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ADHD Severity as a Predictor of Cognitive Task Performance in Children with Autism Spectrum Disorder (ASD)

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Abstract

Background: In recent years, a number of studies have begun to explore the nature of Attention-Deficit/Hyperactivity Disorder (ADHD) in children with Autism Spectrum Disorder (ASD). In this study, we examined the relationship between both symptoms of ADHD and symptoms of ASD on cognitive task performance in a sample of higher-functioning children and adolescents with ASD. Participants completed cognitive tasks tapping aspects of attention, impulsivity/inhibition, and immediate memory.

Aims.—We hypothesized that children with ASD who had higher levels of ADHD symptom severity would be at higher risk for poorer sustained attention and selective attention, greater impulsivity/disinhibition, and weaker memory.

Methods and Procedures: The sample included 92 children (73 males) diagnosed with ASD (Mean Age=9.41 years; Mean Full Scale IQ=84.2).

Outcomes and Results: Using regression analyses, more severe ADHD symptomatology was found to be significantly related to weaker performance on tasks measuring attention, immediate memory, and response inhibition. In contrast, increasing severity of ASD symptomatology was *not* associated with higher risk of poorer performance on any of the cognitive tasks assessed.

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All authors were involved in writing this manuscript. Drs. Pearson, Loveland, Aman, Jerger, Schachar were involved in the conceptualization and methodology of the project. Dr. Pearson, Dr. Loveland, and Ms. Mansour were involved in investigation (i.e., conducting the research, collecting the data). Dr. Lane, Ms. Mansour, and Dr. Ward were involved in data analysis and visualization (preparation of figures). Dr. Pearson was responsible for project administration and funding acquisition.

Conclusions and Implications: These results suggest that children with ASD who have more severe ADHD symptoms are at higher risk for impairments in tasks assessing attention, immediate memory, and response inhibition—similar to ADHD-related impairments seen in the general pediatric population. As such, clinicians should assess various aspects of cognition in pediatric patients with ASD in order to facilitate optimal interventional and educational planning.

Keywords

Autism Spectrum Disorder; Attention-Deficit/Hyperactivity Disorder; attention; impulsivity; memory; cognitive task

1. Introduction

Autism Spectrum Disorder (ASD) and Attention-Deficit/Hyperactivity Disorder (ADHD) are lifelong neurodevelopmental disorders with prevalence rates as high as 2% and 8.8%, respectively (Schieve et al., 2012; Pastor & Reuben, 2008; Thomas et al., 2015). ASD and ADHD are also known to co-occur at high rates. Clinically significant levels of ADHD symptoms are prevalent in ASD and range from 28–87% across research samples (Ames & White, 2011; Frazier et al., 2001; Mansour et al., 2017 Ponde, Novaes, & Losapio, 2010; Sinzig, Walter, & Doepfner, 2009; Simonoff et al., 2008). Thus, the frequent co-occurrence of these disorders has prompted much research into the specific features associated with them.

The detrimental impact of comorbid ADHD symptomatology in individuals with ASD has been more widely studied in recent years. Both disorders cause impairments in a number of areas. For instance, children with both ASD and ADHD had higher rates of comorbid psychiatric symptoms compared to those with ASD alone (Jang et al., 2013; Mansour et al., 2017). Additionally, ADHD symptoms have been found to further impair the cognitive functioning and overall psychiatric adjustment in children with ASD (Frazier et al., 2001; Gadow, DeVincent, & Pomeroy, 2006; Lecavalier, et al., 2009; Yoshida & Uchiyama, 2004). ADHD symptoms comorbid with ASD place children at a higher risk for psychiatric hospitalization (Frazier et al., 2001), predict more difficulties with adaptive and daily functioning impairment (Yerys et al., 2009), and are positively correlated with receiving mental health services (Bryson, et al., 2008).

While ASD and ADHD are both categorized as “Neurodevelopmental Disorders” in the DSM-5 (APA, 2013), these two disorders are defined by different core symptom profiles. ADHD is characterized by attention problems, hyperactivity, and impulsivity, while ASD is defined by impaired social functioning, communication, and restricted and stereotyped patterns of behavior (APA, 2013). In addition to these core symptoms, there are additional common features of ASD that are not as common to ADHD (e.g., intellectual disability and speech delay). Yet, despite these distinct developmental features, the high rates of comorbidity and evidence for a shared inherited liability (Musser et al., 2014; Rommelse at al., 2010) continues to prompt investigation into how the individual clinical domains (i.e., ADHD and ASD symptoms) predict exacerbated impairments in the comorbid ASD+ADHD population.

Overall, research findings on possible cognitive deficits in youth with ASD and comorbid ADHD are not entirely consistent. Several past studies examined whether different profiles of cognitive performance were evident between groups with either disorder (i.e., ASD vs ADHD). These studies concluded that both groups tend to perform worse on cognitive tasks than typically developing children; however, children with ADHD exhibited more pronounced problems with inhibitory control and working memory while children with ASD exhibited more problematic cognitive flexibility and planning skills relative to typically-developing youth (Geurts et al., 2004; Happé, Booth, Charlton, Hughes, 2006; Ozonoff & Jensen. 1999; Pennington & Ozonoff, 1996; Sinzig, 2009). In contrast, others have found areas of weak cognitive performance that are shared across both groups, perhaps with more intense impairments in children with ASD, relative to children with ADHD (Corbett, Constantine, Hendren, & Ozonoff, 2009; Geurts et al., 2004). Overall, the literature suggests that problematic cognitive performance is associated with both disorders while evidence for distinct cognitive impairment profiles specific to each disorder are less consistently obtained (Pennington & Ozonoff, 1996; Sergeant, Geurts, Oosterlaan, 2002).

Some studies have emphasized a dimensional approach by examining the potential contribution of relative severity of ADHD and ASD symptomatology to cognitive underperformance. Greater ADHD symptoms in those with ASD have been found to predict greater cognitive deficits, such as inhibitory control (Sinzig et al., 2009; van der Meere et al., 2012). In addition, others have identified deficits with sustained attention as being more linked to ADHD symptomatology than ASD features in those with ASD (Sinzig et al., 2008). Karalunas and colleagues (2018) examined three diagnostically defined groups (ASD, ADHD, typically developing controls) using latent class analysis in a large sample to examine the contributions of different levels of either ASD or ADHD symptoms to several domains of executive functioning. They concluded that both the ADHD and ASD symptom classes exhibited impairments in response inhibition, working memory, and processing speed that could not be differentiated based on the relative severity of symptoms from either disorder separately. They also posited that a single risk for weak executive functioning may contribute to both disorders. Thus, it remains unclear how ADHD symptom severity leads to the commonly observed ADHD cognitive deficits in a sample of individuals with comorbid ASD.

