○ Yes ○ No

Has any female in your immediate family had a heart attack or sudden death before the age of 65?

○ Yes ○ No

Do you have family history of:

	Yes	No
Heart disease	○	○
Lung disease	○	○
Diabetes	○	○
Strokes	○	○

Has your child been diagnosed with:

	Yes	No
A past or present cardiovascular disease?	○	○
Any significant heart rhythm disorder?	○	○
Hypertension?	○	○
Peripheral vascular disease?	○	○

Tanner Staging

Figure 6.12 (cont'd).

Please select the number that *best represents* your child's pubertal status.

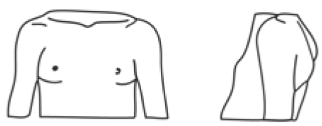
Stage 1

1.

The Breasts are flat.

Stage 2

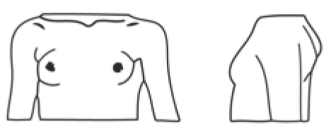
2.



The breasts form small mounds.

Stage 3

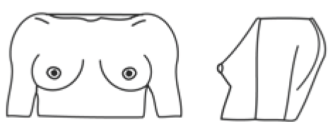
3.



The breasts form larger mounds than in 2.

Stage 4

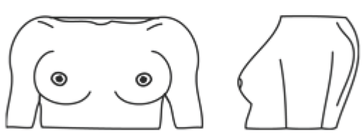
4.



The nipple and the surrounding part (the Areola) make up a mound that sticks up above the breast.

Stage 5

5.

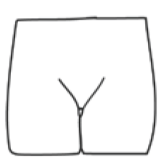


Only the nipple sticks out beyond the breast.

Please select the number that *best represents* your child's pubertal status.

Stage 1

1.



No hairs.

Figure 6.12 (cont'd).

Stage 2

2.

Very little hair.

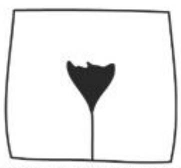
Stage 3

3.

Quite a lot of hair.

Stage 4

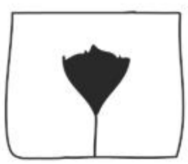
4.



The hair has not spread over the thighs.

Stage 5

5.

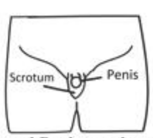


The hair has spread over the thighs.

Please select the number that *best represents* your child's pubertal status.

Stage 1

1.

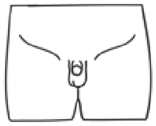


Scrotum and Penis are the same size.

Figure 6.12 (cont'd).

Stage 2

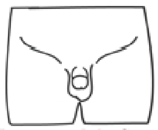
2.



The Scrotum has lowered a bit and the Penis is a little larger.

Stage 3

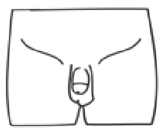
3.



The Penis is Longer and the Scrotum is larger.

Stage 4

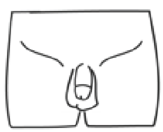
4.



The Penis is longer and wider; the Scrotum is darker and bigger than before.

Stage 5

5.

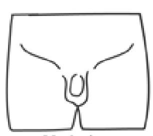


The Penis and Scrotum are the size and shape of an adult.

Please select the number that *best represents* your child's pubertal status.

Stage 1

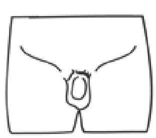
1.



No hairs.

Stage 2

2.

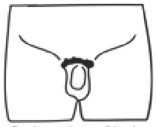


Very little hair.

Figure 6.12 (cont'd).

Stage 3

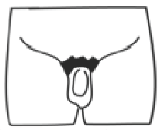
3.



Quite a lot of hair.

○ Stage 4

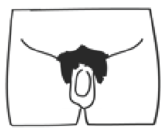
4.



The hair has not spread over the thighs.

○ Stage 5

5.



The hair has spread over the thighs.

Social Communication

Please select the answer that *best describes* your child's behavior **over the last 3 months.**

Although you may be uncertain about whether some behaviors were present or not, please answer *yes* or *no* to every question on the basis of what you think.

	Yes	No
1) Does your child ever use odd phrases or say the same thing over and over in almost exactly the same way (either phrases that they hear other people use or ones that they make up)?	○	○
2) Does your child ever use socially inappropriate question or statements? For example, does your child ever regularly ask personal questions or make personal comments at awkward times?	○	○
3) Does your child ever get their pronouns mixed up (e.g., saying *you* or *she/he* for *I*)?	○	○
4) Does your child ever use words that they seem to have invented or made up themselves; Put things in odd, indirect ways; or use metaphorical ways of saying things (e.g., Saying *hot rain* for *steam*)?	○	○

Figure 6.12 (cont'd).

