Interactive Physical and Cognitive Exercise System (iPACES™): The Neuropsychological Effects for Youth on the Autism Spectrum

By

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ABSTRACT

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Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects 1 in 68 children in the United States (Center for Disease Control, 2016). The disorder is characterized by deficits in social interaction, verbal communication, restricted interests, and repetitive behaviors (DSM-V, 2013). While the apparent cause of ASD is biological, the diagnosis remains based on social deficits (Hapé & Frith, 1996). Exercise has been found to improve executive function for children with an Autism Spectrum Disorder, but motivation is an issue and exergames hold promise. This pilot study evaluated an interactive Physical and Cognitive Exercise System (iPACES™), wherein children pedal and steer along a virtual bike path to score points. Sixteen children participated in a single bout. Paper and pencil assessments of executive function (Trails, Stroop, Digit Span) were used for first participants (n=5), then the assessments (Trails, Stroop, Flanker) were digitized for the rest of the sample (n=11). Four were ASD, and seven were typically developing (TD; mean age = 13.07 ± 3.57). Paired t-tests revealed significant improvement for the entire cohort (n=5) on Stroop C paper assessments (p=.03). Repeated ANOVAs revealed significant improvement on Flanker (p=.047) and Trails (p=.015) ratio scores for the TD group, but not the ASD group. Further research is warranted, given the demonstrated feasibility of iPACES™; a larger sample may clarify the possibly differential effect of exergaming for ASD versus TD, which may be due to varying levels of physical exertion during the neuroexergame.

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INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder that affects 1 in 68 children in the United States (Center for Disease Control [CDC], 2016). The disorder is characterized by deficits in social interaction, verbal communication, restricted interests, and repetitive behaviors (American Psychiatric Association, 2013) and while the apparent cause of ASD is biological, the diagnosis remains based on social deficits (Hapé, 1996). The variety of treatments for individuals on the spectrum ranges from Applied Behavioral Analysis (ABA) and Cognitive Behavioral Therapy (CBT) to pharmacological agents that aim to reduce aggressive behaviors. While the goal of these is a positive one, pharmacological agents have not proven to be very effective and side effects can be quite severe (Lemmon et al., 2011). Although intense and time consuming, ABA and CBT have proven effective in the reduction of restrictive and repetitive behaviors (Kasari & Lawton, 2010). Additionally, growing research suggests that exercise interventions may also positively impact executive dysfunctions, which are characteristic of Autism Spectrum Disorder.

Many biologists and medical specialists have sought to find the underlying biological cause of autism spectrum with hopes of developing a pharmacological cure or discover preventative measures. Through the surplus of research studies countless biological differences have been discovered between typically developing and autism spectrum individuals. Observations have discovered brain and brain structure sizes differing between typically developing and autism spectrum brains (Baron-Cohen, 2004). Particularly, a lower number of Purkinje cells has been noted in the cerebral cortex of autism spectrum brains, consequently resulting in the overexcitement of the cortex and thalamus (Baron-Cohen, 2004). After MRI studies were run Baron-Cohen found that generally the cerebellum, brainstem and corpus callosum were found to be smaller in ASD individuals than typically developing (TD) individuals (Baron-Cohen, 2004). In addition, compared to TD individuals, those on the autism spectrum were more sensitive to the same set of stimuli (Baron-Cohen, 2004). These findings were further investigated in 2007 when Garber investigated ASD abnormalities at the synaptic level. Abnormal neurexin-1 and shank-3 gene abnormalities were discovered, which have the capacity to influence neuronal sensitivity, since Neurexins are found on the pre-synaptic neuron and bind to Neuroligins on the post-synaptic neuron to form the synapse (Garber, 2007). These mutations are believed to be responsible for an imbalance in excitatory and inhibitory signals, which translates into learning and memory deficits and thus language and social impairments as well (Garber, 2007).

Building on the hypothesis of excitatory and inhibitory signal imbalances, Gogolla et al. (2009) genetically altered mice populations to reflect characteristics of autism spectrum disorder to compare the connections in each hemisphere of the brain. In this comparison, they found that there was a different number of parvalbumin cells (PV-cells) in each hemisphere (Gogolla et al., 2009). PV-cells are responsible for inhibitory signals in the cerebral cortex, thus this imbalance of PV-cells in each hemisphere could be a factor in impacting neural plasticity (Gogolla et al., 2009). In continuation of this research, Bolkan and Gordon (2016) manipulated multiple mice colonies' PTCHD1 protein, which resulted in behavioral abnormalities similar to those seen in individuals on the autism spectrum. The PTCHD1 protein is highly expressed in the thalamic reticular nucleus (TRN) in the thalamus during early development (Bolkan & Gordon, 2016). The main function of the TRN is to send inhibitory signals to control various processes most closely associated with movement, vision, and cognition (Bolkan & Gordon, 2016). The manipulated mice colonies had reduced activity within the TRN region, which Bolkan and Gordon attributed to a diminished small potassium (Sk) channel activity (2016). This reduction in SK channel activity inhibits the TRN neurons from effectively inhibiting cell activity, resulting in abnormalities in movement, cognition, and vision (Bolkan & Gordon, 2016). *Wells et al.* restored SK channel activity using pharmacological agents, effectively reversing the apparent dysfunctions that resulted from the mutant PTCHD1 protein (Wells et al., 2016). The executive dysfunctions and behavioral abnormalities of autism spectrum disorder are attributed to these inhibitory signal imbalances in the autism spectrum brain.

Physiological side effects of Autism Spectrum Disorder:

While ASD is characterized and diagnosed mainly by social interaction and verbal communication, physical side effects are also often associated with the developmental disorder. Central nervous system abnormalities cause muscle dystonia, abnormalities in muscle tone, and other motor dysfunctions in the ASD population (Vernazza-Martin et al., 2005). These physiological issues can make it hard for individuals on the autism spectrum to find enjoyable activities involving mobility, such as sports. Social deficits related to ASD also creates trouble for individuals on the spectrum to participate in organized athletics. In 2012, Potvin et al. determined the recreational levels of high-functioning children on the autism spectrum. Various surveys were administered to n=30 children on the spectrum and to n=31 of their TD peers, including the *Children's Assessment of Participation and Enjoyment/Preference for Activities of Children* (CAPE/PAC; Potvin et al., 2012). The CAPE/PAC primarily asks questions regarding recreational activities, such as types of activities, frequency of engagement in each activity, where and with whom the activities take place. It was found that high functioning ASD children participated in up to 20% fewer physical activities than their peers (Potvin et al., 2012). Moreover, children on the autism spectrum lacked participation in team sports and preferred to engage in individual physical activities, such as swimming, and/or biking (Potvin et al., 2012). This leads clinicians to favor programs that result in mental and physical stimulation in areas that appeal to individuals on the autism spectrum. The best chance of success in engaging children on the spectrum in exercise tasks maybe through focusing on the physical activities that they often tend to prefer/enjoy, specifically biking and aquatics.

With so many physical comorbidities accompanying ASD, it is no wonder that children with an ASD diagnosis are not motivated to engage in physically strenuous activities. TD children, on the other hand, are often placed in organized sports at a young age. A meta-analysis conducted by Verburgh et al. (2016) revealed that acute exercise enhances executive functioning in TD individuals between the ages of 6-35 years. This uncovers the question of whether children on the spectrum can gain the same physiological benefits from exercise as TD children. In 2011, Pan addressed this question in his 32-week aquatic physical fitness intervention experiment. A group of seven individuals on the autism spectrum along with their TD siblings participated in the exercise intervention (Pan, 2011). Each participant completed 14 weeks of the aquatic exercise, 14 weeks of control sessions, and four weeks for assessment and transition (Pan, 2011). The exercise sessions were conducted twice a week for 60 minutes each and aquatic fitness was determined by using the Humphries' Assessment of Aquatic Readiness (HAAR) checklist, which is safe for people of all ages with varying skill levels and disabilities (Pan, 2011). As a control, individuals participated in dry-land exercises and Pan tested their fitness by using the Progressive Aerobic Cardiovascular Endurance Run (PACER) multi-stage shuttle run as well as curl-up assessments and sit-and-reach assessments (2011). The progress of each participant was tracked and a significant Cohen's *d* for the respective groups, indicating a significant increase in muscular strength/endurance, and aquatic skills (Pan, 2011). These findings correlated with studies of similar nature and indicated that aquatic interventions, in particular, can establish motor and behavioral skill improvement; however, these improvements were thought to be due in part by the individual and goal-oriented training sessions curriculum of the study (Pan, 2011).

Vernazza-Martin et al. (2005) conducted a study to examine the differences in body movements between children on the autism spectrum and TD children. While wearing a movement tracking suit, the participants were asked to walk towards a playhouse to meet a research assistant in the house holding a toy (Vernazza-Martin, 2005). Due to the ASD population struggling with verbal directions, the research team adjusted their directions for the ASD group. After analyzing the differences in body movements between the ASD and TD groups, it was found that children on the spectrum have more oscillations in their upper bodies, specifically in their head and torso, but use the same stabilizing mechanisms as TD individuals (Vernazza-Martin, 2005). Further inspection revealed that individuals on the autism spectrum struggled with certain movements due to their lack of motivation and inability to plan their movements, mainly caused by an absence of futuristic planning (Vernazza-Martin, 2005). This deficiency often creates a challenge to recognize a goal and direct oneself towards that goal, which is why activities that explicitly create targets are often favored by individuals on the spectrum. Considering this, simple activities such as television and computer games are preferred by children on the spectrum, also possibly in part due to the intense reinforcement they provide.