In summary, the literature strongly suggests that ADHD and ASD each contribute risk for suboptimal cognitive functioning, yet given the high rate of comorbidity, it is important to address their unique impact on cognitive outcomes. In this study, we have used a battery of cognitive performance tasks tapping sustained attention, inhibition, selective attention, impulsivity, and immediate memory that our group has used previously and that are sensitive to attentional impairments (i.e., ADHD) in children with developmental disabilities (e.g., Pearson et. al, 2004). We then analyzed whether ASD symptoms or ADHD symptoms were associated with a higher risk for greater performance decrements on these cognitive tasks. It should be noted that our sample did not exclude participants with IQ <70, who were excluded in some previous studies in this area (e.g. Karalunas et al., 2018; Ozonoff & Jensen, 1999). We felt that inclusion of these children created a sample that was more representative of the comorbid ASD+ADHD population in the community The first goal of this study was to examine the **risk** for cognitive task performance decrements associated with ADHD symptomatology (as measured with a parent report rating scale)—in children with ASD. The second goal of this study was to determine whether **greater severity** of autistic symptomatology in children with ASD is associated with higher levels of inattention and impulsivity.

2. Method

2.1. Participants

The participants in this study were from a larger NIH-funded study assessing cognitive and behavioral functioning in children with ASD (Mansour et al., 2017; Pearson et al., 2012, Pearson et al., 2013 Participants were recruited from the community, including local schools (special education programs, special needs schools), community agencies/clinics, and community advocacy groups. A screening phone interview was conducted using the Social Communication Questionnaire (SCQ; Rutter, Bailey & Lord, 2003) to screen for symptoms of autism. Participants with SCQ scores greater than or equal to 15 were invited to the clinic for the psychological assessment visit.

The specifics of the psychological assessment have been described previously (Mansour, Dovi, Lane, Loveland, & Pearson 2017; Pearson et al., 2012) (Pearson et al., 2013) and specific instruments are detailed below. Briefly, participants underwent a psychological assessment battery that included the Stanford-Binet, 5th Edition (Roid, 2003), a structured psychiatric interview with a parent, and norm-referenced questionnaires completed by both a parent and teacher. Written informed consent was obtained from parents and assent was obtained from those children who were able to provide it. This study was approved by the Committee for the Protection of Human Subjects at the University of Texas Health Science Center at Houston

Diagnostic measures included the Autism Diagnostic Interview-Revised (ADI-R; Lord, Rutter, & Le Couteur, 1994), the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2002) administered by research-reliable clinicians, and follow-up clinical interview by a licensed psychologist. Children were determined to meet DSM-IV-TR criteria for Autistic Disorder, Asperger's Disorder, Pervasive Developmental Disorder-Not Otherwise Specified (PDD-NOS) through case review by two licensed psychologists who were highly experienced in assessing autism and related neurodevelopmental disorders (DAP and KAL). Exclusion criteria included having an IQ of less than 40, not having English as the primary language, and sensory and motor limitations that were severe enough to prevent adequate testing on the cognitive tasks.

As seen in Table 1, our sample consisted of 92 children (73 boys) between the ages of 6 and 13 years old (M=9.41) with a mean FSIQ of 84. Within this sample, 54 children met DSM-IV-TR criteria for Autistic Disorder, 21 met criteria for PDD-NOS, and 17 met criteria for Asperger's Disorder. The children in this sample had a range of symptoms of ADHD severity, with T-scores on the Global Index of the Conners Parent Rating Scale, Revised-Long (CPRS) ranging from 37 to 90, and T-scores on the Global Index of the Conners Teacher Rating Scale, Revised-Long (CTRS) ranging from 45–90. Forty-seven participants

(51%) were being treated with one or more psychoactive medications at study entry, including psychostimulants (n=29), antipsychotics (n=1), atypical antipsychotics (n=16), antidepressants (n=13), atomoxetine (n=4), antihypertensives (n=4), a mood stabilizer (n=1), and an anxiolytic (n=1). Nineteen children (19%) were taking two medications, and six children (6%) were receiving three or more. Although we recognized that children taking psychotropic medications were likely to have greater ADHD symptoms, if we had excluded them, we would have created a sample that was not representative of children with ASD (Aman et al, 1995).

2.2. Measures: Clinical Diagnosis/Characterization of the Sample

The Stanford-Binet Intelligence Scale, 5th Edition (SB5).—The SB5 was used to assess intellectual ability. The SB5 is a widely used, individually administered test normed for ages 2 through 80 years. It yields a measure of Full Scale IQ, Verbal IQ, and Nonverbal IQ. The SB5 has excellent reliability and validity (Roid, 2003b).

Diagnostic Interview for Children and Adolescents, 4th Edition-Parent Interview (DICA-IV).—The DICA-IV (Reich, 2000) is a structured psychiatric interview that was administered to parents or primary caregivers to assess major diagnostic categories. The computerized interview was then followed by a diagnostic interview conducted by a licensed psychologist (DAP). The DICA-IV has been found to be sensitive in children with developmental disabilities (Pearson et al., 2013). The DICA-IV, was used to establish diagnoses of ADHD and other comorbid psychiatric diagnoses (the focus of a previous paper from this group, Monsour et al., 2017). As noted previously (Mansour et al., 2017), an ADHD diagnosis was established if the child had sufficient DSM-IV-TR symptoms of ADHD, as reported by the parent on the DICA-IV and in a follow-up clinical interview with a licensed psychologist (disregarding the DSM-IV-TR prohibition of diagnosing ADHD in the context of autism), our behavioral observations, and T ≥ 65 on the Conners Parent and Teacher Rating Scales, Revised-Long (CPRS-R:L) ADHD Indexes (the ADHD Index being the most strongly associated with ADHD diagnosis; Conners, 1997). We found that 86% of sample met all of these criteria for a comorbid diagnosis of ADHD. Table 2 includes a list of additional comorbid conditions.

The Autism Diagnostic Interview, Revised (ADI-R).—The ADI-R (Rutter, Le Couteur, & Lord, 2003), a semi-structured interview covering current and historical symptoms of autism, was administered to the primary caregiver of participants. It is based on both DSM-IV and ICD-10 criteria. Domains include: 1) reciprocal social interaction, 2) communication and language, and 3) restricted, repetitive, and interests. The interview yields scores on each of the three major domains, as well as a diagnostic algorithm. The sum of major domain scores served as the measure of ASD symptom severity.