	Yes	No
5) Does your child ever say the same thing over and over in exactly the same way or insist that you say the same thing over and over again?	○	○
6) Does your child ever have things that they seem to have to do in a very particular way or order or rituals that they insist that you go through?	○	○
7) Does your child ever use your hand like a tool or as if it were part of their own body (e.g., pointing with your finger or putting your hand on a doorknob to get you to open the door)?	○	○
8) Does your child ever have an interests that preoccupy them and might seem odd to other people (e.g., traffic lights, drainpipes, or timetables)?	○	○
9) Does your child ever seem to be more interested in parts of a toy or an object (e.g., spinning the wheels of a car), rather than in using the object as it was intended?	○	○
10) Does your child ever have any special interests that are unusual in their intensity but otherwise appropriate for their age and peer group (e.g., trains or dinosaurs)?	○	○

Please select the answer that *best describes* your child's behavior **over the last 3 months.**

Although you may be uncertain about whether some behaviors were present or not, please answer *yes* or *no* to every question on the basis of what you think.

	Yes	No
11) Does your child ever seem to be unusually interested in the sight, feel, sound, taste, or smell of things or people.	○	○
12) Does your child ever have any mannerisms or odd ways of moving their hands or fingers, such as flapping or moving their fingers in front of their eyes?	○	○
13) Does your child ever have any repetitive complicated movements of their whole body, such as spinning or bouncing up-and-down?	○	○
14) Does your child ever injure themselves deliberately, such as biting their arm or banging their head?	○	○
15) Does your child ever have any objects (*other* than a soft toy or comfort blanket) that they *have* to carry around?	○	○

Figure 6.12 (cont'd).

	Yes	No
16) Do you have a to and fro "conversation" with your child that involves taking turns or building on what you have said?	○	○
17) Does your child's facial expression usually seem appropriate to the particular situation, as far as you can tell?	○	○
18) Does your child have any particular friends or a best friend?	○	○
19) Does your child ever talk with you just to be friendly (rather than to get something)?	○	○
20) Does your child ever spontaneously copy you (or other people) or what you are doing (such as vacuuming, gardening, or mending things)?	○	○

Please select the answer that *best describes* your child's behavior **over the last 3 months.**

Although you may be uncertain about whether some behaviors were present or not, please answer *yes* or *no* to every question on the basis of what you think.

	Yes	No
21) Does your child ever spontaneously point at things around them just to show you things (not because they want them)?	○	○
22) Does your child ever use gestures, other than pointing or pulling your hand, to let you know what they want?	○	○
23) Does your child nod their head to indicate *yes*?	○	○
24) Does your child nod their head to indicate *no*?	○	○
25) Does your child usually look at you directly in the face when doing things with you or talking with you?	○	○
26) Does your child smile back if someone smiles at them?	○	○
27) Does your child ever show you things that interest them to engage your attention?	○	○
28) Does your child ever offer to share things other than food with you?	○	○
29) Does your child ever seem to what you to join in their enjoyment of something?	○	○
30) Does your child ever try to comfort you if you are sad or hurt?	○	○

Please select the answer that *best describes* your child's behavior **over the last 3 months.**

Figure 6.12 (cont'd).

Although you may be uncertain about whether some behaviors were present or not, please answer *yes* or *no* to every question on the basis of what you think.

	Yes	No
31) If your child wants something or wants help, do they look at you and use gestures with sounds or words to get your attention?	○	○
32) Does your child show a normal range of facial expressions?	○	○
33) Does your child ever spontaneously join in and try to copy the actions in social games, such as "*the Mulberry Bush*" or "*London Bridge is Falling Down*"?	○	○
34) Does your child play any pretend or make-believe games?	○	○
35) Does your child seem interested in other children or approximately the same age whom they do not know?	○	○
36) Does your child respond positively when another child approaches them?	○	○
37) If you come into a room and start talking to your child without calling their name, do they usually look up and pay attention to you?	○	○
38) Does your child ever play imaginative games with another child in such a way that you can tell that each child understands what the other is pretending?	○	○
39) Does your child play cooperatively in games that need some form of joining in with a group of other children, such as hide-and-seek or ball games?	○	○

SNAP - IV

For each item, circle the number which best describes your child:

	Not at All	Just a Little	Quite a Bit	Very Much
1) Often fails to give close attention to details or makes careless mistakes in schoolwork or tasks.	○	○	○	○
2) Often has difficulty sustaining attention in tasks or play activities.	○	○	○	○
3) Often does not seem to listen when spoken to directly.	○	○	○	○

Figure 6.12 (cont'd).

	Not at All	Just a Little	Quite a Bit	Very Much
4) Often does not follow through on instructions and fails to finish schoolwork, chores, or duties.	○	○	○	○
5) Often has difficulty organizing tasks and activities.	○	○	○	○
6) Often avoids, dislikes, or reluctantly engages in tasks requiring sustained mental effort.	○	○	○	○
7) Often loses things necessary for activities (e.g., toys, school assignments, pencils, or books).	○	○	○	○
8) Often is distracted by extraneous stimuli.	○	○	○	○
9) Often is forgetful in daily activities.	○	○	○	○
10) Often has difficulty maintaining alertness, orienting to requests, or executing directions.	○	○	○	○

For each item, circle the number which best describes your child:

	Not at All	Just a Little	Quite a Bit	Very Much
11) Often fidgets with hands or feet or squirms in seat.	○	○	○	○
12) Often leaves seat in classroom or in other situations in which remaining seated is expected.	○	○	○	○
13) Often runs about or climbs excessively in situation in which it is inappropriate.	○	○	○	○
14) Often has difficulty playing or engaging in leisure activities quietly.	○	○	○	○
15) Often is "on the go" or often acts as if "driven by a motor".	○	○	○	○
16) Often talks excessively.	○	○	○	○
17) Often blurts out answers before questions have been completed.	○	○	○	○
18) Often has difficulty awaiting turn.	○	○	○	○
19) Often interrupts or intrudes on others (e.g., butts into conversations/games).	○	○	○	○
20) Often has difficulty sitting still, being quiet, or inhibiting impulses in the classroom or at home.	○	○	○	○

For each item, circle the number which best describes your child:

	Not at All	Just a Little	Quite a Bit	Very Much
21) Often loses temper.	○	○	○	○

Figure 6.12 (cont'd).