Exercise as a treatment of Autism Spectrum Disorder:

Exercise is known to be beneficial for the human body, not just in respect to physique and cardiovascular health, but also regarding increased cognitive function in adults and delaying the onset of neurodegenerative disorders (Anderson-Hanley et al., 2016; Colcombe et al., 2006). There have been many studies examining the benefits of exercise on cognition in children. Singh et al. (2012) conducted a systematic review of 12 papers that analyzed the effects of activity level on children's' academic performances. The level of activity across the literature was self-reported by students, reported by parents, teachers, or academic administrators (Singh et al., 2012). Across all 12 papers reviewed there was a positive correlation between activity level and performance in school, suggesting that exercise improves cognition or at least cognitive performance. There is support from other studies that these results may be due to various biological factors. Physical exercise has been proven to increase concentrations of Brain-Derived Neurotrophic Factor (BDNF; Anderson-Hanley et al., 2012; Leckie et al., 2014) as well as increase profusion in the brain (Delp et al., 2001). It has also been proven to increase brain volume in the prefrontal cortex (Colcombe et al., 2006) and reduce biological waste. These changes have been seen after a single bout of exercise (O'Leary et al., 2011) and have also been linked to neuroplasticity, which may prove promising in the treatment of Autism Spectrum Disorders.

One of the most renowned theories that explains the repetitive behaviors associated with ASD is the executive functioning hypothesis, which suggests that there is a malfunction in executive functioning that results in the individual's inability to control his behavior normally (Turner, 1999). Considering this, an increase in executive functioning should correspondingly result in a decrease in repetitive behaviors. Bahrami et al. conducted a study to examine this theory by looking at the behavioral benefits of Kata techniques, an anaerobic karate practice, on stereotyped behaviors associated with autism (2012). The individuals were chosen at random to either participate in the experimental condition (Kata intervention) or the control condition (no exercise) for 14 weeks (Bahrami et al., 2012). The sample size for each condition was n=15 (Bahrami et al., 2012). There were 15 trained Kata instructors, so that each child could receive an individual trainer. The duration of training was increased from 30 minutes at the start of the study to roughly 90 minutes by week 8 and for the remainder of the study (Bahrami et al., 2012). With the 1:1 instructor to participant ratio, instructors could give an informative and motivational environment for each exercise session. As a baseline measure, the Gilliam Autism Rating Scale 2 (GARS-2) was administered to survey the stereotyped behaviors pre- and post-intervention (Bahrami et al., 2012). A two-way mixed ANOVA was performed and a significant group versus time interaction was found (Bahrami et al., 2012). Subsequently, Bahrami et al. used post hoc testing and determined the stereotypical behaviors associated with autism spectrum disorder decreased over time in the experimental group (Bahrami et al., 2012). Upon examination of the control group there was no significant decrease in stereotyped behaviors between pre- and post-intervention (Bahrami et al., 2012). In conclusion, a 14-week intervention of karate techniques can help improve repetitive characteristic behaviors in children on the autism spectrum, henceforth providing an alternative treatment method through the execution of alternative exercise techniques.

Expanding upon this idea, individuals have developed more accessible exercise packages where participants engage in physical activity while playing a game. This idea is referred to as exergaming (also called active gaming), defined as "technology-driven physical activities" (http://www.acsm.org/docs/brochures/exergaming.pdf). This could be in the form of requiring an individual to use their body to physically control a character in a video game, such as Dance Dance Revolution. These exergames were developed to motivate individuals who lacked a drive to exercise. Anderson-Hanley et al. (2011) explored the executive function hypothesis in conjunction with exergaming by conducting a within-subjects design study comparing the benefits of exergaming via DanceDance Revolution (a videogame with a sensor mat that controlled the characters in the game) and via cybercycling (CBC; a stationary bike that controlled a videogame). Digit Span, the Stroop task, and Color Trails were administered pre-exercise condition, then a 20-minute exercise period (playing DDR or CBC) was executed, and alternate forms of the tests were given afterwards (Anderson-Hanley et al., 2011). In the cybercycle group, participants were administered the Digit Span as well as the Stroop task, then were asked to partake in a 20-minute cybercycle bout before alternate forms of the tests were administered (Anderson-Hanley et al., 2011). After running statistical analyses on the data obtained there was found to be a statistically significant reduction of repetitive behaviors after both conditions of exergaming (DDR and cybercycling), which was also correlated with an increase in cognitive benefits post-exergame (Anderson-Hanley et al., 2011). Thus, the fruitful results from already established exergames guides the current study in a promising direction to replicate and extend these results with other exergaming set-ups, particularly a neuroexergaming set-up that combines physical and mental exercise (Anderson-Hanley et al., 2016).

Need for future research:

As technology advances, there is a greater emphasis on the need to motivate children (TD and ASD) to exercise. With this comes a surplus of emerging exergame systems, including Wii Fit, DanceDance Revolution, and the Fisher Price Game Bike. With this pilot study we aim to replicate and extend prior research involving the ASD population and, moreover, to evaluate the efficacy of the Interactive Physical and Cognitive Exercise System (iPACES™) game, Memory Lane™, in the ASD population and in hopes that the combination of physical and mental exercise is thought to benefit the brain more than simply engaging in regular exercise.

Hypothesis:

- It is expected that the ASD and TD populations will increase in executive functioning after a 20-minute exercise bout, as shown in executive functioning tasks.

- It is also expected that the ASD population will have more "room to grow" between pre- and post exergame system bouts than the TD population, due to the executive dysfunction characteristic of ASD.

METHODS

Participants

Overall, six ASD and ten TD youth participated. Participants were characterized as autism spectrum or typically developing based on a prior diagnosis by a clinician. Due to improvements and availability of new methodologies in the lab over the course of this study, initial paper and pencil measurement was changed to electronic assessments about half-way through the data collection.

Electronic Assessments

The sample that participated in digital assessments (n=11) consisted of children between the ages of 10 and 21 years (mean = 13.07 ± 3.57) with a mean education level of 8.36 years. The participant pool consisted of two TD males, five TD females, two males on the autism spectrum and two females on the autism spectrum. The demographics of the sample are reported in Table 1.

Paper and Pencil Assessments

The sample that participated in pencil and paper assessments (n=5) were between the ages of 10 and 21 years (mean =10.6±SD). The participants consisted of three TD males, and two males on the autism spectrum. The demographics of the sample are reported in Table 1.

All participants volunteered to participate and were recruited via fliers presented around Union College, distributed at the 2016 Autism Exposition and Art Exhibit in Saratoga Springs, New York or were solicited through the database of volunteers who had participated in previous studies carried out by other members in the Healthy Aging & Neuropsychology (HAN) Research Lab at Union College. These participants had given consent to be contacted for future studies. Children with a diagnosis of autism spectrum disorder were recruited along with TD children in the same age range, often TD siblings of the ASD volunteers. Study risks and benefits were reviewed and all parents/guardians of participants signed an informed consent document and participants signed informed assent documents, all which were approved by the Institutional Review Board at Union College.

Procedures

A pre- to post- test quasi-experimental design was used in which the intervention consisted of a pre-exergame executive function evaluation, followed by a 20-minute neuroexergame bout using the Interactive Physical and Cognitive Exercise System (iPACES™) Memory Lane™ game (see Figures 1 and 2), and a post-exergame executive function assessment. Based on participant request, the experiment was conducted in either the HAN Lab at Union College, in the participants' homes (with a pair of trained Research Assistants conducting the procedure), or in an empty multi-purpose room at the local ASD support group location. All except one participant reported themselves as Caucasian (see Table 1 for complete demographics). The neuroexergame that was utilized was the Interactive Physical and Cognitive Exercise System (iPACES™), where participants used an under-the-table elliptical and joystick to control a character in the Memory Lane™ videogame. The videogame simulated the character biking along a path and presented a list of neighborhood errand locations (such as dentist, a friend's house, videogame store, etc.) and required the player to recall the order of the locations visited in forwards and then as returning home (reverse order; see Figure 1). This type of physical exercise was prospectively designed to improve cognition, in this case executive function, by encouraging mental and physical stimulation simultaneously. Prior to the exercise bout, each participant's target heart rate was calculated based on age. Each participant wore a heart rate monitor for the duration of the exergame, and it was monitored to ensure that target heart rate was being reached. Part way into the study, the lab obtained additional grant-funding and improved resources became available including an improved version of the iPACES as well as more refined measurement tools. The neuropsychological assessments were thus converted to e-assessments and digitized using the BrainBaseline application on Apple iPads. The same neuropsychological tests were used with the addition of the Flanker Task (Digital Artifacts, LLC, 2016; see Appendix C for full revised protocol).

Measures

The participants were asked to evaluate their exercise history using the Exercise History Questionnaire (Appendix D) developed in the HAN Lab. See Table 1 for the results. They were also given a Demographics Questionnaire (Appendix E), which also evaluated each participant's education level and confirmed or refuted an Autism Spectrum Diagnosis by a clinician. See Table 1 for complete recount of the population demographics.

Both Color Trails (D'Elia et al., 1996) and Trails Making (Digital Artifacts, LLC, 2016) tasks were used. Color Trails is an executive function measure requiring the participant to utilize task-switching skills. Version 1 requires a trail to be made by connecting the numbers in consecutive order, while version 2 initiates task-switching by requiring participants to create a trail through numbers consecutively while alternating between pink and yellow colored numbers. For example, the individual would connect a yellow one to a pink two to a yellow three and so on. The Trails Making task is the e-assessment of the Color Trails task, but is in black and white. Version 1 requires the participant to connect the dots in consecutive order starting with one and continuing until all the dots have been drawn through. Version 2 also initiates task-switching skills by requiring participants to connect numbers and letters alternating between numerical and alphabetical order. For example, the individual connects the number one to the letter A to the number two to the letter B and so on. For both electronic and paper assessments, the task performance is measured by the time to completion of the trail. A shorter time indicates a better performance.