Autism Diagnostic Observation Schedule (ADOS).—The ADOS (Lord, Rutter, DiLavore, & Risi, 2001) consists of a standard series of events (e.g., activities, conversations), observations, and codes of behavior that can yield a formal DSM IV/ICD-10 diagnosis of Autism. Domains that are assessed by the ADOS include social behaviors, communication, and restricted and repetitive behaviors. The ADOS yields subdomain scores as well as a total score reflecting the severity of ASD symptomatology.

Social Communication Questionnaire, Lifetime (SCQ).—The SCQ (Rutter, Bailey & Lord, 2003) is a 40-item, parent-report questionnaire used to screen for symptoms associated with ASD. It provides a total score that ranges from 0–40. Scores exceeding the cut-off score of 15 indicate that an individual may have ASD and suggests that a more comprehensive assessment should be completed.

Conners' Rating Scales, Revised-Long (CPRS-R:L).—As we did previously ((Mansour et al., 2017), the Global Index from the CPRS-R:L (Conners, Sitarenios, Parker, & Epstein, 1998) was used to assess overall severity of ADHD symptomatology. The CPRS-R: L is a widely used screening measure that assesses symptoms of ADHD and of other behavioral/emotional disorders frequently associated with ADHD (e.g., oppositional behavior, social problems). The Conners scales are normed for children of ages 3–17 years. Only the parent Global Index was used, as we have demonstrated previously that parent and teacher ratings of ADHD symptoms in this population have high concordance (Pearson et al., 2012).

2.3. Measures: Cognitive Tasks

The tasks used in this investigation were selected on the basis of their demonstrated ability to assess sustained attention, selective attention, impulsivity/inhibition, and immediate memory in children with attention deficits, as well as their appropriateness for the cognitive developmental level of the children. (e.g., Pearson et al., 1996; Pearson et al., 2004).

Sustained Attention:

Continuous Performance Test.: On this version of the classic CPT (Rosvold et al., 1956), participants were presented with a series of black and white familiar pictures one at a time. They were instructed to press the response key only when they saw the witch (i.e., the target). There were four blocks of 100 stimuli (including 15% targets); each picture was presented for 200 msec, and the interstimulus interval was 1500 msec. The task lasted approximately 12 minutes. CPT performance was assessed by the number errors (omissions and commissions), and response time. The CPT differentiates children with and without ADHD among typically developing populations (e.g., Sykes, Douglas, & Morgenstern, 1973), as well as among children with intellectual disability (Pearson, Yaffee, Loveland, & Lewis, 1996). It has also shown to be sensitive to stimulant treatment in children with ADHD, with and without ID (Aman, 1991; Aman, Kern, McGhee, & Arnold, 1993; Sykes, Douglas, Weiss, & Minde, 1971).

Selective Attention:

Speeded Classification Task.: The Speeded Classification Task (SCT; Strutt, Anderson, & Well, 1975) is a computerized measure of visual selective attention in which children sort stimuli on the basis of a binary (two-choice) dimension. The dimension could be a shape (circle or square), line orientation (vertical or horizontal), or relative location of a star (above or below the middle of the screen). The relevant dimension could appear by itself (e.g., just a circle), or with one or two distracting dimensions (e.g., a circle with a horizontal line drawn through it and a star above it). Children responded by selecting the best-matching stimulus, using a computer touch screen. SCT performance was assessed by examining sorting errors and response time. The SCT discriminates children with and without ADHD of normal intelligence (Rosenthal and Allen, 1980), as well as children with and without ADHD who have intellectual disabilities (Pearson et al., 1996). It is also sensitive to methylphenidate (MPH) treatment in the latter (Pearson et al., 2004).

Selective Listening Task.: The stimuli used for the Selective Listening Task were taken from the competing sentences subtest of the Dichotic Speech Intelligibility Test (DSI; Jerger, 1987), and were presented from the computer through headphones. Sentences were presented simultaneously in both ears, with one ear being the target channel and the other being the distracter channel. Participants were required to identify the target stimuli from a list while inhibiting information presented in the distractor channel. Sentences were first presented at equal decibel levels in the target and distracter channel. The remainder of the distractor conditions followed with 10db increases in distractor volume per condition. Performance was measured by percent of correct responses, omission errors (when participants failed to make a response), and intrusion errors (i.e., reporting the distractor). All children received a hearing screen before completing the task. Selective listening tasks have been shown to differentiate children with and without ADHD (Prior, Samson, Freethy, & Geffen, 1985; Pearson et al., 1991).

Impulsivity/Inhibition:

Delay of Gratification (DOG) Task.: This task, adapted from the preschool delay task of the Gordon Diagnostic System (Gordon, 1983), measures the ability to suppress or delay impulsive behavioral responses. Children were told that a star would appear on the computer screen if they waited "long enough" to press a response key. If a child responded sooner than four seconds after their previous response, they did not earn a star, and the 4-second counter restarted. Children performed one block as practice, and then four 92-second blocks during the actual test. Performance was measured by the number of correct responses and the efficiency ratio (# correct responses/total # responses). The DOG differentiates children with and without ADHD of normal intelligence (McClure & Gordon, 1984), and is sensitive to MPH treatment in these children (Hall & Kataria, 1992) and in children with ADHD who have intellectual disabilities (Pearson et al., 2004).

Matching Familiar Figures Test (MFFT).: This task consisted of a computerized version of Kagan's (1964) MFFT, in which the child saw a test picture at the top of the computer screen, along with six alternatives (one of which matched the test stimulus) further down on the screen. Participants were told to select the picture below that matched the test stimulus above. There were two practice items (mug, ruler), followed by 23 experimental items Incorrect responses resulted in a synthesized voice (DML) saying "try again," while correct responses resulted in the same voice saying "that's right." Subjects continue responding on each trial until correct. Performance was measured by number of matching errors and response time. The MFFT discriminates children with and without ADHD in the general pediatric population (Prior et al. 1985; Pearson et al. 1991) and has been found to be sensitive to MPH in children with ADHD in the general pediatric population (e.g., Campbell et al., 1971), and in children with ADHD and intellectual disabilities (Aman et al., 1991b; Pearson et al., 2004).