	Not at All	Just a Little	Quite a Bit	Very Much
22) Often argues with adults.	○	○	○	○
23) Often actively defies or refuses adult requests or rules.	○	○	○	○
24) Often deliberately does things that annoy other people.	○	○	○	○
25) Often blames others for his or her mistakes or misbehavior.	○	○	○	○
26) Often touchy or easily annoyed by others.	○	○	○	○
27) Often is angry and resentful.	○	○	○	○
28) Often is spiteful or vindictive.	○	○	○	○
29) Often is quarrelsome.	○	○	○	○
30) Often is negative, defiant, disobedient, or hostile toward authority figures.	○	○	○	○

For each item, circle the number which best describes your child:

	Not at All	Just a Little	Quite a Bit	Very Much
31) Often makes noises (e.g., humming or odd sounds).	○	○	○	○
32) Often is excitable, impulsive.	○	○	○	○
33) Often cries easily.	○	○	○	○
34) Often is uncooperative.	○	○	○	○
35) Often acts "smart".	○	○	○	○
36) Often is restless or overactive.	○	○	○	○
37) Often disturbs other children.	○	○	○	○
38) Often changes mood quickly and drastically.	○	○	○	○
39) Often easily frustrated if demands are not met immediately.	○	○	○	○
40) Often teases other children and interferes with their activities.	○	○	○	○

For each item, circle the number which best describes your child:

	Not at All	Just a Little	Quite a Bit	Very Much
81) Has difficulty getting started of classroom assignments.	○	○	○	○
82) Has difficulty staying on task for an entire classroom period.	○	○	○	○
83) Has problems in completion of work on classroom assignments.	○	○	○	○
84) Has problems in accuracy or neatness of written work in the classroom.	○	○	○	○

Figure 6.12 (cont'd).

	Not at All	Just a Little	Quite a Bit	Very Much
85) Has difficulty attending to a group classroom activity or discussion.	○	○	○	○
86) Has difficulty making transitions to the next topic or classroom period.	○	○	○	○
87) Has problems in interactions with peers in the classroom.	○	○	○	○
88) Has problems in interactions with staff (teacher or aide).	○	○	○	○
89) Has difficulty remaining quiet according to classroom rules.	○	○	○	○
90) Has difficulty staying seated according to classroom rules.	○	○	○	○

Other

Is there anything else you feel we should know about your child's current/past health?

Appendix P: Tables for Results Section

Table 6.1.

Participant demographic values (Mean ± SD).

Measure	ASD	TD
N	18 (0 female)	18 (4 female)
Non-White	6	8
Age (years)	12.7 ± 4.2	12.3 ± 4.7
Tanner stage		
Pre-pubescent (Stage 1)	6	9
Initial development (Stage 2)	4	3
Continued development (Stages 3 & 4)	3	2
Post-Pubescent (Stage 5)	5	4
WASI-II Composite (IQ)	97.4 ± 18.2*	112.7 ± 17.0*
Socioeconomic status (SES)		
Middle SES	18	18
Education (Grade)	6.2 ± 4.1	6.6 ± 4.4
SNAP-IV		
Inattention subscale	1.6 ± 0.7**	0.7 ± 0.6**
Hyperactivity/Impulsivity subscale	1.4 ± 0.6**	0.4 ± 0.4**
Combined subscale	1.5 ± 0.6**	0.5 ± 0.4**
Social Communication Questionnaire (SCQ)	15.2 ± 4.8**	6.0 ± 3.7**
Age-Predicted HR_{max} (bpm)	207.3 ± 4.2	207.7 ± 4.7
Physical Activity Engagement		
Weekday (hours/day)	1.8 ± 1.0	2.8 ± 1.6
Weekend (hours/day)	2.2 ± 1.0	2.6 ± 1.1

Note: WASI-II – Full Scale-2 composite, utilizing vocabulary and matrix reasoning sub-tests. Socioeconomic status – Low = 1, Middle = 2, & High = 3. SNAP-IV measures – mean scores on each respective subset of questions based on parent report. Social Communication Questionnaire – total score based on parent report. Age-Predicted HR_{max} – calculated using 220 – participant age. *$p \leq 0.05$; **$p \leq 0.001$.

Table 6.2.

Ranges for participant demographics.

