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Autism and Attention Deficit Hyperactivity Disorder: Assessing Comorbidity with the Integrated Visual and Auditory Continuous Performance Test

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Abstract

Symptoms of attention deficit hyperactivity disorder (ADHD) have been reported in significant numbers of children with autism spectrum disorder (ASD). The current study investigated the comorbidity of ADHD in children with ASD using a neuropsychological measure of attention and response control, the Integrated Visual and Auditory Continuous Performance Test (IVA). Results indicate that a substantial majority of children with ASD show significant deficits in visual and auditory attention that were indistinguishable from children with ADHD. Further, the children with ASD showed greater deficits in impulsivity than the ADHD or the typically developing children. Issues of comorbidity are discussed.

Introduction

Autism is a severe neurodevelopmental disorder characterized by qualitative impairment before the age of three in verbal and nonverbal communication, reciprocal social interaction, and a markedly restricted repertoire of activities and interests (APA, 1994). In addition to these features, attentional abnormalities and hyperactive behavior have been suggested to occur in some children with pervasive developmental disorder (PDD;(Wing, 1997). In fact it has been theorized that impairments in attention and arousal may underlie some of the primary neuropathological functioning of individuals with autism (Courchesne, Lincoln, Yeung-Courchesne, Elmasian, & Grillon, 1989; Dawson, Finley, Phillips, & Lewy, 1989; Wainwright-Sharp & Bryson, 1993). Nevertheless, some neuropsychological investigations do not support theories purporting fundamental deficits in attention (Garretson, Fein, & Waterhouse, 1990; Minshew, Goldstein, Muenz, & Payton, 1992). Attentional problems impact the child with autism in the ability to accurately perceive, understand and respond in a meaningful way to environmental and social stimuli. Various studies have linked the attentional difficulties present in many individuals with autism spectrum disorders (ASD) to the specificity, complexity or motivational features of the stimuli (Courchesne et al., 1994; Garretson et al., 1990; Mann & Walker, 2003; Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998; Pierce, Glad, & Schreibman, 1997) .

Some investigations have attempted to establish phenotypes by identifying subgroups of children with autism spectrum disorder based on the presence or absence of symptomotology. For example, deficits in various aspects of attention have been

associated with subtypes of autism (Bonde, 2000). Most recently, Sturm and colleagues (Sturm, Fernell, & Gillberg, 2004) determined that 95% of the children in their sample exhibited attentional problems, 75% had motor difficulties, 86% had problems with regulating activity level and 50% demonstrated impulsive behavior. These results are highly suggestive of a large subgroup of children with ASD that present with symptoms of attention deficit hyperactivity disorder (ADHD). Children with ADHD are characterized by symptoms of inattention, hyperactivity and impulsivity (APA, 1994). Although many clinicians and researchers will acknowledge that varying degrees of ADHD symptoms may be present, the question of comorbidity, defined as the presence of two or more co-occurring disorders, must be elucidated and considered in the assessment and treatment of ASD.

Clinicians and researchers have frequently reported that many children with high-functioning autism are often misdiagnosed or initially diagnosed with ADHD (Jensen, Larrieu, & Mack, 1997; Keen & Ward, 2004; Perry, 1998). It has been postulated that the increased identification of autism in children with ADHD may be a contributing factor in the rise of reported prevalence of autism(Charman & Baird, 2002; Keen & Ward, 2004). Conversely, Clark (Clark, Feehan, Tinline, & Vostanis, 1999) warned that children diagnosed with ADHD should also be evaluated for symptoms of PDD. Thus, it is apparent that differentiating between these disorders, particularly high functioning autism (HFA) and ADHD, can be quite challenging (Barkley, 1990; Gillberg, 1992) due to overlapping symptoms (Clark et al., 1999; Pennington & Ozonoff, 1996; Roeyers, Keymeulen, & Buysse, 1998).