Stroop task (van der Elst et al., 2006) was administered in a brief 40-item form in a traditional fashion with Stroop A administered, then B followed by C. The executive function task is Stroop C (the interference trial). Stroop A requires the participant to verbally identify the colors of a series of colored blocks (either blue, green, red or yellow). Stroop B requires the participant to verbally read colors written in black ink, and Stroop C requires the participant to ignore the typed word and identify the color of the ink. For the e-assessment (Digital Artifacts, LLC, 2016), each word is presented to the individual in colored ink. There are incongruent trials, where the color of the ink is contrasting the word typed, congruent trials, where the color of the ink and the word typed match, and neutral trials, where the word typed in colored ink is not a color. An example of a neutral trial would be "locker" written in blue ink. The task performance is measured by the time to completion of the trail. A shorter time indicates a better performance.

The Flanker (Digital Artifacts, LLC, 2016) task is only compatible with e-assessments. Five arrows were displayed on the screen with their heads pointing either to the right or left. Trials were categorized as congruent when all the arrows were facing in a single direction (either left or right), and categorized as incongruent when some arrows were facing in one direction and the remainder were facing in the other. The task for the participant was to identify the direction that the middle arrow was facing. In order to record their score, they click either a button on the left or right side of the screen, corresponding to the center arrow's direction. The task performance is measured in two ways: (1) subtracting the congruent trials from the incongruent trials, a large negative value indicates a better performance; (2) creating a ratio of congruent task performance time over incongruent task performance time, a larger number indicates better performance.

Statistical Analysis

Data collected was cleaned using Microsoft Excel and analyzed using the most recent version of the Statistical Package for the Social Sciences (SPSS). There was an attempt to reconcile the differences between paper assessments and e-assessments, but it was unsuccessful due to difficulties converting to a common metric without standardization samples scores within tests. Due to the small sample size and a lack of normative data, analyses were limited to t-tests, and small power ANOVA with age as a covariant to analyze improvements in executive function after the neuroexergame bout. The scores of each participant's correctly answered congruent and incongruent scores were independently averaged in order to isolate the executive function effect of each participant. Ratio ($\frac{congruent}{incongruent}$) scores were calculated to normalize digital scores and allow for an easier interpretation across measures. Two outliers (one ASD one TD) were removed from the Flanker task analyses as they do not accurately represent the population data points (see Figures 7 and 8).

RESULTS

Data from preliminary tests was analyzed from five participants who were assessed using the paper and pencil assessments. Three were TD and two were ASD (mean age = 10.6 years; standard deviation [SD] = 2.93; all were male; see Table 1 for complete demographics). Repeated tests were run to compare the changes in executive function before and after the exercise. A statistically significant condition x time interaction was found for Stroop C task ($n=5$; $p<.05$; see Figures 3-5). Data were analyzed from eleven additional participants using the electronic assessments (mean age = 13.0 years; SD = 3.57), seven TD and four ASD (See Table 1 for complete demographics). Statistically significant condition x time interactions were found for the TD cohort for Flanker ($n=7$; $p<.05$; see Figure 7) and Trails Making ($n=7$; $p<.05$; see Figure 6) ratio scores. Digital assessments did not yield statistically significant results for the ASD cohort, but there is an apparent positive trend ($p=.08$) for the ASD population that parallels the TD group (see Figure 6). Further exploratory results and alternative analyses were also conducted (see Figures 9-10 and Table 2).

DISCUSSION

After a 20-minute exercise bout using the Interactive Physical and Cognitive Exercise System the preliminary paper and pencil Stroop C assessment utilized showed significant improvement ($p < .05$) of executive function for the entire tested population (n=5; two ASD). In subsequent data collection utilizing electronic assessments, a differential effect of exergaming was found on executive function for children on the spectrum and an unexpected greater impact on executive function in typically developing children was found. The significant increase in executive functioning for typically developing individuals as shown by the Trail Making and Flanker tasks ($p < .05$) was unexpected, especially since it was not accompanied by an improvement in the ASD cohort. These findings did not support the hypothesis that both TD and ASD individuals would gain an increase in executive functioning post-exercise, and further, that children on the spectrum would have more room to grow; instead it appeared that in this sample of ASD there was already strong executive function and thus there was a "ceiling" effect wherein there was not much room for improvement.

The unexpected finding of greater benefit for TD versus ASD participants was consistent with findings associated with a quantitative review composed by Leung and Zakzanis (2014). Across a plethora of studies examined there was a difference in the performance of the participants based on the presentation of the tasks (paper and pencil versus electronic). The same individual's score varied across the different mediums used to assess the individual, which helps identify the differences in results across digital and paper and pencil assessments in this pilot study (Leung & Zakzanis, 2014). The findings also indicated that the measures of cognitive flexibility (a sub-category of executive functioning) may not be sensitive enough to discriminate the changes exemplified in the autism spectrum population (Leung & Zakzanis, 2014). This distinction is shown in the fact that there is no difference in cognitive flexibility, as measured by Children's Color Trails, between TD children and those on the autism spectrum (Leung & Zakzanis, 2014). The trends seen regarding individual improvements for participants on the autism spectrum suggest that a larger sample size may show a significant improvement in executive functioning after a single exergame bout.

Furthermore, the significant improvement in executive functioning seen in typically developing participants supports the initial hypothesis that TD participants would gain a significant improvement in executive functioning after the acute exergame bout. This gives promising indications for future studies in this realm, particularly involving the iPACES™ neuroexergame set-up.

Strengths

The sample was composed of individuals on the spectrum with their typically developing siblings, which controlled for confounding variables such as home environment and upbringing. Additionally, there is an advantage of using the digital tasks in that there is no room for human error in recording time, presenting the tasks, or interpreting answers.

Since knowing how to bike is almost universal, the fact that the iPACES™ game utilizes an under-the-table elliptical makes it an easy game to play. Unlike other exergames where new exercise modes are used, such as DanceDance Revolution and Wii Fit, the iPACES™ set-up has a familiar means of exercise and thus can be easily grasped. Additionally, this neuroexergame appears to motivate both ASD and TD populations in such a way that the system could potentially replace exercise, especially for those individuals who are deterred by organized sports.

Limitations

The small sample size of this study really limited the effects that we could find. Having only seven typically developing children and four children on the autism spectrum posed an issue for the digital assessment analysis, especially when considering the comparison across TD and ASD individuals. Despite this, we do see significant effects for the typically developing population and positive trends for the autism spectrum population, suggestive of significant results in the future with a larger sample.

Additionally, recruiting participants was a limitation to this study as well. While we successfully recruited most of our participant pool by attending Spectrum Life Strategies' group therapy sessions in the Capital Region, we were not successful in enrolling the majority of the group. Despite the extensive availability and flexibility that our research assistants had for scheduling, many children on the spectrum and families with spectrum children are unable to factor in 45-60 minutes of time to participate. This is often due to their rigidly structured schedules and need to adhere to such schedules.

As a result of using digitized assessments, it was challenging to ensure that all participants were reading the instructions thoughtfully and thoroughly prior to beginning each assessment. Moreover, exposure effects are present since the research design is a pretest to posttest design. That is, although alternative forms of the assessments were presented, each participant could obtain understanding of the game during the pretest, and then already know how to properly go through the assessment for the posttest. Thus, practice effects were present and may have affected the validity of the pre- to post tests.

The challenge and involvement level of the iPACES™ game varied based on the level of cognitive functioning and age of each participant. That is, older children and those with higher levels of cognition found the game to be easier than those who were younger and/or had lower levels of cognitive functioning. This might have influenced the intensity of mental exercise that the game aimed to induce in each participant. If the game could be altered to accommodate level of difficulty based on age, then it may compensate for such discrepancies.

Future Research

Executive dysfunction is characteristic of children on the autism spectrum, and there is a surplus of support for the benefits of exercise on executive function (Anderson-Hanley et al., 2011). These findings from this pilot study support prior findings regarding improvements in executive functioning for typically developing children, but does not conclusively yield results for benefits of executive functioning for children on the autism spectrum. As technology advances, there is a greater emphasis on the need to motivate children (TD and ASD) to exercise. The cognitive improvements associated with exergaming needs to be further examined to determine if there is truly an executive function benefit for children on the spectrum. Future directions for these studies would include the Reverse Digit Span Recall assessment, due to the promising results from the exergaming study done by Anderson-Hanley et al. (2011). Additionally, Leung and Zakzanis (2014) mention that reverse rehearsal tasks might engage a more cognitively advanced process, which could lead to identifying a link between behavioral abnormalities and their underlying neurobiological causes. Furthermore, including a non-exercise control group such as children playing with LEGOs® would allow for the comparison between exercise and non-exercise conditions to more accurately identify any cognitive improvements after exercise.

The executive function benefits seen in the TD cohort along with the trends seen in the ASD cohort may be due to an increase in peripheral BDNF levels resulting from exercise (Anderson-Hanley et al., 2012; Leckie et al., 2014) in combination with the mental benefits resulting from the dual-task. Basak et al. (2008) investigated the impact of dual-tasks on executive function in older adults. It was found that, compared to the control, individuals who were trained to play a "real-time strategy video game" (like a neuroexergame) had a significant increase in executive function after playing the game (Basak et al., 2008). Additionally, Anderson-Hanley et al. (2012) found a significant increase in levels of BDNF in saliva post-cybercycle bout, which suggests promising results for the iPACES™ set-up. Future studies should combine the dual-task executive function analysis with an analysis of BDNF levels after the bout.

Other future studies should also consider the possibility of a longer intervention, such that each participant participates in two to three 20-minute exercise bouts per week. Thus, the progression of executive function improvements could be examined over time and the impact of extensive exercise could be investigated as well. Following a similar intervention set-up as Anderson-Hanley et al. (2016) where the iPACES™ set-up is lent to each participant for the duration of the study and incremental follow-up visits are conducted where executive function assessments are administered to track progress.