Measure	ASD	TD
Age (years)	[6.8, 22.0]	[7.3, 22.2]
WASI-II Composite (IQ)	[62.0, 125.0]	[88.0, 147.0]
Education (Grade)	[0.0, 14.0]	[2.0, 16.0]
SNAP-IV		
Inattention subscale	[0.4, 2.6]	[0.0, 1.7]
Hyperactivity/Impulsivity subscale	[0.1, 2.2]	[0.0, 1.1]
Combined subscale	[0.4, 2.3]	[0.0, 1.3]
Social Communication Questionnaire (SCQ)	[8.0, 23.0]	[0.0, 12.0]
Age-Predicted HR_{max} (bpm)	[198.0, 213.2]	[197.8, 212.7]
Physical Activity Engagement		
Weekday (hours/day)	[1.0, 5.0]	[1.0, 8.0]
Weekend (hours/day)	[1.0, 5.0]	[1.0, 5.0]

Note: WASI-II – Full Scale-2 composite, utilizing vocabulary and matrix reasoning sub-tests. Socioeconomic status – Low = 1, Middle = 2, & High = 3. SNAP-IV measures – mean scores on each respective subset of questions based on parent report. Social Communication Questionnaire – total score based on parent report. Age-Predicted HR_{max} – calculated using 220 – participant age. $^{*}p \leq 0.05$; $^{**}p \leq 0.001$.

Table 6.3.

Clinical status confirmation for the ASD group (Mean ± SD).

Measure	ASD
ADOS Module 3	
N	12
Overall Total (SA + RRB)	12.3 ± 4.4
Social Affect (SA)	10.2 ± 4.1
Restricted and Repetitive Behavior (RRB)	2.2 ± 1.6
Comparison Score	7.0 ± 1.9
ADOS Module 4	
N	6
Communication	3.8 ± 1.1
Social Interaction	6.2 ± 2.5
Imagination/Creativity	0.6 ± 0.5
Stereotyped Behaviors and Restricted Interests	1.8 ± 0.8

Note: All scores represent total scores for the respective assessment category.

Table 6.4.

Mean (± SD) Task Performance Characteristics.

	Reaction Time (ms)		Response Accuracy (%)	
Condition	ASD	TD	ASD	TD
Rest – Pretest				
Congruent	454.7 ± 143.3	445.7 ± 108.9	78.3 ± 18.9	83.5 ± 17.2
Incongruent	472.7 ± 150.9	480.3 ± 117.8	62.4 ± 20.9	76.1 ± 16.4
Rest – Posttest				
Congruent	462.6 ± 154.2	439.6 ± 107.2	78.6 ± 19.7	84.4 ± 17.9
Incongruent	490.0 ± 158.4	480.5 ± 119.9	62.0 ± 23.0	78.4 ± 19.0
Exercise – Pretest				
Congruent	487.0 ± 146.6	444.0 ± 100.9	80.3 ± 15.8	87.1 ± 13.2
Incongruent	504.5 ± 151.1	476.7 ± 114.9	62.7 ± 23.4	77.5 ± 16.5
Exercise – Posttest				
Congruent	479.2 ± 164.4	455.5 ± 113.3	78.8 ± 18.7	88.7 ± 14.6
Incongruent	500.8 ± 144.9	485.4 ± 122.0	61.8 ± 21.8	80.3 ± 16.3