In consideration of the diagnoses of ASD and ADHD, the possibility of comorbidity remains a plausible but tentative option for many clinicians. Although the current DSM-IV diagnostic manual identifies short attention span, impulsivity and hyperactive behavior as part of the associated features of autism, a diagnosis of ADHD cannot be provided "if the symptoms of inattention and hyperactivity occur exclusively during the course of a pervasive developmental disorder"(APA, 1994). Despite this restriction many clinicians determine that the two disorders are comorbid and choose to make a dual diagnosis. Ghaziuddin and colleagues (Ghaziuddin, Tsai, & Alessi, 1992) argued that when appropriate a separate diagnosis of ADHD in PDD will provide clinical utility, guide treatment and encourage research into the comorbidity of these disorders. The presence of ADHD with ASD is critical to recognize because of the impact of associated problems with these disorders (Kadesjo & Gillberg, 2001) and the possible exponential risk associated with such cases of comorbidity (Goldstein & Schwebach, 2004).

To date, there have been surprisingly few empirical studies to support or refute the dual diagnosis practice. Frazier et al., (Frazier, 2001) reported that 83% of children with PDD exceeded the threshold and met full diagnostic criteria and were shown to be more impaired than children without comorbid ADHD. Yoshida and Uchiyama (Yoshida & Uchiyama, 2004) evaluated 53 subjects with autism spectrum disorders and determined that a significant percentage met criteria for ADHD. Specifically, the co-occurrence rate of ADHD was reported to be 85% for Asperger syndrome and pervasive developmental disorder-not otherwise specified (PDD-NOS) and 57.6% for children with autistic

disorder. Furthermore, the authors found that ADHD symptoms were more common in younger children. This age related finding was also reported in an earlier study of children with Asperger syndrome (Ghaziuddin, Weidmer-Mikhail, & Ghaziuddin, 1998). In a retrospective chart review to determine the comorbidity of ADHD in children with PDD, Goldstein and Schwebach (Goldstein & Schwebach, 2004) demonstrated that 26% met DSM-IV criteria for the Combined Type and 33% met criteria for Predominantly Inattentive Type. These results support clinical observation of a substantial subgroup of children evidencing comorbid ADHD with PDD.

The behavior of children with autism and ADHD has been characterized as similar to that of patients with frontal lobe damage (Damasio & Maurer, 1978; Stuss & Benson, 1984). Neuropsychological (Bennetto, Pennington, & Rogers, 1996; Ozonoff & Jensen, 1999; Prior & Hoffmann, 1990; Rumsey & Hamburger, 1988), neuropathological (Casanova, Buxhoeveden, Switala, & Roy, 2002), as well as structural and functional investigations (Baron-Cohen et al., 1999; Horwitz, Rumsey, Grady, & Rapoport, 1988; Luna et al., 2002; Minshew, Luna, & Sweeney, 1999) have implicated involvement of the frontal cortex in autism. Similarly, numerous neuroimaging investigations have provided strong support for the involvement of the frontal lobes in ADHD (Faraone & Biederman, 1998; Hale, Hariri, & McCracken, 2000; Lou, Henriksen, & Bruhn, 1984). A few studies have compared both groups and have shown comparable frontal lobe involvement (Aoyagi et al., 2002).

Despite the neuropsychological overlap, a few studies have attempted to distinguish the two disorders using social and communication checklists and questionnaires. Guerts et al., (Geurts et al., 2004) used the parent and teacher Children's Communication Checklist (Bishop, 1998) in which a discriminant function analysis correctly classified 73-78% of the cases. Similarly, Luteijn and colleagues (Luteijn et al., 2000) used a variety of parent report questionnaires, which were able to distinguish children with PDD-NOS from ADHD by the nature and severity of their social problems. Nevertheless, children with PDD-NOS demonstrated attentional problems comparable to those with ADHD and children with both disorders showed attention deficits in excess of ADHD alone (Luteijn et al., 2000).

Thus, issues of comorbidity (co-occurring diagnoses), phenotypes (subgroups of individuals within a disorder) and profiles (levels of functioning across domains of ability within or between disorders) in these heterogeneous disorders demands further exploration. Until such investigations are able to separate these theoretical constructs, clinicians need to provide more comprehensive neuropsychological evaluations to identify the individual strengths and weaknesses to guide treatment; and research must be expanded to evaluate these groups in parallel.