Stop Signal Task (SST).: The SST (Schachar et al. 1993) is a measure of motor response inhibition, involving a choice reaction time task and a stop task. The choice reaction time task (go task) involves two visual stimuli, either X or O, presented in the middle of a computer screen. On 75% of the trials (the “go trials”), the children were told to respond as quickly and accurately as possible by pressing the correct button corresponding to the letter on screen. On 25% of the trials (the “stop trials”), the child also heard a tone (the “stop signal”) and was told to withhold responding. Short stop signal delays increase the probability of inhibiting (e.g., it is easier to stop a prepotent response earlier than later), while longer delays increase the probability of responding. Total trial time is 3500 msec, with a 500 msec fixation, a 1000 msec go stimulus display (X or O), and a 2000 msec inter-trial interval (ITI). The onset of the stop stimulus (stop signal delay) is modified based on subject performance. On the first trial, the stop signal occurs 250 msec after the onset of the go stimulus. For each correct answer, an additional 50 msec is added to the onset time and for each incorrect answer, 50 msec is removed from the onset time. Participants completed a practice block, followed by 6 experimental blocks with 32 trials per block. The duration of this task is 12 minutes, Primary outcome variables included “Go Accuracy” (correct responses on “go” trials), “Go RT” (response time on “go” trials), “Stop Accuracy” (correct responses on “stop” trials), and “Stop Signal RT” (which is computed based on the “integration method,” as per R.J. Schachar, personal communication, 6/12/2011; also outlined in Verbruggen et al. 2019), and Stop Signal Delay (the time between the visual stimulus and the stop stimulus). Children with ADHD are less able than their non-ADHD peers to successfully inhibit when given the stop signal, as indicated by a longer Stop Signal RT (Lipszyc and Schachar, 2010; Schachar et al. 1993). The SSRT has been used to study inhibition in higher-functioning children with ASD (Ozonoff and Strayer, 1997) and has been found to be sensitive to MPH treatment in children with ADHD (Bedard et al. 2003).

Immediate Memory:

Delayed Match to Sample Task (DMTS).—The DMTS was adapted from the version used by Aman et al. (1991b). During the DMTS participants were first presented with a single color square (target) on the computer screen for 1000 msec and were instructed to commit the figure to memory and then touch the color. After a 1000 msec delay, participants see three colored squares (red, blue, and yellow), one of which was the matching the color they saw in the previous screen. Participants are asked to select the matching color by touching it on the screen. The delay between the target and the choices is increased by 1000 msec for every 3 correct responses to a maximum of a 12000 msec (i.e., 12 sec) delay. For every 3 incorrect responses, the delay is decreased by 1000 msec. There are 36 trials and the task can last up to 12 minutes. Performance was measured by the proportion of correct matches, response time, and the maximum delay. Past research has found the DMTS to be sensitive to MPH treatment in children with ADHD and intellectual disabilities (Aman et al., 1991b).

2.4. Procedure

Parents completed their report measures in a quiet, private room in the clinic. They were interviewed in the office of a licensed psychologist. For children who were taking medication (particularly stimulants), parents and teachers were instructed, to the extent possible, to complete their questionnaires by rating the child's behavior when he or she was not taking medication. All cognitive tasks were administered in a quiet room in our clinic.

Finally, psychostimulant treatment was discontinued two days prior to testing (with pediatrician approval), in order for children to be tested in their "natural" state. Every effort was made to do this cognitive testing on Mondays, so there was minimal interference with the child's academic performance (i.e., we strived to make medication-free days fall on weekends). Before each task, the children were given practice trials, during which time we gave feedback on their performance. With the exception of the Matching Familiar Figures Test, no feedback was given during the actual test trials, but the child was redirected to task if s/he looked away or spoke.

3. Results

Primary statistical analyses utilized a multiple regression approach similar to that used in a previous study by this group (Mansour et al., 2017). As expected, mental age (from the SB5 full scale age-equivalent score) was significantly correlated with most dependent variables (mean r=.37); therefore, mental age was included as a covariate predictor in each regression model. As shown in Table 3, no significant correlations emerged among the independent variables (ASD severity, ASD severity, and mental age).

Variable distributions were examined prior to statistical analyses and transformations were applied as appropriate following the Tukey Ladder of Transformations (Winer et al., 1971; see Table 2). Multiple regression models examined the unique associations between ASD symptom severity (ADI-R Total Score) and ADHD symptom severity (CPRS Global Index) and each cognitive outcome (i.e., ASD severity, ADHD severity, and mental age were predictors in each model predicting a separate cognitive task measure). Table 2 shows results of the regression models; reporting the relationships between the predictor and dependent variables. Although we examined the interaction between ASD and ADHD severity as predictors of each dependent variable, no significant interactions emerged (p>.05). The relationships between predictor and dependent variables are illustrated in separate partial plot figures (Figures 1–4). A partial plot shows the relationship between the predictor variable and the outcome variable with the variance of all the other predictor variables partialled out (i.e., the relationship that is tested by the regression model; see Velleman & Welsch, 1981).

3.1 Sustained Attention

Continuous Performance Task.—Figure 1 illustrates the significant relationship between ADHD severity and number of commission errors, b=0.12 (95% CI=.001 to .023), ΔR^2 of .046, F(1,84)=4.48, p=.037. In contrast, the relationship between ASD severity and the number of commission errors was not significant, p=.200. Furthermore, there were no significant effects of ADHD severity or ASD severity on the other CPT dependent variables.

3.2 Selective Attention

Speeded Classification Task.—Although there was some evidence of a positive association between ADHD severity and number of errors, this effect was not significant at conventional levels, b=.007 (95% CI= −.001 to .014), ΔR^2=.023, $F(1,82)$=3.40, p=.069. Similarly, there was a pattern suggesting that increasing ADHD severity was associated with decreasing (i.e., faster) response times, but again it fell short of the conventional significance threshold, b=−4.86 (95% CI= −10.14 to .419), ΔR^2=.031, $F(1,82)$=3.35, p=.071. ASD severity was not a significant predictor of errors or response times, all p>.455. Overall, these results may suggest that greater ADHD severity predicted faster response times, but less accurate responding.

Dichotic Listening Task.—The effect of ADHD severity on DSI errors was not significant on any dependent variables (all $p \geq .180$), nor was the effect of ASD severity, all $p \geq .668$.

3.3 Impulsivity/Inhibition

Delay of Gratification (DOG) Task.—Separate models examined efficiency ratio, correct responses, and number of overall responses as dependent variables with ASD severity and ADHD severity as predictors. There were no significant relationships (all $p \geq .177$).