Appendix Q: Figures for Results Section

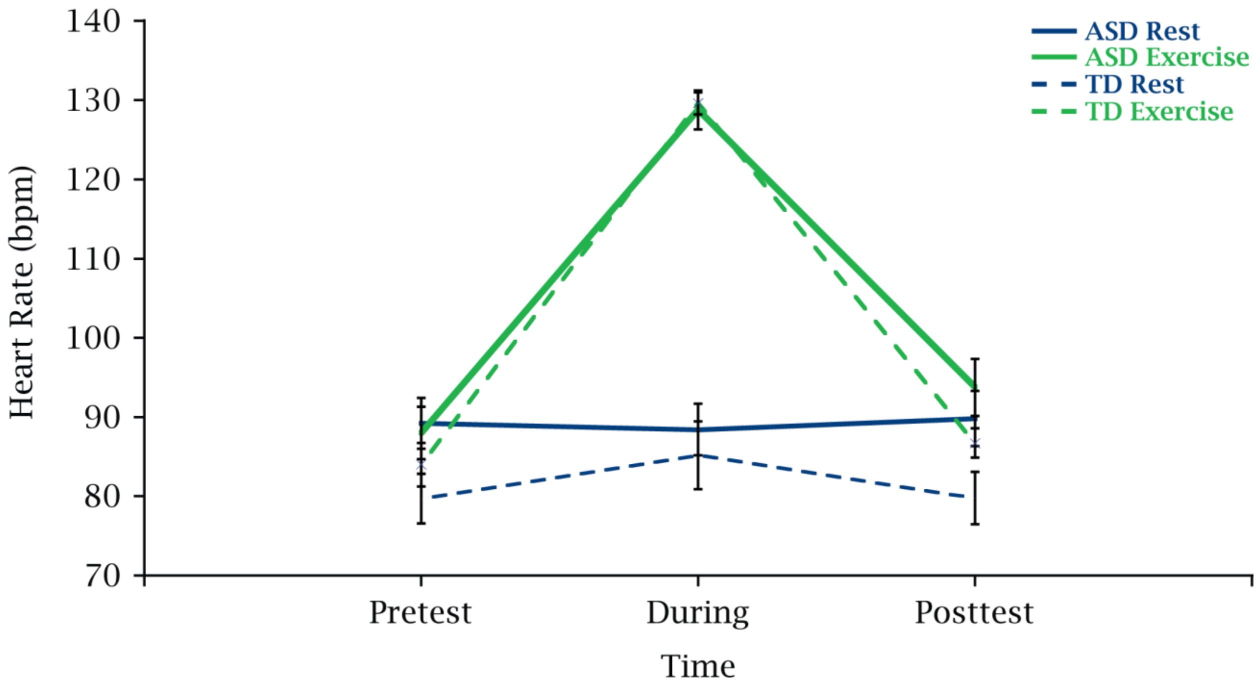


Figure 6.13. Mean HR (± SE) for each group across experimental condition.

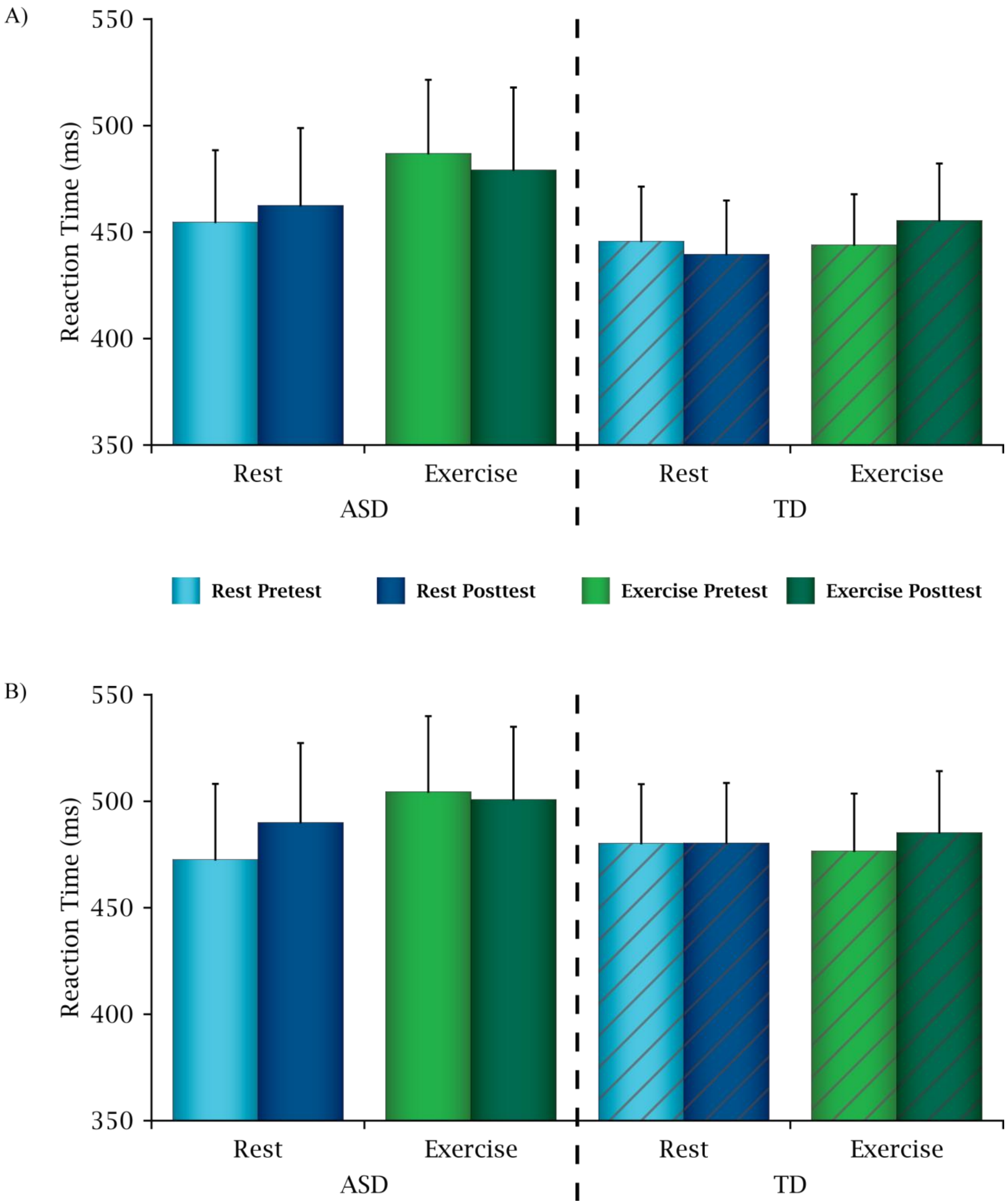


Figure 6.14. Mean (± SE) RT latency for (A) congruent and (B) incongruent trials for each condition by group.