The current investigation explores the presence of attention deficits in autism as compared to children with ADHD and typically developing children. This was accomplished through three goals. The first goal was to determine the comorbidity of ADHD in children with ASD. The second goal was to assess the utility of a

neuropsychological measure designed to facilitate the diagnosis of ADHD in being able to identify ADHD across diagnostic groups (i.e., autism with ADHD). The third goal was to compare the objective neuropsychological data to parent report measures pertaining to factors of attention and hyperactivity. In short, the current investigation attempts to profile attentional deficits for both children with ADHD and children with ASD.

The term Continuous Performance Test (CPT) was first coined by Rosvold and colleagues (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) to refer to a test that was designed to measure lapses in attention in individuals with epilepsy. Over the years, a variety of presentation methods have been designed (e.g., visual, auditory, verbal). Following extensive review of neuropsychological measures, Barkley (Barkley, 1994) concluded that CPTs are the best objective measure for diagnostic accuracy of ADHD. Nevertheless, a CPT is usually one of many sources of information, including history that contributes to the clinical diagnosis.

Theoretical Basis of the IVA

The Integrated Visual and Auditory (IVA) Continuous Performance Test (CPT) was designed primarily to help in the diagnosis and quantification of the symptoms of ADHD (Sandford & Turner, 2000). It has also been used to measure attention and self-control across a variety of neurodevelopmental and psychiatric conditions as well as serving as an objective measure of the effects of treatment. The IVA has been shown to make a significant contribution to neuropsychological testing; however, it is unclear how well it can differentiate diagnostic groups (Tinius, 2003).

The IVA is based on theoretical conceptualizations of ADHD advanced by Barkley (Barkley, 1993)as well as Sohlberg and Mateer's (Sohlberg & Mateer, 1987) model that conceptualized attention as a multidimensional capacity that includes five primary factors including focused, sustained, selective, alternating and divided attention. *Focused attention* refers to the ability to make correct discriminative responses to the specific targets. *Sustained attention* refers to the ability to maintain a stable and reliable behavioral response measured by changes in reaction time. *Selective attention* includes the ability to correctly maintain a cognitive set of internalized rules that involve inhibiting and responding discriminatively to specific stimuli. *Alternating attention* involves the ability to flexibly shift mental set to different cognitive demands. *Divided attention* refers to the ability to simultaneously respond to specific, multiple and demanding tasks by balancing both accuracy and speed across two modalities.

The IVA is comprised of twenty-two subscales that provide data regarding inattention, inhibition, consistency of response, variability in attention and overall speed of discriminating reaction time. The IVA can be administered to individuals between 5 years to adult. The test is intended to be mildly boring and to produce errors of commission (i.e., impulsivity) and errors of omission (i.e., inattention) through a series of trial sets requiring responding and not responding, respectively. Thus, the IVA combines inattention and impulsivity in a counter-balanced design across both visual and auditory modalities; thus, integrating four CPTs in one.

In addition, the approach of the IVA was developed specifically to be useful in following the DSM-IV diagnostic criteria to facilitate differentiating the three primary subtypes of ADHD (Predominantly Inattentive, Predominantly Hyperactive-Impulsive, and Combined). The measure provides standardized quotients with a mean of 100 and a standard deviation of 15. The Full Scale Response Quotient (FSRQ) is based on the Auditory Response Control Quotient (ARCQ) and the Visual Response Control Quotient (VRCQ). The ARCQ and the VRCQ are in turn based on equal weights of Prudence (impulsivity and response inhibition), Consistency (reliability of response time and staying on task), and Stamina (sustained attention and effort over time). The Full Scale Attention Quotient (FSAQ) is based on the Auditory Attention Quotient (AAQ) and Visual Attention Quotient (VAQ). Subsequently, the AAQ and VAQ are based on equal rates of Vigilance (inattention), Focus (speed of mental processing), and Speed (reaction time).