Additionally, future studies should implement the Exercise Induced Feeling Inventory (EIFI) after the exercise bout to properly assess the level of exercise reached for each individual participant. Each participants' heartrate was monitored periodically throughout the bout, but may not have remained within the target heartrate for the entire bout. Implementing the EIFI would give self-reported measures on the level of fatigue and effort exerted in the bout, which would then allow the exclusion of participants who did not get adequate exercise from the analysis. As seen in Figure 9, half of the participants are improving while the remainder have no improvement. This may be due to an individual's inability to reaching a target heartrate while others reached a significant level of exercise, possibly overexerting themselves and putting themselves at a disadvantage for the post-exercise assessments. Conversely, some individuals may have overexerted themselves while the others did not, and therefore gained the greatest benefit from the neuroexergame bout. If the EIFI had been administered it could be determined which speculation is more accurate.

These executive function improvements may be attributed to the known benefits of exercise. As stated before, the thalamic deficits in the TRN causes fewer inhibitory signals to be sent. Holschneider et al. (2007) examined the cranial differences between exercised and non-exercised rats. The exercised rats had a greater activation in their cerebellar-thalamic-cortical circuits (Holschneider et al., 2007). The executive function proliferation seen post-exercise may be attributed to the increase in this pathway, specifically with the increase in thalamic activity. Moreover, van Praag et al. (2005) investigated how exercise influenced neurogenesis in the hippocampus in mice and found a significant increase in the number of new neurons after one month of exercise. These findings show promise for children with and without cognitive deficits since more exercise will cause an increase in neurogenesis and thus, as seen in this study, cognition.

Conclusions

This pilot study examined the impact of a single 20-minute bout of exergaming with the Interactive Physical and Cognitive Exercise System (iPACES™) on typically developing youth and those on the autism spectrum. The findings suggest a positive impact on executive functioning, particularly on typically developing children when utilizing both paper/pencil (n=3) and digital (n=7) cognitive assessments. Executive function improvements for the TD individuals were shown through improvements in Erikson's Flanker digital assessment ($p<.05$), paper and pencil Stroop C Task ($p<.05$), and a digital Trails Making Task ($p<.05$). Although not significant, there was a visible trend in the post-exergame effects in executive functioning for participants on the autism spectrum ($p=.08$). These trends are suggestive of significant effects in the future with a larger sample size. In conclusion, the Interactive Physical and Cognitive Exercise System proves positively impactful on executive functioning, even after a short 20-minute bout of acute exercise.

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APPENDIX A

Figures and Tables

Table 1. Total sample Demographics (n=16).

Ethnicity	**TD Participants**	**ASD Participants**
Asian-American	0	1
Caucasian/White	9	5
Hispanic-American	1	0
African-American/Black	0	0
Native American	0	0
Other	0	0
Mean±SD Experience Pedaling a Bike (0-Never; 5-Almost Daily)	2.1±0.93	2.2±0.63
Mean±SD Experience Playing Videogames	3.16±0.98	2.8±1.14
Mean±SD Experience with Computers	3.5±0.55	3.1±0.99

Figure 1. A sample set-up of the exergame. The participant uses the Wii remote to steer himself along the path, while pedaling using the under-the-table elliptical to propel himself forwards.

Figure 2. A snapshot of a fork in the road of the Memory Lane™ videogame. Participants were asked to steer towards the location that was listed first. For example, if "Gym" appeared before "Movie Theater" participants were steer towards the left fork, labeled "Gym".

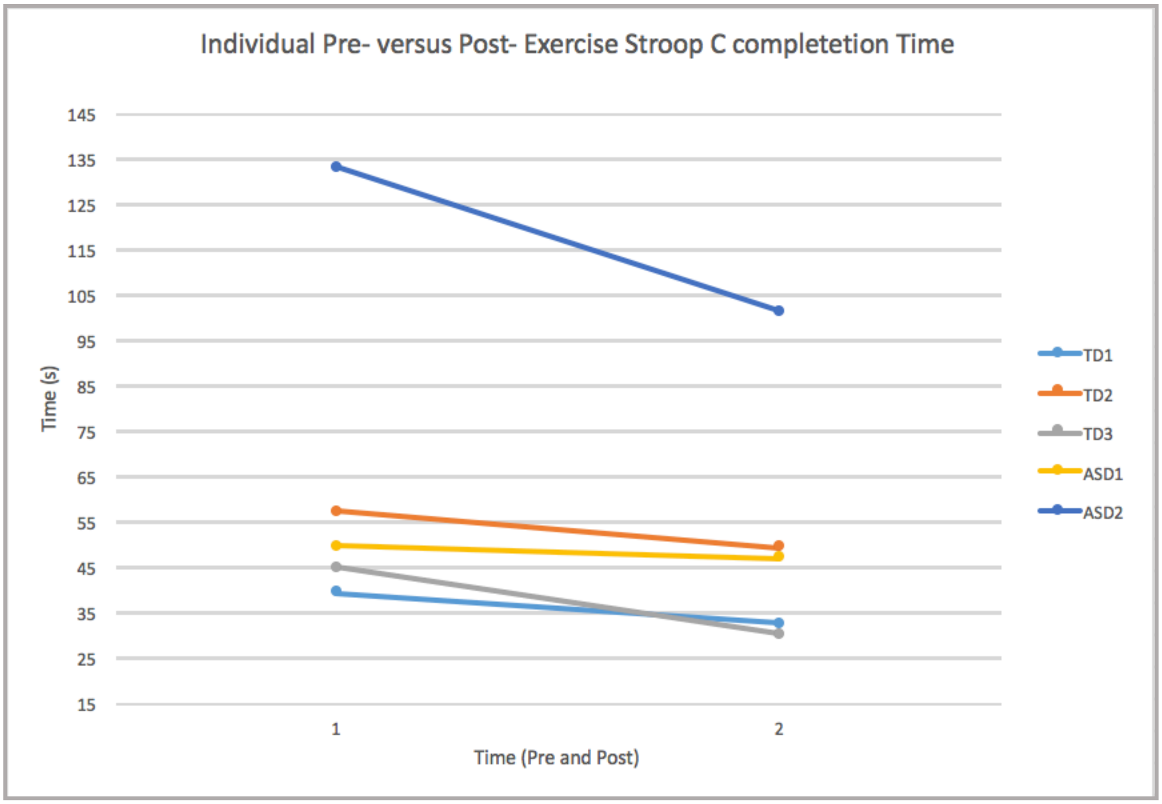

Figure 3. The time to completion of Stroop C Task for each individual participant (TD n=3; ASD n=2). These were recorded by using paper and pencil Stroop Tasks.

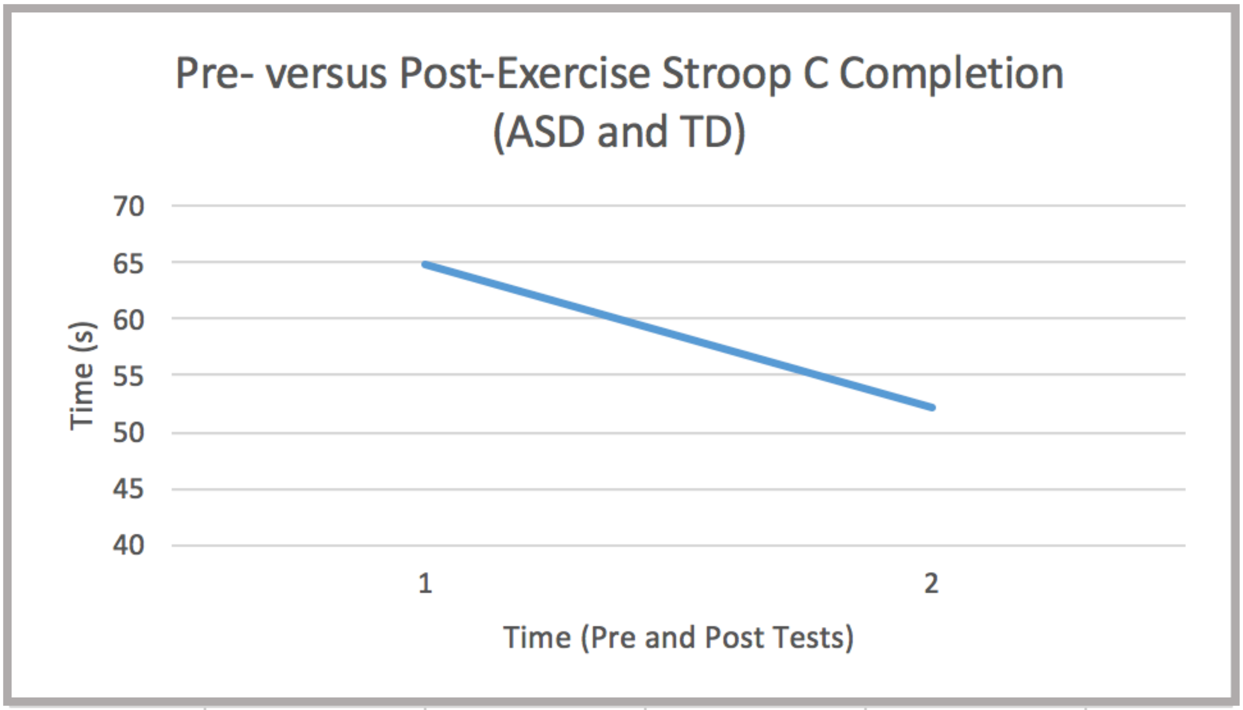

Figure 4. The time to completion of Stroop C Task for ASD and TD participants (n=5). These were recorded by using paper and pencil Stroop Tasks.