Matching Familiar Figures Test.—The relationship between ADHD severity and total errors on the MFFT was significant and positive, b=0.303 (95% CI=.056 to .551), ΔR^2=.052, $F(1,77)$=5.96, p=.017, suggesting that more severe ADHD symptoms predicted less accuracy on this task (Figure 2). In contrast, the association between ASD severity and total errors was not significant, p=.429. Response time was not significantly predicted by either ADHD severity, p=.127, nor by ASD severity, p=.735.

Stop Signal Task (SST).—As can be seen in Figure 3, increasing ADHD severity was a significant negative predictor of accuracy during "Go" trials (i.e., trials with no stop tone telling the child to inhibit responding), b=−2783 (95% CI= −5018 to −547), ΔR^2=.065, $F(1,74)$=6.15, p=.015. In contrast, the relationship between ASD severity and accuracy on go trials was not significant, p=.100. Thus, greater ADHD severity predicted worse accuracy on Go trials, while ASD severity did not impact Go trial accuracy.

There were no significant effects of ADHD severity and ASD severity on the other SST dependent variables, including stop signal response time, go response time, stop signal accuracy, and stop signal delay, all p>.110.

3.4 Immediate Memory

Delayed Match to Sample (DMTS) Task.—As can be seen in Figure 4, greater ADHD severity significantly predicted slower response time, b=.006 (95% CI=.00063 to .012),

ΔR^2=.046, $F(1,86)=4.87$, p=.030. Please note that *b* and CI were multiplied by 1000 to make the regression analyses more easily interpretable. In contrast, ASD severity did not significantly predict response time, p=.596. Neither ADHD severity nor ASD severity significantly predicted correct responses (all p>.49).

4. Discussion

Elevated symptoms and diagnoses of ADHD are common among youth with ASD (Gadow, DeVincent & Pomeroy, 2006). Evidence indicates that youth with ASD and comorbid ADHD experience myriad impairments beyond those of youth with ASD alone, including greater variety and intensity of comorbid psychopathology (Mansour et al., 2017). In addition, a growing literature suggests that deficits in executive functioning and related cognitive domains are characteristic of both ASD and ADHD. Yet, it was only within the last decade that research began to earnestly examine how these cognitive differences manifest among this common comorbid profile (i.e., ASD+ADHD). This study suggests that greater ADHD symptom severity was uniquely associated with weaker performance on measures of attention, immediate memory, and response inhibition, over and above what would be predicted on the basis of mental age. In contract, ASD severity did not account for unique variance in any cognitive measures investigated. Taken together, it appears that comorbid ADHD symptomatology may confer additional problems in these cognitive domains beyond what is already associated with ASD.

With respect to the specific dimensions of attentional impairment, ADHD severity uniquely predicted increased errors of commission as measured by CPT, suggesting poorer ability to inhibit responding to non-targets. Wilson and colleagues (2016) also noted that commission errors can suggest absentmindedness or lower attentional focus in longer tasks with greater proportions of no-go stimuli such as the version used here. Thus, in the present study, commission errors likely reflect poor sustained attention. With regard to visual selective attention, greater ADHD severity predicted faster response time on the SCT above and beyond the effect of ASD severity; however, the relation between ADHD severity and task accuracy fell just short of significance (p=.07). These results seem to suggest faster and less accurate responding overall.

With regard to immediate visual memory on the DMTS, ADHD severity was a unique predictor of slower response time, indicating slower memory processing or slower responding. However, there was no significant added effect of ADHD symptoms on task accuracy. This finding may suggest that, while ADHD severity was not related to accuracy of responding on this short-term memory task, those ASD youth with more severe ADHD symptoms are slower to retrieve/recognize the matching stimulus from short-term memory and/or are slower to generate a response. With regard to the impact of ADHD on short-term memory, previous findings are not consistent. Corbett and colleagues (2009) reported that ASD-diagnosed youth performed worse than a group of youth with ADHD on a spatial working memory measure, but several children in their ASD-diagnosed group also had significant ADHD symptoms, while ASD symptoms were an exclusion criterion for the ADHD group. In a more recent study, more severe ASD symptoms predicted worse working memory performance relative to ADHD-only and typically developing youth (Karalunas et al., 2018). The most consistently supported conclusion is that overall working memory is impacted for both disorders relative to typically developing youth.

Examination of response inhibition with the SST revealed that ADHD severity did not uniquely predict increased problematic response inhibition or slower responding. However, ADHD severity did predict worse accuracy during “Go” trials. These results indicate less efficient perception and execution of the correct response during this forced choice task. In contrast, ADHD severity did predict more errors on the MFFT as well as commission errors on the CPT. These results signify that, among ASD youth, comorbid ADHD symptoms may compound disruptions in response inhibition.

Previous studies have generally concluded that weakened performance in particular cognitive domains are characteristic of both ASD and ADHD (Corbett et al., 2009; Sinzig et al., 2008). Although some studies indicate more pronounced difficulties in one diagnosis or the other, the emerging findings in this small literature are mixed (Boxhoorn et al., 2018; Geurts et al., 2004; Happe et al., 2006). Among youth with comorbid ASD, severity of ADHD has been associated with weaker performance on tasks tapping attention and response inhibition (Sanderson & Allen, 2013; Sinzig et al., 2008). Overall, we obtained support for the hypothesis that comorbid ADHD symptomatology in youth with ASD is associated with more problems on tasks tapping attention, impulsivity, and immediate memory. Across most tasks, elevated ADHD severity also predicted slower responding (with the exception of the SCT, where there was also a trend toward poor accuracy).

As with any study, there are limitations to note. An important interpretive factor is that the current cross-sectional findings cannot establish causality or direction of effect. While these findings may indicated that greater ADHD severity leads to disruptions in underlying cognitive domains, it is possible that the underlying disruptions of these domains are shared across phenotypes and ADHD behavior emerges through a unique process in youth with ASD. Indeed, a recent study with a large sample using empirical methods to define diagnostic “classes” concluded some cognitive impairment was shared across both disorders while other cognitive deficits appeared to be unique to each diagnostic class (Karalunas et al. 2018). Longitudinal examination of cognitive development within the population of individuals with ASD is needed to clarify these processes.

Although it would be of interest, investigating the impact of ADHD presentation types (i.e., combined, predominately inattentive, and predominantly hyperactive/impulsive presentations) and other comorbid psychiatric symptomatology on cognitive task performance was not undertaken in this study due to limitations of statistical power due to our sample size. However, future studies should investigate whether all three ADHD presentations are significantly associated with weaker cognitive performance—and associated areas of decrement. Such studies and could potentially inform intervention for children with comorbid ASD and ADHD. Future studies may also be able to assess the role that attentional factors have on inhibition, and vice versa, to examine additional layers of cognitive performance that may be affected by symptoms of ADHD and ASD in children with ASD.