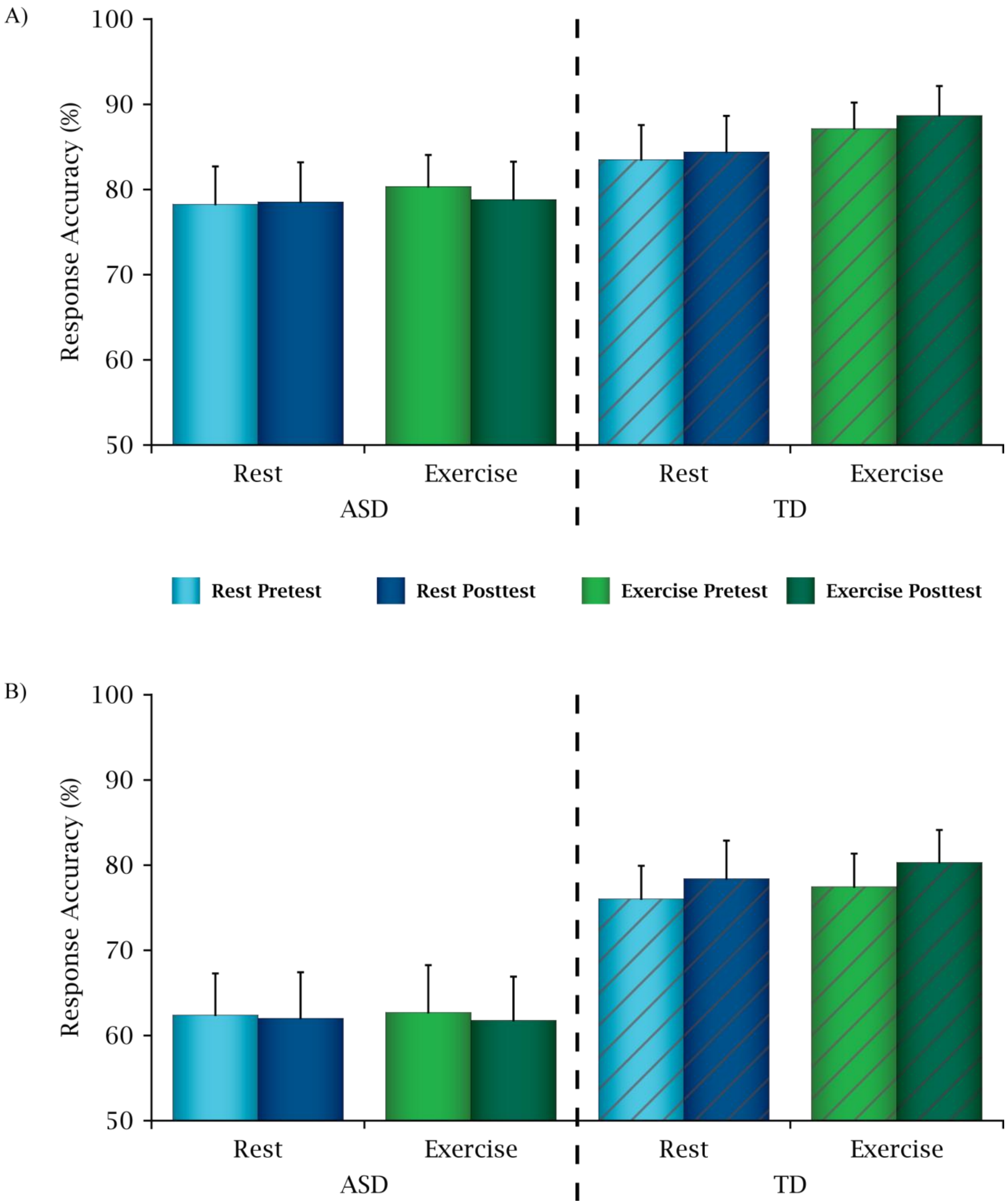


Figure 6.15. Mean (± SE) response accuracy for (A) congruent and (B) incongruent trials for each condition by group.