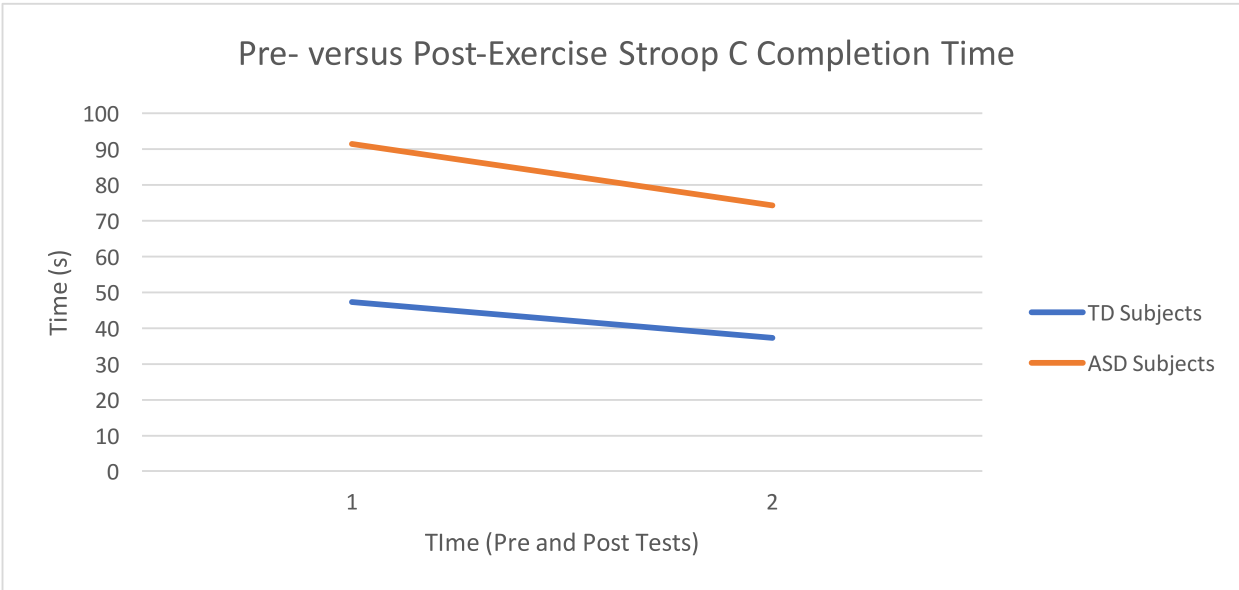

Figure 5. Time to completion of Stroop C Task for all TD individuals (n=3) and all ASD individuals (n=2). These were collected using paper and pencil assessments.

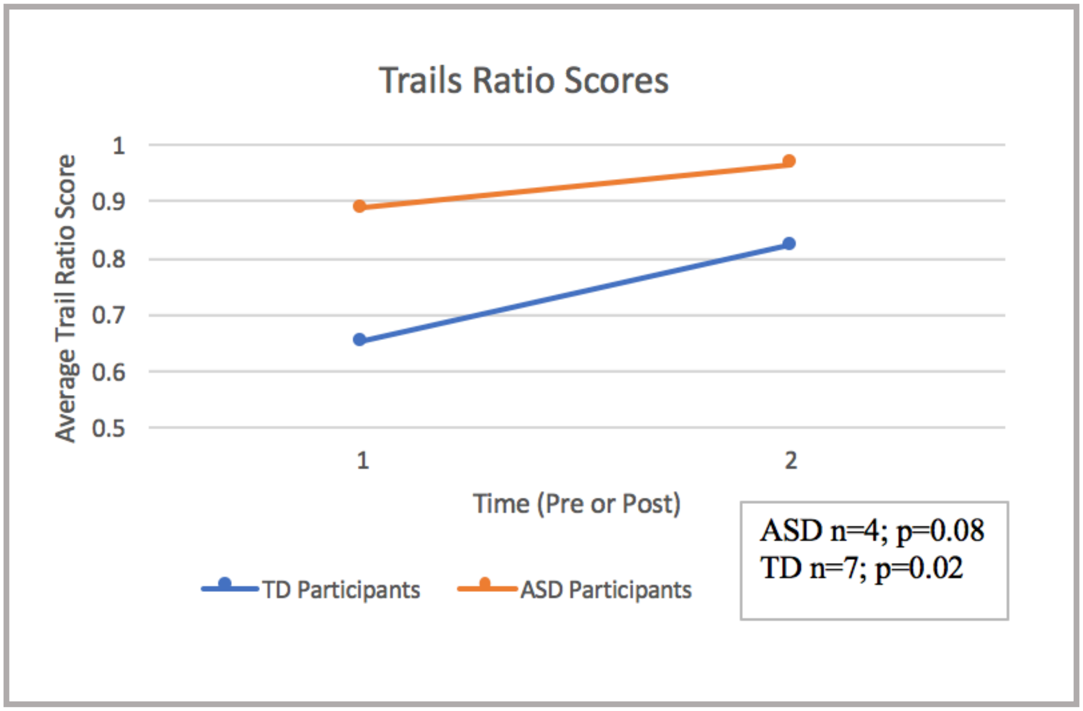

Figure 6. Trails ratio scores (congruent/incongruent) for all participants (n=11), ASD participants (n=4), and TD participants (n=7).

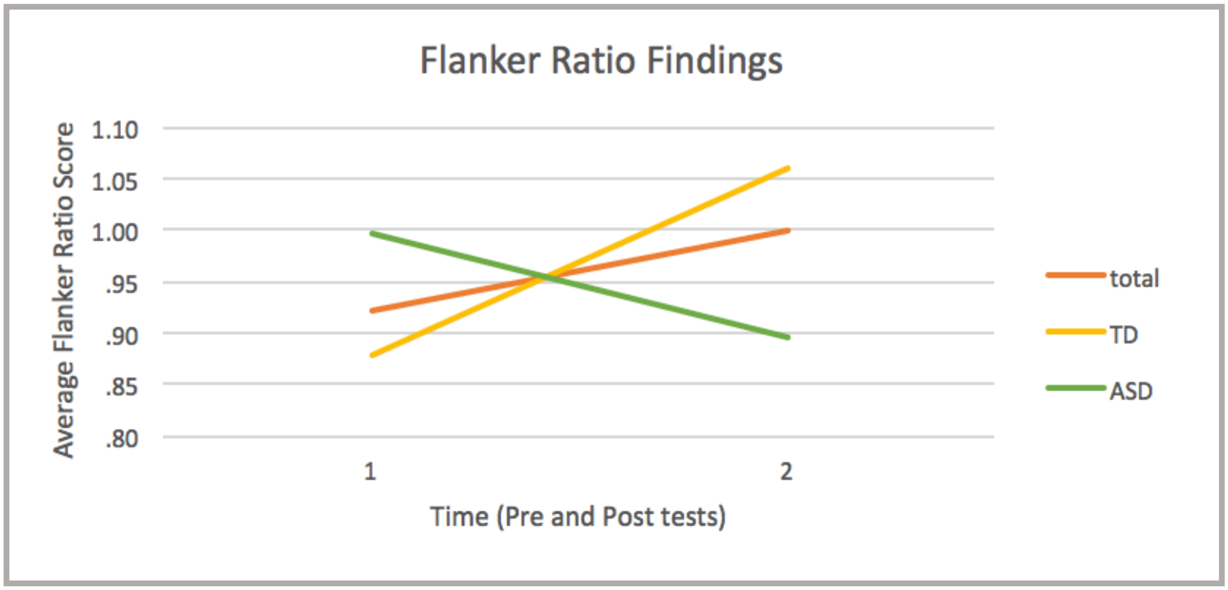

Figure 7. Flanker ratio scores (congruent/incongruent) for all participants (n=11), ASD participants (n=4), and TD participants (n=7).

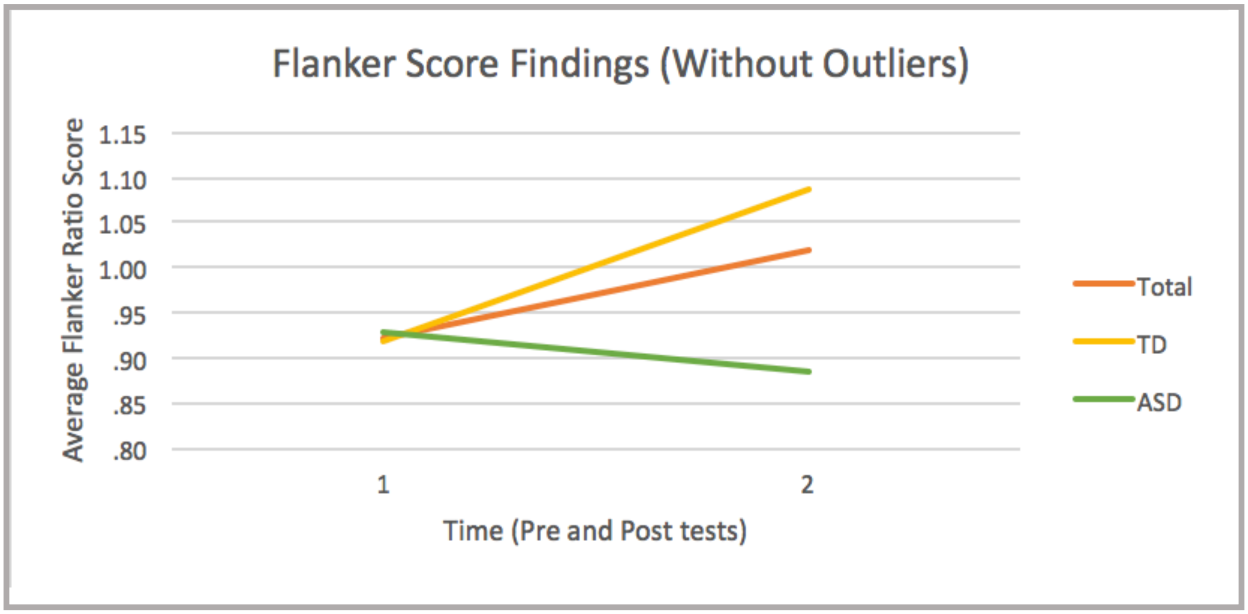

Figure 8. Flanker ratio scores (congruent/incongruent) without outliers (n=9).