Methods

Participants:

Three groups of children participated in this study: 15 children with high functioning (IQ > 70) ASD (autism = 8, Asperger = 3, PDD-NOS = 4); 15 children with ADHD (combined = 13, primarily inattentive = 0, primarily hyperactive/impulsive = 2) and 15 typically developing children (TYP). The experimental and control groups were balanced on age, gender and ethnicity, but not intellectual functioning. The children ranged in age between 7 to 12 years with the mean age of 9.76 years. The mean IQ for the total sample was 107 (see Table 1.). The ethnicity of the groups were as follows: ASD

and TYP = 1 African-American, 2 = Hispanic, 12 = Caucasian; ADHD: 1 = Asian, 1 African-American, 3 = Hispanic, 10 = Caucasian. The medication status of the participants included: 7 ADHD participants were on stimulant medication (Dexedrine, Methylphenidate, Adderall), 3 ASD participants were on SSRI medication (Fluoxetine, Paroxetine), and 1 ASD participant was on stimulant medication (Adderall). Children prescribed methylphenidate were asked to discontinue medication the day prior to testing. Inclusion criteria for all subjects consisted of having an IQ $\geq$70, an absence of Fragile X or other serious neurological (e.g., seizures), psychiatric (e.g., Bipolar disorder) or medical conditions. All subjects were screened for current and past physical illness. Children with known endocrine, cardiovascular, pulmonary, liver or kidney disease were excluded from enrollment in the study.

The children with ASD were diagnosed using previous records or concurrent testing with the Autism Diagnostic Observation Schedule (ADOS; (Lord, 1999) and clinical judgment based on DSM-IV criteria (APA, 1994). Criteria for acceptance into the ADHD group consisted of current diagnosis based on DSM-IV criteria (APA, 1994), documentation from previous record or concurrent neuropsychological testing, and parent screening measures. The typically developing children were screened via parent interview for the absence of neurodevelopmental disorders, including autism and ADHD.

Research participants were recruited from the University of California, Davis M.I.N.D. (Medical Investigation of Neurodevelopmental Disorders) Institute Subject Tracking System (STS) or responded to announcements placed in various schools, recreational

facilities and websites. The University of California, Davis Institutional Review Board (IRB) approved the study. Prior to inclusion, the child's parent completed written informed consent and the child assented to participate in the study. The completion of the diagnostic, neuropsychological measures and questionnaires were part of an ongoing comprehensive investigation.

Instruments

Autism Diagnostic Observation Schedule (ADOS; (Lord, 1999). The ADOS is comprised of semi-structured interactive activities conducted with a child and designed to assess specific current behaviors indicative of autism. The tasks focus upon the three areas of impairment associated with autism: social functioning, communicative functioning, and restricted activities. The ADOS provides an algorithm with cut-offs for autism spectrum disorders (Lord, 1999).

Conners' Parent Rating Scale-Revised (Short) (CPRS-R:S; (Conners, 2001). The CPRS-R:S is a parent rating scale, which provides a narrow range of information about behaviors associated with attention and/or hyperactivity as well as oppositional behavior. The Conners' is considered a standard and valid measure frequently used in the assessment of ADHD. The Conners' was given to all participants. The internal reliability Cronbach's alpha coefficient for the Conners' ranges from .91 to .94 for the total scores for the age groups in this investigation. Test-retest reliability is moderate to high across various forms with coefficients as follows: Oppositional 0.62, Cognitive Problems/Inattention 0.73, Hyperactivity 0.85, and ADHD Index 0.72. The data for the

CPRS-R:S items had excellent fit to the three-factor model. The results are presented as T-scores in which the average range is defined by scores from 40 to 60. It was used as an index of reported ADHD symptoms.