Another potential limitation of our study is that it did not include a large number of children with ASD who did not have significant ADHD symptoms. Although it was beyond the scope of this investigation to do so, future studies including groups of ASD-diagnosed youth with a wider range of clinical symptoms of ADHD comorbidity are still needed (Rommelse, 2011). Additionally, as noted in Mansour et al. (2017), the children seen in this study were on average somewhat higher functioning (mean IQ=84) relative to the full spectrum of ASD. As others have noted (e.g., Aman, 1991) ADHD may be manifested in a more “cognitive” manner in higher-functioning individuals with developmental disability, and in a more “motoric” manner in lower-functioning individuals. Future studies might include more specific ranges of cognitive profiles (e.g., lower vs. higher IQ levels)—and thus may be able to provide further insight into this question. It is clearly an issue warranting further investigation.

Additional potential limitations include the fact that some children were taking non-stimulant medications when they were tested, and some had other psychiatric conditions. Although these factors may have impacted task performance, we did not have sufficient statistical power to assess these effects in our sample. Although beyond the scope of this study to assess these possible effects, such factors warrant further investigation in future studies with larger sample sizes.

The current results support the conception that comorbid ADHD symptomatology in youth with ASD places them at higher risk for impaired attention and memory on cognitive tasks. It will remain for future investigations to assess the extent to which task performance is associated with cognition in the “real world” in children with ASD+ADHD. Research has also documented that among youth with ADHD, similar cognitive difficulties (as associated with cognitive task performance) are associated with functional impairment in academics, social functioning and behavioral dysregulation (Gropper & Tannock, 2009). Thus, the current results support the need to closely evaluate various aspects of cognitive function in children with ASD +ADHD to inform treatment planning. In doing so, the intervention plan for children with ASD +ADHD may facilitate more optimal developmental outcomes.

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What this paper adds:

This paper contributes to the growing literature studying the nature of ADHD in the context of ASD. Our findings are that the cognitive deficits that are typically associated with ADHD in the general pediatric population are also found in higher-functioning children with ASD who also have significant ADHD symptomatology—and that these deficits become more severe as ADHD symptoms become more severe. Our findings also demonstrated that these cognitive task deficits are unrelated to ASD symptomatology. Taken collectively, these findings provides further evidence that ADHD and ASD are two distinct disorders—and that higher-functioning children with ADHD+ASD may have similar profiles on cognitive task performance that are seen in children with ADHD in the general pediatric population.

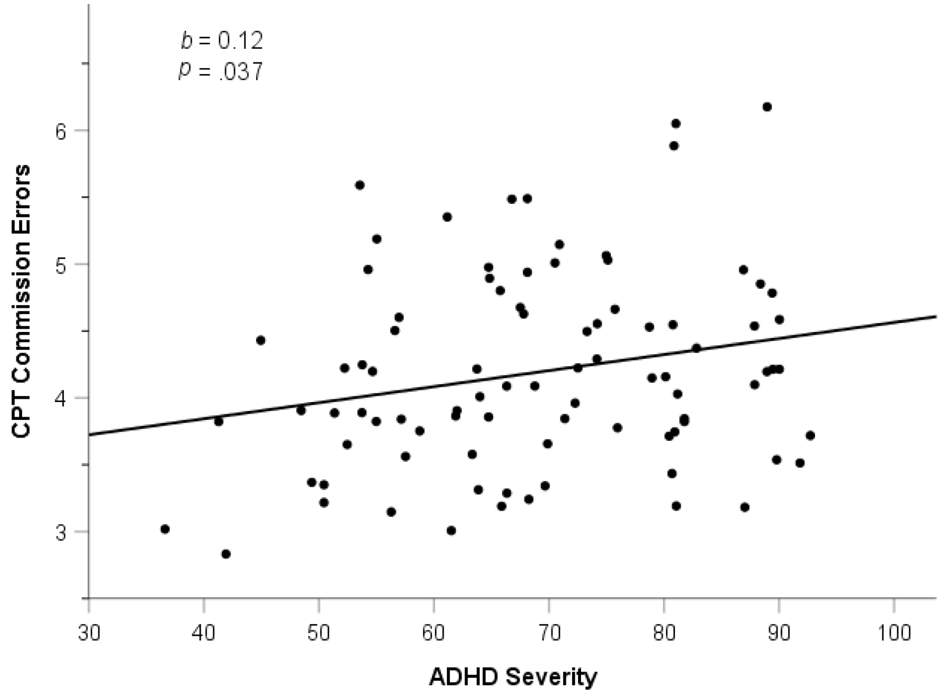

Figure 1.
Partial plot of Continuous Performance Task commission errors and ADHD severity