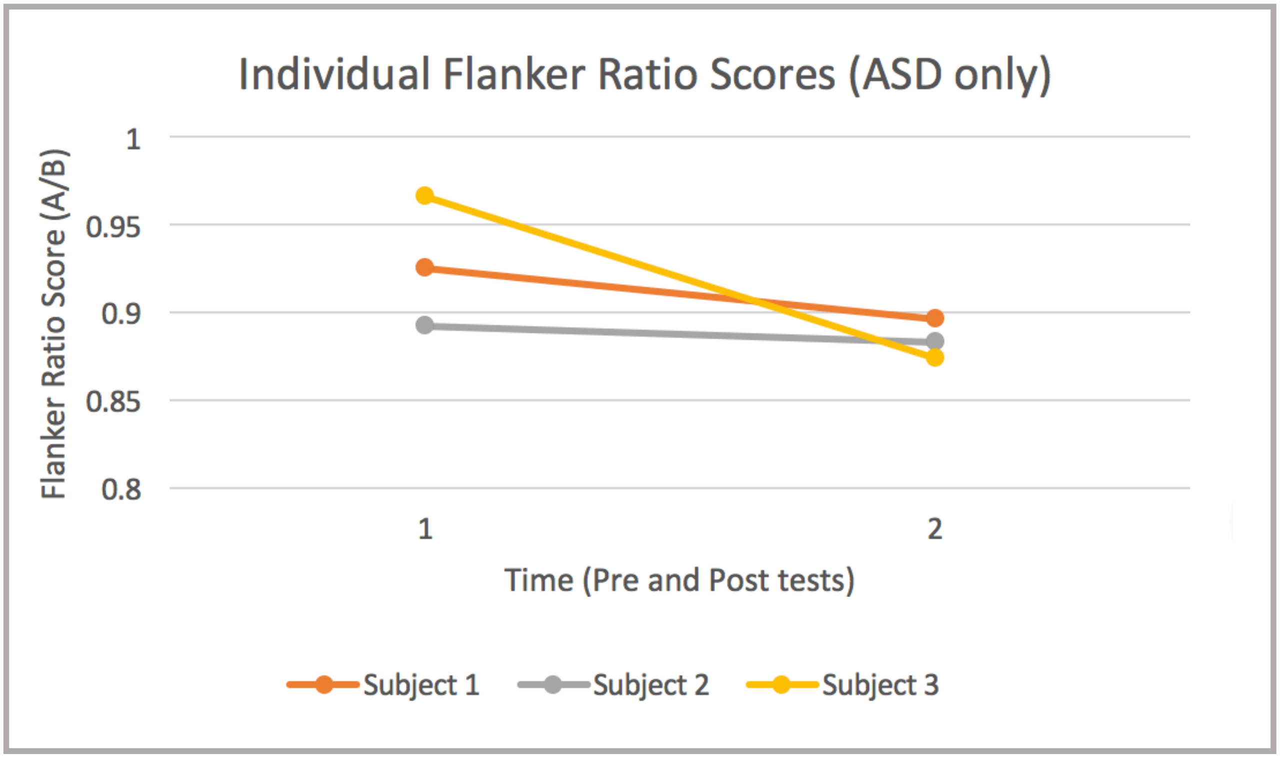

Figure 9. Individual ASD Flanker ratio scores (congruent/incongruent) without outliers (n=3).

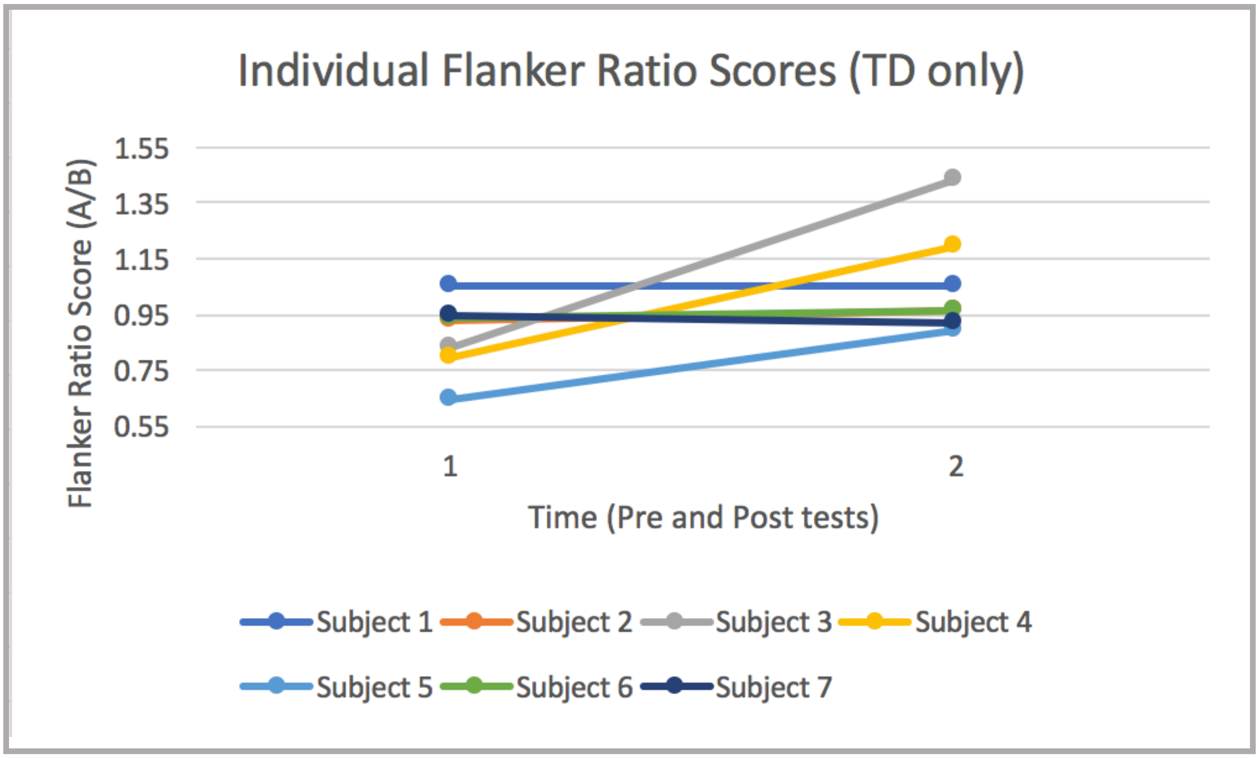

Figure 10. Individual TD Flanker ratio scores (congruent/incongruent; n=7).

Table 2. The percent of correct answers for incongruent Erikson's Flanker tests carried out by participants on the autism spectrum (n=4). A positive difference indicates an improvement in accuracy.

Participant Number	Pre-Test % Correct	Post-Test % Correct	% Difference
1	58%	95%	+38%
2	98%	93%	-5%
3	96%	95%	-1%
4	96%	99%	+3%

APPENDIX B

First Version Protocol Instructions

Participant ID# ___________ Date ____________
Location: ______________________ Time (include am or pm) _____________________________________

Evaluator Initials __________
Experimental Condition: _______________________

Instructions Form

______ Welcome participant to the study.
I greatly appreciate you taking the time to meet with me today so that we might learn more about the benefits of exercise. Please understand that most of what I say to you will be read directly from this packet in order to ensure consistency across evaluations. We want to make sure that the directions are explained to each participant in the same way to prevent any confusion. This evaluation process should take about one hour. Please let me know if you have any questions at any time.

______ Give participant and guardian a copy of the Informed Consent and Assent Forms.
I'd like to start by going over some paperwork. Please read this Informed Consent and Assent forms carefully and sign at the bottom (*review assent with participant*). **If you have any questions, do not hesitate to ask.**

______ Administer Demographic Questionnaire, Exercise History Questionnaire, and GARS-3 screening.

Please fill out these questionnaires to the best of your ability. Remember that all answers will remain confidential.
PRE-SINGLE BOUT

_____ Now, I have a variety of puzzle-like tasks for us to work on, such as repeating numbers and working with shapes. Hopefully, you will find most of the tasks very interesting. Some tasks you will probably feel very easy while others will seem quite difficult. No one is expected to be able to do all the tasks given, but I do want you to do your very best on each task. Try not to get discouraged if you find something hard, it is normal to find some tasks more difficult since they are designed to test the limits of your abilities. Just do the best you can. Do you have any questions before we begin?

- *Check to see if they need to use the restroom before beginning*
- *Ask to turn phone off/ringer to silent to minimize distractions*
- *Check to confirm wearing glasses/hearing aids if needed.*

_____ Administer Word List Memory (LIST 1)
Trial 1: **Now, I want to see how well you can learn a list of words. I am going to show you some words printed on these cards one at a time. Please read each word out loud and try to remember it, because later I will ask you to try to remember all of the words I have shown you. Ready? Read the word and try to remember it.** *Present each word card for approximately 1-2 seconds.*

Good, now tell me all the words you can remember. *Record responses (write first couple of ltrs if necessary to keep up with participant's rate of production).*
Trials 2 & 3: **Now I'm going to show you the same words again. Read each word out loud and try to remember it.** Do not warn the participant that they will be asked to later recall the words.