Behavior Assessment System for Children Monitor (BASC-M; (Kamphaus & Reynolds, 1998) is a parent-report targeted measure of ADHD behaviors. The BASC-M is comprised of 45 items across four scales: Attention Problems, Hyperactivity, Internalizing Problems, and Adaptive Scales. The BASC-M can be used from age 4 through 18 years of age. The reliability for the BASC-M ranges from moderate to good across the domains. Specifically, internal consistency values of coefficient alpha range from .71 to .83 for Attention Problems, .64 to .73 for Hyperactivity, .67 to .81 for Internalizing Problems, and .80 to .82 for Adaptive Skills. In regards to validity, previous studies have shown that the BASC-M was able to differentiate between ADHD subgroups as well as between ADHD and non-ADHD children (Kamphaus & Reynolds, 1998; Vaughn, Riccio, Hynd, & Hall, 1997) . The questionnaire was used as an additional index of current ADHD symptoms.

Wechsler Abbreviated Intelligence Scale (WASI; (Wechsler, 1999) is a measure of general intelligence to obtain an estimated IQ for inclusion/exclusion into the study. The WASI was used for participants if IQ assessment had not been completed within the past year with a more comprehensive intelligence measure (i.e., Wechsler Intelligence Scale for Children-Fourth Edition).

The Integrated Visual and Auditory (IVA) Continuous Performance Test (CPT; (Sandford & Turner, 2000) was used as the primary dependent measure. The measure produces a mean of 100 and a standard deviation of 15. Thus scores between 85 to115 define the average range. The test-retest reliability correlations range from .37 to .75 on the various scales indicating moderate to good stability over time. The proportion of ADHD determined to be positive using the IVA, or sensitivity, was 92%. The specificity, or proportion of non-ADHD children who received a negative finding on the IVA was 90%. Further, 89% of ADHD individuals test positive (Positive Predictive Power) and 93% test negative (Negative Predictive Power) using the IVA (Sandford & Turner, 2000). In regards to typically children the IVA shows acceptable false positive rates of 7.7%. The IVA was found to have excellent concurrent validity when compared to other CPTs and parental rating forms for diagnosing ADHD (Sandford & Turner, 2000).

Procedures:

All participants were tested individually during the course of one visit. The parents were sent letters providing the results of their child's performance. The children received minimal financial compensation and selected toys at the conclusion of testing.

The IVA test was completed on an HP Compaq Intel Pentium 4 computer with a 15 in flat panel HP 1530 monitor. Participants were seated approximately 24 inches away from the screen. We used Koss UR-10 headphones on the participant. A two-button mouse was placed in the dominant hand of the participant.

Instructions were presented through visual and auditory instruction on the computer. During the warm-up, the participant was instructed to click the mouse when they *saw* a "1" (10 trials) followed by instruction to click when they *heard* a "1" (10 trials). Next, the participants were instructed and provided with practice trials to click the mouse when they saw or heard a "1" (target) but to not click the mouse when they saw or heard a "2" (foil). During the main test portion of the IVA, choice reaction time (CRT) was recorded for the participant's responses to the target and foil stimuli on five sets of 100 trials for a total of 500 trials. Each set consisted of two blocks of 50 trials each. Each trial is 1.5 seconds. The visual targets are 1.5 inches high and are presented for 167 milliseconds (ms). The auditory stimuli last 50 ms.

The first block of the main test collects a measure of impulsivity by creating a ratio of target to foil of 5.25:1.0 resulting in 84% of trials or 42 out of 50 trials presenting "1"s (targets) intermixed with eight "2"s (foils). The second block pulls for inattention by reversing the order and presenting many "2"s or foils and few "1"s or targets resulting in 165 of stimuli being "1"s. The stimuli are presented in a psuedo-random order of visual and auditory stimuli. This is followed by a "cool down" period. The duration of the main portion of the test was 13 minutes. However, the entire IVA with introduction, practice, testing and cool down took approximately 20 minutes.