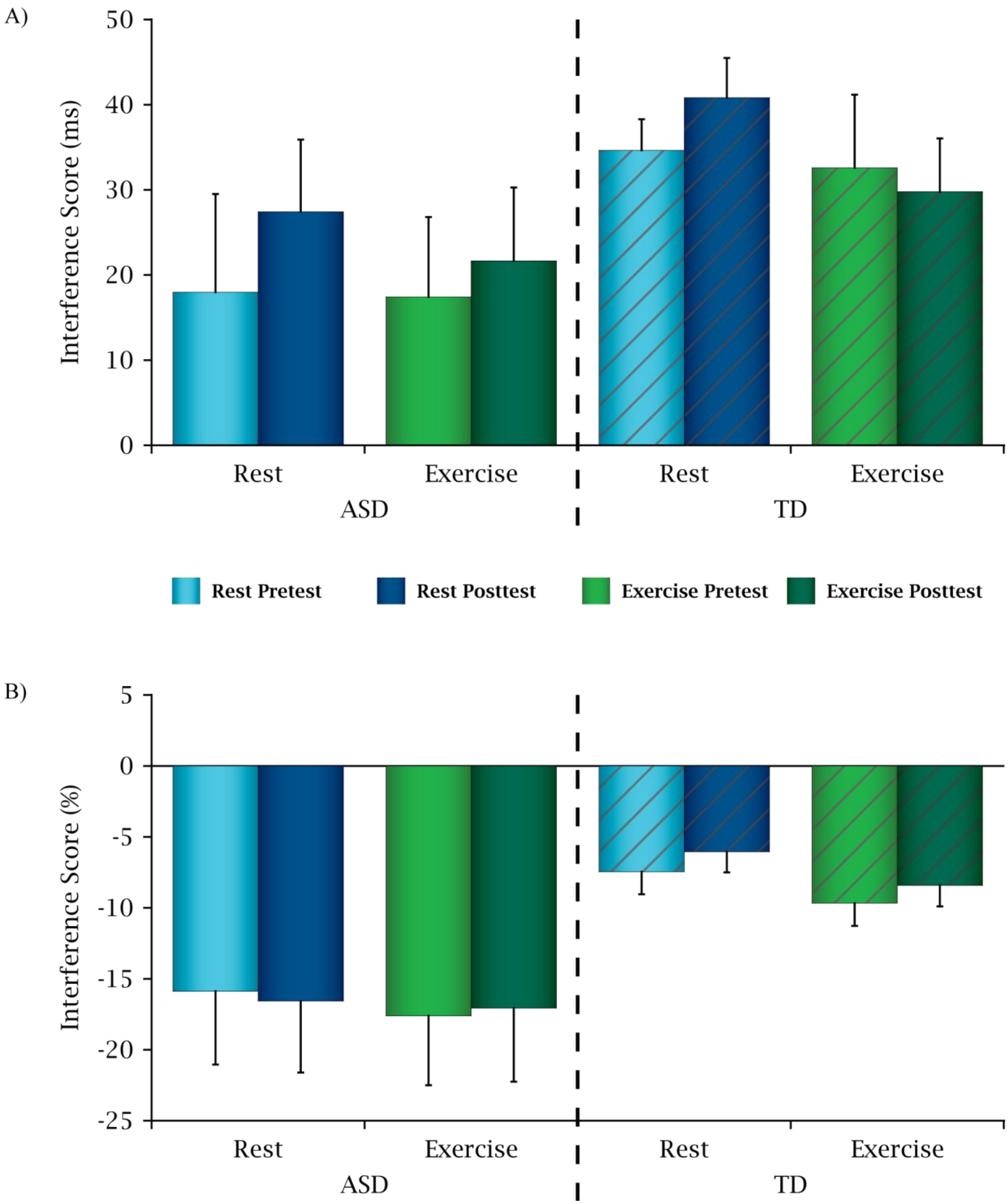


Figure 6.16. Mean (± SE) interference score for (A) reaction time latency and (B) response accuracy for each condition by group.