When complete, record time on clock: _________ *+ 5' =* ________ *time to do recall*

_____ Administer Color Trails A (time to complete if less than 60 sec or stop participant at 60 sec and record # correct)
Be sure to be ready with the stopwatch, even a one second difference in recording time can be significant.

PRACTICE: Color Trails I-A
In this box are different colored circles with numbers in them. When I say "begin," I want you to take this pen and connect the circles by going from 1 *(point to the 1),* **2** *(point to the 2),* **3** *(point to the 3)*, **and so on, until you reach the end. I want you to connect the circles in the correct order as quickly as you can, without lifting the pen from the paper. If you make a mistake, I will point it out. When I do, I want you to move the pen back to the last correct circle and continue from there. The line that you draw must go through the circles and must do so in the right order. Do you have any questions? Okay, let's practice. Put your pen here where this hand tells you to start. When I say "begin," connect the circles in order as quickly as you can until you reach the circle next to the hand telling you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle.)*

TEST: Color Trails I-A
Now I have a sheet with several more numbers and circles. Connect the circles in order like you did just a moment ago. Again, work as quickly as you can, and do not lift the pen from the paper as you go. Make sure that your lines touch the circles.
Point to the first circle and say the following: **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle. Be sure to record # of dot just completed at 60 seconds, as well as time to complete all).*
Record circle color and number at 60 seconds: _____
Record time to complete (in seconds): _____

PRACTICE: Color Trails II-A
In this box are different colored circles with numbers in them. This time I want you to take the pen and connect the circles in order by going from *this* color 1 *(point to the pink 1)*, **to *this* color 2** *(point to the yellow 2)*, **to *this* color 3** *(point to the pink 3)*, **and so on, until you reach the last number next to the hand telling you to stop.** *Take the pen and point to the example below the box as you say the following:* **Notice that the color changes each time you go to the next number. I want you to work as quickly as you can. Do not lift the pen from the paper once you have started. If you make a mistake, I will point it out. When I do, I want you to move the pen to the last correct circle and continue from there. As before, the line you draw must go through the circles in the correct order. Do you have any questions? Okay, let's practice. Put your pen here next to the hand telling you to start. When I say "begin," connect the circles in order as quickly as you can, changing from one color to the**

next, until you reach the hand telling you to stop, ready? Begin. *(Begin timing as soon as you detect movement toward the first circle.)*
TEST: Color Trails II-A
Now I have a sheet with several more numbers and colored circles. Connect the circles like you did just a moment ago. Again, work as quickly as you can. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing as soon as you detect movement toward the first circle. Be sure to record # of dot just completed at 60 seconds, as well as time to complete all).*

Record circle color and number at 60 seconds: _____
Record time to complete (in seconds): _____

_____ Administer Word List Memory (LIST 2)
Now, I want to see how well you can learn a list of words. I am going to show you some words printed on these cards one at a time. Please read each word out loud and try to remember it, because later I will ask you to try to remember all the words I have shown you. Ready? Read the word and try to remember it. *Present each word card for approximately 1-2 seconds.* **Good, now tell me all the words you can remember.** *Record responses (write first couple of ltrs if necessary to keep up with participant's rate of production).*
Now I'm going to show you the same words again. Read each word out loud and try to remember it. Do not warn the participant that they will be asked to later recall the words.
Repeat the list 1 more time as above (so 3 total).
When complete, record time on clock: _________ + 5' = ________ time to do recall

Administer the Stroop Task (VERSION 1)
Before showing the examinee any of the cards, say:
COLOR BLOCKS:
I am going to show you a few different pages. On this first page, there are some colored blocks. Please tell me the names of the colors you see on this top, sample row *(point to the row). If necessary, clarify that the names to use are: red, blue, & green. If the examinee cannot distinguish the colors, perhaps due to color-blindness, move on to the next task.*

If the examinee completes the sample line successfully, say: **Good. Now I want you to tell me the names of each color block starting here and going as quickly as you can, without making mistakes, across the row and down to the next line and across, etc., until you finish all the rows** *(point to the end).* **Are you ready? Go.** *Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections.*
BLACK WORDS:
Ok good, on the next page you will see that the task is similar, but slightly different. Here, read the words as quickly as you can. Please try the sample line *(point).*

Fine. Now I want you to start here *(point)* **and read across as quickly as you can without making mistakes. Again, go across each row and then down until you finish all the rows** *(point to the end).* **Are you ready? Go.** *Be sure to start & stop the timer precisely. Mark all*

answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for correction.
COLORED WORDS (incongruous/interference):
Good. On this last page, your task is to tell me the color of the ink and ignore the written word. *Feel free to empathize if the examinee laughs, gasps, etc. – e.g., say something like:* I realize this is getting more challenging, but do the best you can). Please try the sample line.

Fine. *If not, please explain again and repeat practice until clear understands, or abandon task.* **Start here** *(point)* **and read across and then down as quickly as you can without making mistakes until the end** *(point)*. **Are you ready? Go.** *Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections.*
_____ Administer Digit Span (digits forward)
Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.
I am going to say some numbers. Then when I am through, I want you to repeat them right after me. For example, if I say 8-9 you will say 8-9. You'll just say exactly what I say.
_____Administer Digit Span (digits backward).
Read numbers at rate of one second per number, with downward intonation at end. Be sure to record all responses whether right or wrong. Discontinue after 2 failures of the same length of digits.

Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-9, what would you say?
_____ Physiological Measurements

Height = _________ (in / cm – *circle one*) Weight = _________ (lb / kg – *circle one*)
Blood Pressure = _______/_______ mm/hg Pulse = _______bpm

___CONDITION: COGNITIVE TRAINING

INSTRUCTIONS FOR COGNITIVE TRAINING:
____ You **will be given a cognitive task to complete in the form of a videogame. As you begin a list of words will appear and you will be asked to memorize this list.**
As you move further along the trail, you will come to forks in the road where you will be asked to choose to turn either left or right depending on the place you'd like to go. We ask that you choose where to go based on the places you memorized earlier in the trail. For example, if "museum" was in your original list, then when you come to the fork in the road and are presented with the choice of turning left for "museum" or turning right for "doctor's," you should turn left for museum. Once you have completed this task all the way through, you will be asked to do the same task in reverse.

Once you successfully complete one list both forwards and backwards, you will receive another list of words of the same length. Once you complete this second task of the same length in its totality, you will be moved on to the next level where you will be asked to remember one more word than was in the previous sequence.

_____Commence single-bout of game play
Allow them to pedal/steer for 2-3 minutes, address questions. **Now, I would like you to play the game/exercise for 20 minutes.**

Note start time on clock: ____________ *When complete, record time on clock:* ____________
POST SINGLE-BOUT
_____ Repeat neuropsych tests as above using alternate forms
You will now take the same neuropsychological tests you completed earlier. After we are done with the evaluations, we will move on to the final part of the study. Do you have any questions?

_____ Administer Word List Memory (LIST 2)
Now, I want to see how well you can learn a list of words. I am going to show you some words printed on these cards one at a time. Please read each word out loud and try to remember it, because later I will ask you to try to remember all of the words I have shown you. Ready? Read the word and try to remember it. *Present each word card for approximately 1-2 seconds.* **Good, now tell me all the words you can remember.** *Record responses (write first couple of ltrs if necessary to keep up with participant's rate of production).*
Now I'm going to show you the same words again. Read each word out loud and try to remember it. Do not warn the participant that they will be asked to later recall the words.
Repeat the list 1 more time as above (so 3 total).
When complete, record time on clock: _________ + 5' = ________ time to do recall

_____ Administer Color Trails B

PRACTICE: Color Trails I-B
In this box are different colored circles with numbers in them. When I say, "begin", I want you to take this pen and connect the circles by going from 1 *(point to the 1),* **2** *(point to the 2),* **3** *(point to the 3)*, **and so on, until you reach the end. I want you to connect the circles in the correct order as quickly as you can, without lifting the pen from the paper. If you make a mistake, I will point it out. When I do, I want you to move the pen back to the last correct circle and continue from there. The line that you draw must go through the circles and must do so in the correct order. Do you have any questions?**
Okay, let's practice. Put your pen here where this hand tells you to start. When I say, "begin", connect the circles in order as quickly as you can until you reach the circle next to the hand telling you to stop. Ready? Begin.

TEST: Color Trails I-B
Now I have a sheet with several more numbers and circles. Connect the circles in order like you did just a moment ago. Again, work as quickly as you can, and do not lift the pen from the paper as you go. Make sure that your lines touch the circles. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing. Be sure to record the # of the dot just completed at 60 seconds, as well as time to complete all).*
Record circle color and number at 60 seconds: Color =_____ Number = _____
Record time to complete (in seconds): _____sec

<u>PRACTICE: Color Trails II-B</u>

In this box are different colored circles with numbers in them. This time I want you to take the pen and connect the circles in order by going from *this* color 1 *(point to the pink 1)*, **to *this* color 2** *(point to the yellow 2)*, **to *this* color 3** *(point to the pink 3)*, **and so on, until you reach the last number next to the hand telling you to stop.** *Take the pen and point to the example below the box as you say the following:* **Notice that the color changes each time you go to the next number. I want you to work as quickly as you can. Do not lift the pen from the paper once you have started. If you make a mistake, I will point it out. When I do, I want you to move the pen to the last correct circle and continue from there. As before, the line you draw must go through the circles in the correct order. Do you have any questions?**

Okay, let's practice. Put your pen here next to the hand telling you to start. When I say, "begin", connect the circles in order as quickly as you can, changing from one color to the next, until you reach the hand telling you to stop. Ready? Begin.