Statistical Analysis

Data analysis was designed to yield information relative to the presence of attention and impulsivity in children with autism and ADHD compared to typically developing

children. It was hypothesized that children with autism would demonstrate attention and response control deficits commensurate with children with ADHD. Secondly, it was hypothesized that the dependent measures would discriminate those children with and without ADHD symptoms. Statistical analysis was performed using SPSS® (Narusis, 1993). Multivariate analysis of covariance (MANCOVAs) were conducted using age and FSIQ as covariates. FSIQ was controlled for due to the significant group differences for estimated intelligence. Age was controlled for because attention, activity level and speed of processing are still developing across this age range despite the fact that there were no group differences for age in our sample. Discriminant functional analysis (DFA) was performed to determine the contribution of the dependent variables in predicting ADHD and in classifying the groups. Lastly, it was hypothesized that the objective neuropsychological measures would be highly correlated with parental report measures.

Quantitative Analysis:

The IVA manual (Sandford & Turner, 2000) provides detailed guidelines for characterizing children across the three ADHD diagnostic categories (predominantly inattentive, predominantly hyperactive-impulse, combined) based on their performance on the IVA. We used the general guidelines but chose a cut-off criteria of 1 standard deviation or a standard score of < 85 on the various discriminating domains (i.e., FSAQ).

Results

Descriptive statistics for the 45 participants across the three groups are presented in Table 1. Chi square analysis demonstrated that the three groups did not differ relative to gender

χ^2 (2, N=45) = 1.67, p= 0.44, or age χ^2 (2, N=45) = 0.52, p= 0.77 or ethnicity χ^2 (2, N=45) = 0.97, p= 0.61. There was a significant difference between the groups for IQ F(2, 42) = .6.18, p= 0.04. Hotelling's T^2 was performed to determine that the results of the variable did not occur by chance alone, and the results were statistically significant, F(6,42) = 2.11, p <.001.

Insert Table. 1 about here

The means and standard deviations are reported in Table 2. for the parent report measures, which include the Conners' Parent Rating Scales and the BASC Monitor. The groups differed significantly on all of the variables with the exception of the BASC adaptive scale F(2,40) = 2.51, p = .09.

Insert Table 2. about here

The means and standard deviations of the six dependent measures were compared between the experimental and comparison groups and are presented in Table 3. as well as in Graphs 1 and 2.

Insert Table 3. about here

Insert Graph 1 and 2 about here

The MANCOVA results were statistically significant for all variables except for the ARCQ, which approached significance (see Table 4). The independent pairwise univariate comparison results were as follows: FSRQ ($F(2,40) = 10.44$, $p<.001$); ARCQ ($F(2,40) = 3.20$, $p=.051$); VRCQ ($F(2,40) = 16.47$, $p<.001$); FSAQ ($F(2,40) = 6.66$, $p=.003$); AAQ ($F(2,40) = 4.85$, $p=.013$); VAQ ($F(2,40) = 4.49$, $p=.017$).

Insert Table 4. about here

The DFA using all six IVA variables was significant in classifying subjects as either ASD, ADHD or TYP, $\chi^2(4, N=45) = 42.84$, $p<.000$. The analysis resulted in two functions; Function 1 was comprised primarily of response control variables and Function 2 was comprised primarily of the attention variables. The structured coefficients, which are pooled within-group correlations between the discriminating variables and the canonical discriminant function, are presented in Table 5. As can be seen from the structure coefficients, the largest correlations occur between the VRCQ for Function 1 and FSAQ for Function 2. A stepwise discriminant analysis (not presented here) confirmed these results with only these two variables entered into the model. Thus the DFA is comprised primarily of the aforementioned variables. The correlation of the other remaining variables seems essentially the result of how they correlate with the VRCQ and the FSAQ.

Insert Table 5. about here

The classification results, presented in Table 6., indicate that 75.6% of the original group cases are correctly classified. Specifically, 86.7% of the ASD, 66.7% and 73.3% of the cases were correctly classified.

Insert Table 6. about here

The qualitative analysis of the IVA using the manual guidelines (Sandford & Turner, 2000) for characterizing the children across the three ADHD diagnostic categories (combined, predominantly inattentive, predominantly hyperactive-impulse) based on their performance on the IVA resulted in 76% of the sample being correctly classified (Table 7).