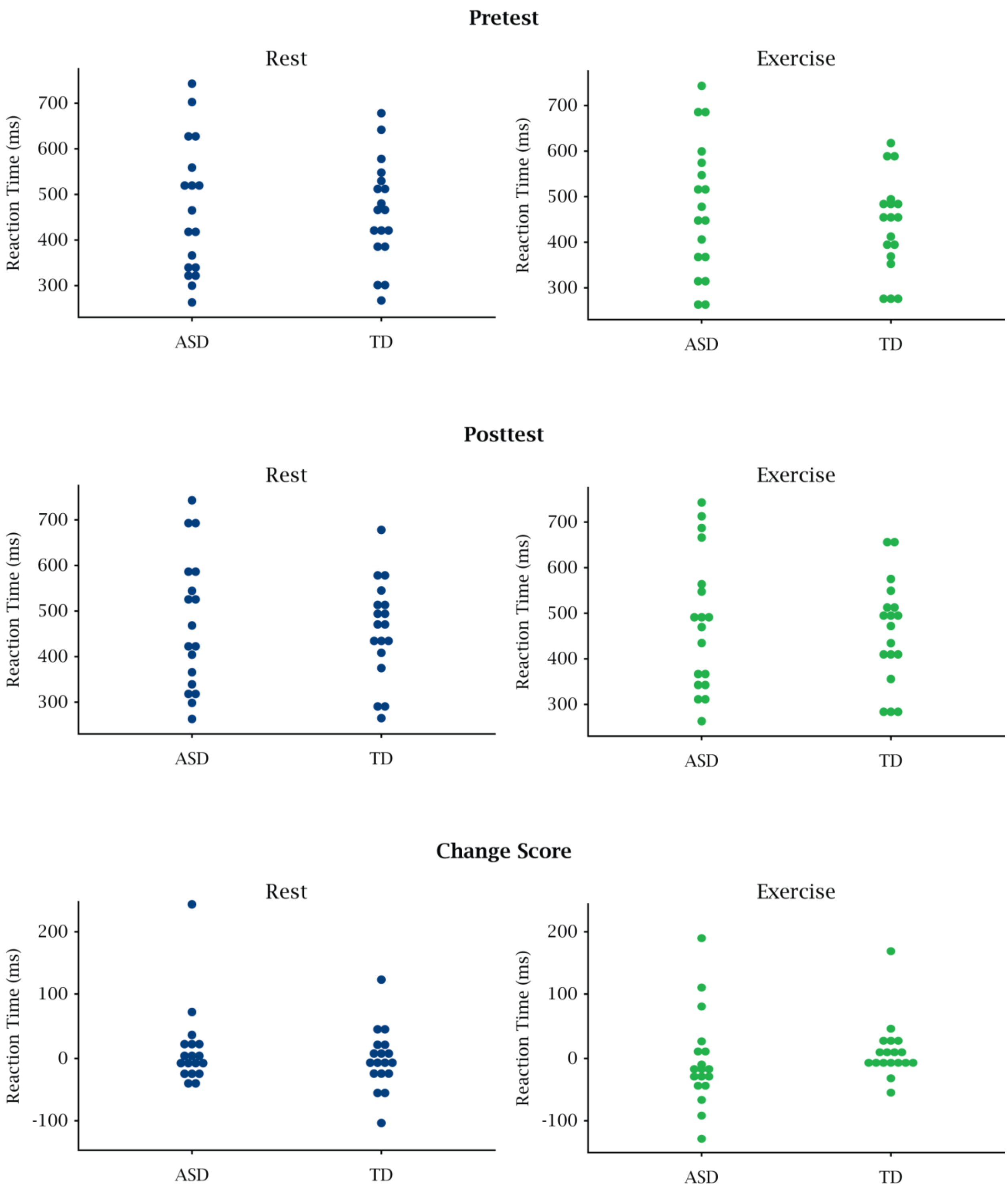


Figure 6.17. Dot plots for reaction time latency at pretest, posttest, and change score for each condition by group.

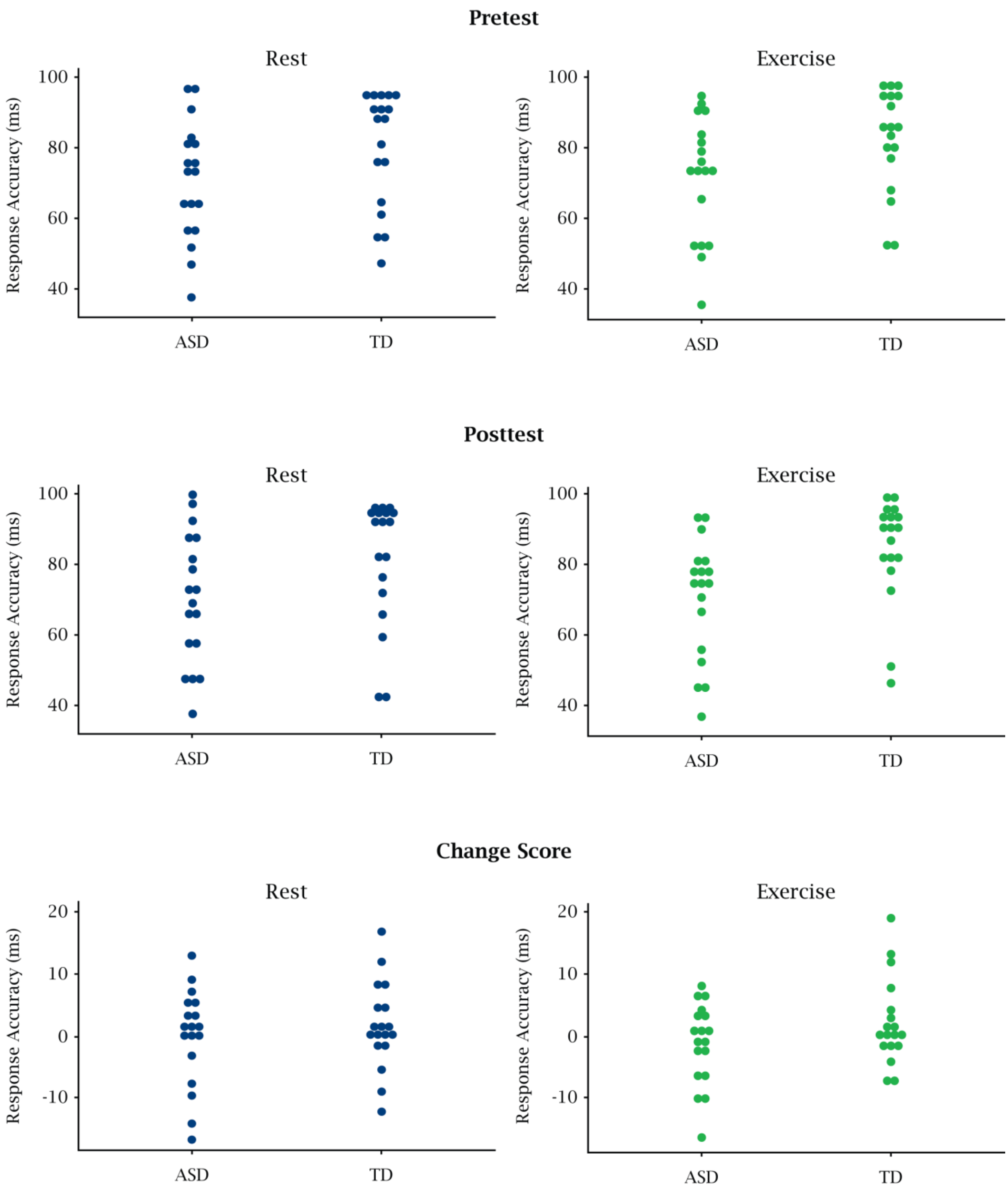


Figure 6.18. Dot plots for response accuracy at pretest, posttest, and change score for each condition by group.

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