<u>TEST: Color Trails II-B</u>

Now I have a sheet with several more numbers and colored circles. Connect the circles like you did just a moment ago. Again, work as quickly as you can. *Point to the first circle and say the following:* **You will start here, where the hand tells you to start, and end where the hand tells you to stop. Ready? Begin.** *(Begin timing)*

Record circle color and number at 60 seconds: Color =_____ Number = _____

Record time to complete (in seconds): _____sec

_____ Administer Word List Recall *(5' after last list recall - record time on clock: __________)*

Now I want you to try to remember the words that I showed you earlier on printed cards. Can you tell me any of those words? *Allow a maximum of two minutes for recall. Record responses (write first couple of ltrs if necessary to keep up with participant's rate of production).*

_____ Administer the Stroop Task (VERSION 2)

Before showing the examinee any of the cards, say:

<u>COLOR BLOCKS:</u>

I am going to show you a few different pages. On this first page, there are some colored blocks. Please tell me the names of the colors you see on this top, sample row *(point to the row). If necessary, clarify that the names to use are: red, blue, & green. If the examinee cannot distinguish the colors, perhaps due to color-blindness, move on to the next task.*

If the examinee completes the sample line successfully, say: **Good. Now I want you to tell me the names of each color block starting here and going as quickly as you can, without making mistakes, across the row and down to the next line and across, etc., until you finish all the rows** *(point to the end).* **Are you ready? Go.** *Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections.*

<u>BLACK WORDS:</u>

Ok good, on the next page you will see that the task is similar, but slightly different. Here, read the words as quickly as you can. Please try the sample line *(point).*

Fine. Now I want you to start here *(point)* **and read across as quickly as you can without making mistakes. Again, go across each row and then down until you finish all the rows**

(point to the end). **Are you ready? Go.** *Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for correction.*
<u>COLORED WORDS (incongruous/interference):</u>
Good. On this last page, your task is to tell me the color of the ink and ignore the written word. *Feel free to empathize if the examinee laughs, gasps, etc. – e.g., say something like:* I realize this is getting more challenging, but do the best you can). Please try the sample line. **Fine.** *If not, please explain again and repeat practice until clear understands, or abandon task.* **Start here** *(point)* **and read across and then down as quickly as you can without making mistakes until the end** *(point)*. **Are you ready? Go.** *Be sure to start & stop the timer precisely. Mark all answers on your record sheet so that you can tally the number of errors later. Examinee can self-correct, but do not prompt for corrections.*

_____ Administer Digit Span (digits forward – VERSION 2)
I am going to say some numbers. Then when I am through, I want you to repeat them right after me. For example, if I say 8-9 you will say 8-9. You'll just say exactly what I say. *Read numbers at rate of one second per number, with downward intonation at end. Be sure to record <u>all</u> responses verbatim whether right or wrong. Discontinue after 2 failures of the same length of digits.*
_____ Administer Digit Span (digits backward – VERSION 2)

Now I am going to say some more numbers. But this time when I stop, I want you to say them backward. For example, if I say 7-9, what would you say? *Read numbers at rate of one second per number, with downward intonation at end. Be sure to record <u>all</u> responses verbatim whether right or wrong. Discontinue after 2 failures of the same length of digits.*

_____ Thank the participant. **You did a fine job today! I want to <u>thank you</u> for taking the time and putting in the effort to go through these tasks to help us with this research project. Do you have any questions or concerns I can address now?** *If they ask questions that you feel you cannot adequately address, tell them you will get back to them. If they ask how they did, note that you thought they did fine, but that you can't answer specific Qs (e.g., how many did I get right?) since they may take the tests again. Note that their formal results cannot be made available to them since they are not considered "clinically valid" due to the fact that this was a research study only.*

_____ **Remember, that if you have any questions, problems, or concerns, call us at 518-388-6430.**

APPENDIX C

Revised Protocol for Digital Tests

Participant ID# ___________ Date ____________
Location: _______________________ Time (include am or pm)
____
Evaluator Initials __________

Instructions Form

______Welcome participant to the study.
I greatly appreciate you taking the time to meet with me today so that we might learn more about the benefits of exercise. Please understand that most of what I say to you will be read directly from this packet in order to ensure consistency across evaluations. We want to make sure that the directions are explained to each participant in the same way to prevent any confusion. This evaluation process should take about one hour. Please let me know if you have any questions at any time.

______ Give participant and guardian a copy of the Informed Consent and Assent Forms.

I'd like to start by going over some paperwork. Please read this Informed Consent and Assent forms carefully and sign at the bottom (*review assent with participant*). **If you have any questions, do not hesitate to ask.**

______ Administer Demographic Questionnaire, Exercise History Questionnaire, and GARS-3 screening.

Please fill out these questionnaires to the best of your ability. Remember that all answers will remain confidential.

PRE-SINGLE BOUT

_____ **Now, I have a variety of puzzle-like tasks for you to work on on the iPAD, such as memorizing numbers and working with shapes. Hopefully, you will find most of the tasks very interesting. Some tasks you will probably feel very easy while others will seem quite difficult. No one is expected to be able to do all the tasks given, but I do want you to do your very best on each task. Try not to get discouraged if you find something hard, it is normal to find some tasks more difficult since they are designed to test the limits of your abilities. Just do the best you can. Each test has a practice round before the real test. The directions will appear on the screen, read them and ask me any clarifying questions. Do you have any questions before we begin?**

· *Check to see if they need to use the restroom before beginning*
· *Ask to turn phone off/ringer to silent to minimize distractions*
· *Check to confirm wearing glasses/hearing aids if needed.*

_____ Physiological Measurements
Height = _________ (in / cm – *circle one*) Weight = _________ (lb / kg – *circle one*)
Blood Pressure = _______/_______ mm/hg Pulse = _______bpm

___CONDITION: COGNITIVE TRAINING

INSTRUCTIONS FOR COGNITIVE TRAINING:
____ **You will be given a cognitive task to complete in the form of a videogame. As you begin a list of words will appear and you will be asked to memorize this list.**
As you move further along the trail, you will come to forks in the road where you will be asked to choose to turn either left or right depending on the place you'd like to go. We ask that you choose where to go based on the places you memorized earlier in the trail. For example, if "museum" was

in your original list, then when you come to the fork in the road and are presented with the choice of turning left for "museum" or turning right for "doctor's," you should turn left for museum. Once you have completed this task all the way through, you will be asked to do the same task in reverse.

Once you successfully complete one list both forwards and backwards, you will receive another list of words of the same length. Once you complete this second task of the same length in its totality, you will be moved on to the next level where you will be asked to remember one more word than was in the previous sequence.
_____Commence single-bout of game play

Allow them to pedal/steer for 2-3 minutes, address questions. **Now, I would like you to play the game/exercise for 20 minutes.**

Note start time on clock: ____________ *When complete, record time on clock:* ____________

______ Administer Flow Questionnaire

_____ Repeat neuropsych tests as above using alternate forms
You will now take the same tests you completed earlier. Do you have any questions?

_____ Thank the participant. **You did a fine job today! I want to thank you for taking the time and putting in the effort to go through these tasks to help us with this research project. Do you have any questions or concerns I can address now?** *If they ask questions that you feel you cannot adequately address, tell them you will get back to them. If they ask how they did, note that you thought they did fine, but that you can't answer specific Qs (e.g., how many did I get right?) since they may take the tests again. Note that their formal results cannot be made available to them since they are not considered "clinically valid" due to the fact that this was a research study only.*

_____ **Remember, that if you have any questions, problems, or concerns, call us at 518-388-6430.**

APPENDIX D
Exercise History Questionnaire

Which one of the five physical activity categories reflects your usual pattern of daily physical activity? Please check the box next to each level of physical activity.

- ◻ **Level 1**: Inactive or little activity other than usual daily activities.
- ◻ **Level 2**: Regular (>5 days/week) participation in physical activities for at least 10 min at a time that require low levels of exertion resulting in only slight increases in breathing and heart rate.
- ◻ **Level 3**: Engage in aerobic exercises (e.g. brisk walking, jogging or running, cycling, swimming, or vigorous sports) at a comfortable pace for 20-60 min per week.
- ◻ **Level 4**: Participate in aerobic exercises at a comfortable place for 1-3 hour per week.
- ◻ **Level 5**: Participate in aerobic exercises at a comfortable pace for over 3 hours per week.

Please answer the following questions to the best of your ability.

1) Approximate length (min) of a single session of exercise ________________

2) Identify which type(s) of exercise of which you typically participate.

- ◻ Strength/Resistance Exercise (e.g. weightlifting)
- ◻ Flexibility Training/Exercise (e.g. static or dynamic stretching)
- ◻ Stamina and Endurance Exercise (e.g. cardiovascular exercise, all types of aerobic exercise)
- ◻ Balance Exercise (e.g. Yoga)

3) Rate the intensity at which you typically exercise:

Low Intensity   Moderate/Self-Paced Intensity   High Intensity

4) What is your reason for exercising? (please circle all that apply)

To lose weight   To stay healthy   Because it is enjoyable   Other

If other, please specify: ____

APPENDIX E
Demographics Questionnaire

ID#: __________ Date: ________________ Group: ASD or TD

Years of Education (High School = 12)
____

First language? (English or list other)
____

Gender (male or female?)
____

Which hand do you write with?
____

Which hand do you use to throw a ball?

Parent(s)/caregiver occupation?
____

Ethnicity (circle as many as apply)

African-American/Black
Hispanic-American
Native American
Caucasian/White
Asian-American
Other: _______________

How much experience have you had **pedaling a bike** (either stationary or road bike)?

0	1	2	3	4
none	very rarely	occasionally	used pretty	lots
never used one	used	used	regularly	used almost daily

How much experience have you had with **computers**?

0	1	2	3	4
none	very rarely	occasionally	used pretty	lots
never used one	used	used	regularly	used almost daily

How much experience have you had with **video games**?

0	1	2	3	4
none	very rarely	occasionally	used pretty	lots
never used one	used	used	regularly	used almost daily