Insert Table 7. about here

Lastly, Pierson correlation coefficients were calculated between the six IVA dependent variables and the attention and hyperactivity domain scores for the parent report measures. The FSAQ from the IVA showed a moderate correlation with the two attention domains of the BASC (B-ATT $r = -.51$, $p = .000$) and the Conners (C-INA $r = -.49$, $p = .001$), respectively. However, the FSRQ showed only a modest correlation with the B-ATT $r = .32$, $p = .032$) and did not correlate with the attention or hyperactivity indices from both parent report measures.

Discussion

The current study had three goals to elucidate the comorbidity of ADHD in children with autism spectrum disorder. The first goal was to determine the presence of ADHD symptoms using a neuropsychological measure of attention and response control. The second goal was to assess the utility of a neuropsychological measure designed to facilitate the diagnosis of ADHD in being able to identify ADHD across diagnostic groups (i.e., autism with ADHD). The third goal was to compare the objective neuropsychological data to parent report measures pertaining to factors of attention and hyperactivity. In short, the current investigation attempts to profile attentional deficits for both children with ADHD and children with ASD.

Specifically, the IVA CPT was used to determine the performance of omission (inattention) and commission (impulsivity) errors in both visual and auditory domains. The results of the IVA elicited significant differences between the diagnostic groups as compared to the typically developing children. In regards to response control, the ASD group showed the most impairment, especially in the visual domain. The ADHD group performed better than the ASD children but still falling significantly below the typically developing children. The ADHD group, in contrast to the ASD children, favored the visual domain and performed less well in the auditory domain, which more closely matched the profile of the typically developing children.

The results of the attention quotients were striking in that the ASD children are essentially indistinguishable from the ADHD children. Both groups demonstrated significant deficits across both modes yet with poorer performance in the visual domain. Our findings are highly suggestive of a large subgroup of children with ASD that present with symptoms of ADHD and are consistent with previous findings in which the majority of children with ASD showed attentional deficits (95%), impulsivity (50%) and problems regulating activity level (Sturm et al., 2004).

In test design, the optimal separation of scores between groups is the point of minimal classification in experimental groups (Spreen & Strauss, 1998). *Sensitivity* refers to the true positive rate in which experimental subjects (e.g., ADHD) are correctly classified as having a specific impairment. Whereas *specificity* refers to the true negative rate in which the control group (e.g., typically developing children) are correctly classified as unimpaired. In targeting the second goal of our investigation, the IVA using discriminant function analysis showed moderate ability to classify children with ADHD (73%), good ability to classify children with autism with ADHD symptoms (86%), and moderate to poor ability to correctly classify typically developing children (67%). The results of high true positive rate for ASD, moderate positive rates for ADHD and moderate-to-poor true negative rates for the typically developing children, suggests good sensitivity but limited specificity. There was a 33% false negative rate for the ADHD children, a finding similar to previous CPT results reporting a 15% to 35% false-negative rate (legitimate ADHD subjects scoring normally on the test) using the Gordon CPT (Gordon & Mettelman, 1988). Utilizing the classification guidelines for the IVA demonstrated excellent

sensitivity for the ADHD and ASD groups and poor specificity for the typically developing children in which 40% fell within an ADHD domain (20% predominantly inattentive and 20% combined).

The IVA classified a substantial majority of the children with ASD in our sample as falling within the ADHD classification suggesting a high rate of comorbidity across these two disorders. Previous investigations have also reported equally high percentages ranging from 83% (Frazier, 2001) to 85% (Yoshida & Uchiyama, 2004) for children with PDD. In regards to subtyping within ADHD, the IVA classification guidelines demonstrated that 73% of the ASD children met criteria for combined type, 7% for predominantly inattentive, and 13% met for predominantly hyperactive/impulsive. Utilizing retrospective chart review, Goldstein and Schwebach (Goldstein & Schwebach, 2004) also subclassified children with PDD to a moderately high degree. These results support clinical observation and scant but robust research findings of a substantial subgroup of children evidencing comorbid ADHD within ASD.