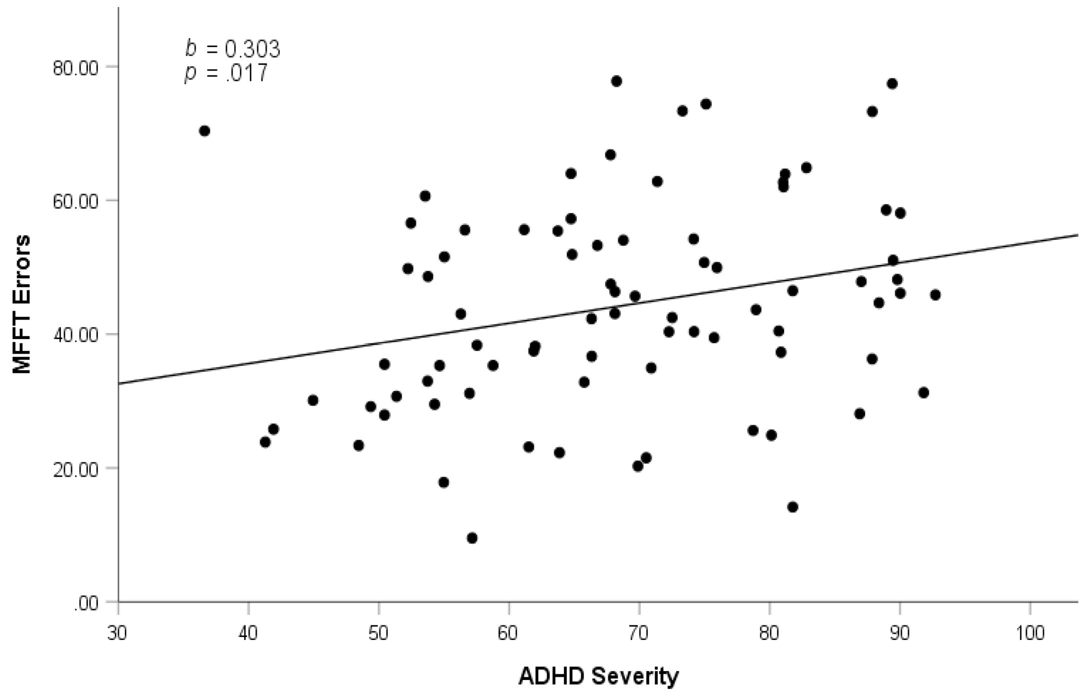

Figure 2.
Partial plot of Matching Familiar Task errors and ADHD severity

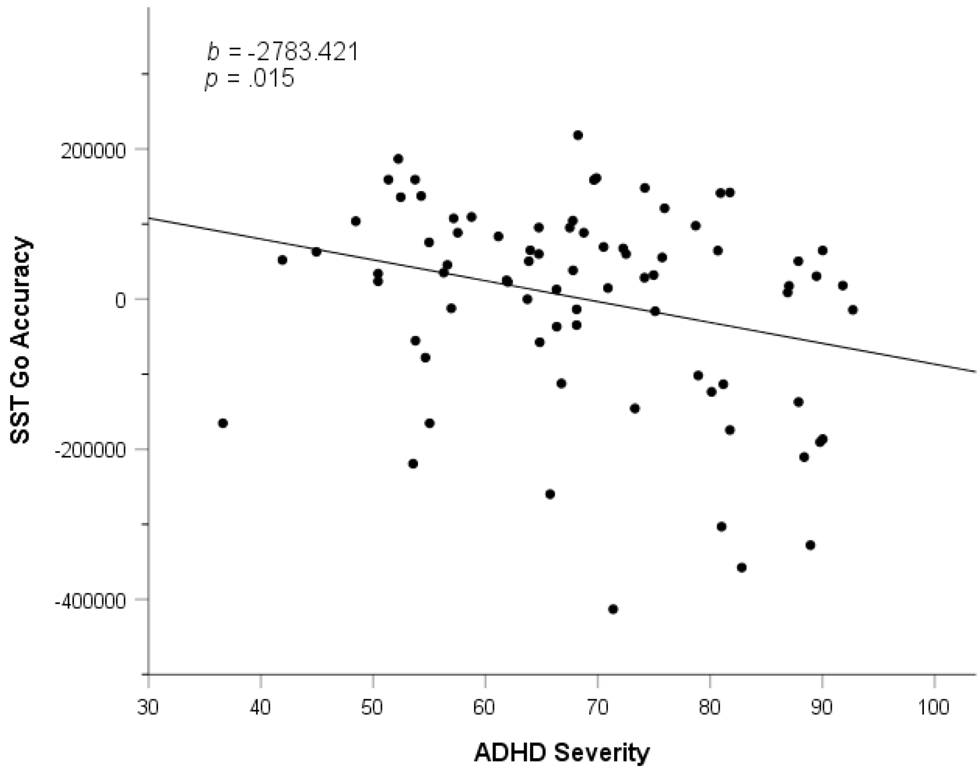

Figure 3.

Partial plot of Stop Signal Task “Go” trial accuracy and ADHD severity

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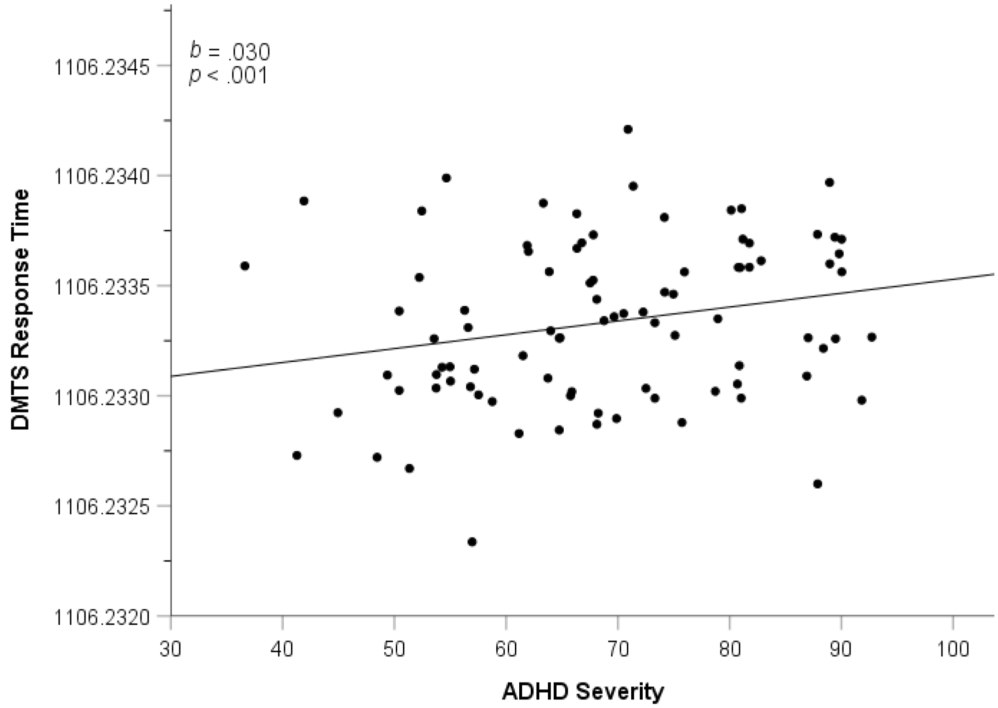

Figure 4.

Partial plot of Delayed Match to Sample Task response time and ADHD severity

Table 1.

Participant Characteristics

Characteristic	n	%
Gender		
Male	73	79.3
Female	19	20.7
Autism Diagnosis		
Autistic Disorder	54	58.7
Asperger's	17	18.5
PDD-NOS	21	22.8
Race/ethnicity		
Caucasian	56	60.9
African American	14	15.2
Hispanic	16	17.4
Asian	5	5.4
"Other" or no data provided	1	1.1
Comorbid Diagnoses Assessed		
ADHD	80	87
Predominantly Inattentive	20	25
Predominantly Hyperactive-Impulsive	1	1
Combined	59	74
Specific Phobia	27	29
Oppositional Defiant Diagnosis	18	20
Enuresis	10	11
Social Phobia	6	7
Encopresis	2	2
Dysthymic Disorder	3	3
Conduct Disorder	2	2
Generalized Anxiety Disorder	2	2
Major Depressive Disorder	1	1
Separation Anxiety Disorder	1	1
Anorexia Nervosa	1	1
Variable	***Mean (SD)***	***Range***
Age (years)	9.41 (1.87)	6.67–13.50
SB5 Full Scale IQ	84.18 (19.56)	46–128
SB5 Mental Age (years)	7.94 (3.24)	3.1–21
ADI-R Sum of Subscales	47.71 (10.90)	23–66
CPRS Global Index T Score	68.91 (13.50)	37–90
CTRS Global Index T Score	67.99 (12.11)	45–90

Table 2.

Comparative effects of ADHD symptom severity and ASD symptoms severity on Cognitive Tasks (with SB5 Mental Age as a Covariate)

Task/Variable	Mean (SD)	Transformation Used	*F*	*p*	Partial Slope (b)	Incremental R^2
Continuous Performance Task (*n*=88)						
Commissions	4.19 (5.84)	ln(x+c)				
ADHD Severity			4.48	.037	.012	.046
ASD Severity			1.67	.200	−.009	.017
SB5 Mental Age (MA)			7.60	.007	−.623	.078
Omissions	1.59 (2.07)	−(1/x+c)				
ADHD Severity			1.83	.179	.003	.016
ASD Severity			0.30	.585	−.001	.003
MA			25.88	.000	−.414	.221
Response Time	557.99 (127.84)	ln(x+c)				
ADHD Severity			0.01	.914	<001	<.001
ASD Severity			0.06	.813	−.001	<.001
MA			11.89	001	−.226	.124
Speeded Classification Task (*n*=86)						
Errors	3.68 (3.16)	ln(x+c)				
ADHD Severity			3.40	.069	.007	.023
ASD Severity			0.56	.455	−.004	.004
MA			57.44	.000	−1.12	.397
Response Time	1037.65 (375.93)	N/A				
ADHD Severity			3.35	.071	−4.860	.031
ASD Severity			0.04	.850	−.646	<.001
MA			24.08	.000	−522.50	.221
Dichotic Listening Task (*n*=71)						
% Correct Responses	78.08 (20.18)	N/A				
ADHD Severity			0.80	.373	.006	.007
ASD Severity			0.04	.848	.002	<.001
MA			52.64	.000	−2.15	.429
Omission Errors	0.13 (0.31)	$-(1/(x+1)^2)$				
ADHD Severity			0.15	.702	.001	.002
ASD Severity			0.19	.668	.001	.002
MA			17.90	.000	−.336	.213
Intrusion Errors	0.69 (0.71)	N/A				
ADHD Severity			1.83	.180	.007	.019
ASD Severity			0.67	.797	.002	.001
MA			27.00	.000	−1.22	.275

Task/Variable	Mean (SD)	Transformation Used	*F*	*p*	Partial Slope (b)	Incremental R^2
Delay of Gratification (*n*=86)						
Overall Efficiency	0.74 (0.20)	N/A				
ADHD Severity			1.41	.238	−.002	.014
ASD Severity			1.31	.255	.002	.013
MA			18.44	.000	.244	.182
Correct responses	46.06 (10.75)	N/A				
ADHD Severity			0.04	.845	−.015	<.001
ASD Severity			0.92	.341	−.094	.009
MA			21.36	.000	13.62	.201
Number of Responses	67.13 (21.31)	N/A				
ADHD Severity			0.45	.503	.116	.005
ASD Severity			1.86	.177	−.304	.022
MA			.82	.369	−6.00	.010
Matching Familiar Figures Task (n=81)						
Errors	44.22 (18.38)	N/A				
ADHD Severity			5.96	.017	.303	.052
ASD Severity			0.63	.429	.126	.006
MA			30.92	.000	−29.33	.270
Response Time	6065.16 (3511.43)	N/A				
ADHD Severity			2.38	.127	−43.875	.030
ASD Severity			0.12	.735	12.349	.001
MA			0.01	.913	133.190	<.001
Stop Signal Task (*n*=79)						
Stop Signal RT	427.20 (204.13)	sqrt(x+c)				
ADHD Severity			1.90	.172	.051	.020
ASD Severity			0.39	.534	−1.088	.021
MA			17.77	.000	−6.30	.189
Stop Signal Accuracy	50.85 (10.35)	N/A				
ADHD Severity			2.49	.119	−.136	.031
ASD Severity			0.32	.571	.061	.004
MA			3.31	.073	6.36	.041
Go Accuracy	93.93 (6.11)	x^3				
ADHD Severity			6.15	.015	−2783.421	.065
ASD Severity			2.77	.100	2292.715	.029
MA			12.21	.001	158416.39	.129
Stop Signal Delay	362.57 (166.92)	N/A				
ADHD Severity			0.56	.456	−1.045	.007
ASD Severity			2.70	.105	2.858	.034

Task/Variable	**Mean (SD)**	**Transformation Used**	***F***	***p***	**Partial Slope (b)**	**Incremental R^2**
MA			1.36	.247	66.61	.017
Delayed Match to Sample (*n*=90)						
Response time	1106.23 (567.45)	−(1/x+c)				
ADHD Severity			4.87	.030	<.001	.046
ASD Severity			0.28	.596	<−.001	.003
MA			13.67	.000	.000	.143
Proportion Correct	0.61 (0.19)	N/A				
ADHD Severity			0.47	.494	.001	.005
ASD Severity			0.02	.889	<.001	<.001
MA			3.23	.076	.100	.036

Please note: Mental age from the SB-5 served as a covariate in all models. ADHD severity = CPRS-R:L Global Index T Score. ASD severity = Total sum of ADI-R. Means are untransformed, while inferential statistics are reported as transformed data. Incremental R^2 = difference between R^2 with all variables in the model and the R^2 with the variable of interest removed. The partial slope is the unstandardized regression coefficient.

Table 3.

Correlation Matrix of Independent Variables (including associated confidence intervals) associated with each correlation

Variable	ADHD Severity	ASD Severity	Mental Age (Transformed)
ADHD Severity	1.00	−.01* (−0.214 to 0.195)	−.07** (−0.27 to 0.136)
ASD Severity	−.01* (−0.214 to 0.195)	1.00	−.19* (−0.38 to 0.015)
Mental Age (Transformed)	−.07** (−0.27 to 0.136)	−.19* (−0.38 to 0.015)	1.00

Note.

* p=.90

** p=.50

*** p=.069.