It is important to consider that the diagnosis of ADHD should be made from multiple sources and several levels of analysis including genetic, neurological, neuropsychological, behavioral, familial and social factors (Barkley, 1990). With this consideration, the contribution of a measure being able to correctly classify a group on average at 76% whether using the DFA or the IVA guidelines may be considered quite useful. The CPT may provide a valuable contribution to a comprehensive clinical evaluation of ADHD within and between diagnostic groups such as ASD.

In regards to the final goal of the study, the relationship between the neuropsychological findings and the parent report measures of ADHD symptoms showed moderate correlation in regards to attention, but modest correlation with the hyperactivity indices. It is apparent that these different forms of assessment tools may be measuring different constructs. This assumption is supported by previous investigation examining the relationship between 27 different measures of inattention, hyperactive and impulsive behavior (Brewis, 2002). Factor analysis demonstrated that report measures (e.g., parent rating) and other objective measures (e.g., CPT) each measure different aspects of this complex neurodevelopmental disorder, as opposed to some tests being better than others at measuring the same underlying construct.

Although several of the parents of the research participants reported that they had concerns regarding their child's attention and activity level, interestingly, only one of the ASD participants had been previously diagnosed with comorbid ADHD. Our results indicate that a significant percentage of children with ASD meet full diagnostic criteria for ADHD, which support previous findings and questions the current diagnostic exclusionary practice of offering a dual diagnosis of ADHD in PDD. It has been suggested that there needs to be a serious reconsideration of the DSM-IV (APA, 1994) nomenclature preventing clinicians from appropriately diagnosing individuals with PDD with ADHD (Goldstein & Schwebach, 2004). As noted, an appropriate diagnosis of ADHD in PDD will provide clinical utility, guide treatment and encourage research into the comorbidity of these disorders (Ghaziuddin et al., 1992). The serious impact of these

two conditions and their associated problems under comorbid conditions likely present unique and possibly exponential associated risks (Goldstein & Schwebach, 2004; Kadesjo & Gillberg, 2001).

Despite these interesting findings, there are a number of important limitations. It is unclear if the current sample of subjects is truly representative of most children with autism spectrum disorders or ADHD for that matter. The study is limited by small sample size reducing its generalizability and thus must be interpreted cautiously. It is possible that some families enrolled the children in the study knowing that an investigation of ADHD was underway. As such, we may have enrolled a higher proportion of children with ADHD symptoms within ASD. A larger more comprehensive investigation will be able to address such concerns. An additional consideration of diagnosis is also presented pertaining to the children with ADHD in that a consistent and rigorous ADHD assessment was not performed across all subjects. Although the subjects had received a clinical diagnosis, which was confirmed by clinical judgment, history and parent questionnaires, other more rigorous neuropsychological measures were not consistently employed. Lastly, the investigation did not utilize an eye tracker or a method to ensure that the children were actually looking at the visual stimuli. Nevertheless, the instructions of the IVA do not permit redirecting the child back to the screen. The only prompts provided were to encourage the child to complete the task.

In summary, the current investigation provides additional evidence of the co-occurrence of ADHD symptoms in a substantial majority of children with autism spectrum disorders.

Additional research is warranted to elucidate the profiles, comorbidity and phenotypes within and between ADHD and ASD in order to better assess, characterize and treat these heterogeneous and complex disorders.

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Table 1. Descriptive Statistics.

Variable	ASD		ADHD		TYP	
	M	(SD)	M	(SD)	M	(SD)
Age	10.01	(2.04)	9.70	(1.84)	9.56	(1.89)
IQ	97.07	(17.47)	106.80	(14.73)	117.40	(15.17)

Note. ASD = 15 (13 males, 2 females), ADHD = 15 (11 males, 4 females), TYP = 15 (10 males, 5 females)

Table 2. Means and Standard Deviations for the Diagnostic Measures.

Variable	ASD		ADHD		TYP			
	M	(SD)	M	(SD)	M	(SD)	t	p
Conners								
C-OPP	57.27	(10.82)	68.00	(14.04)	54.80	(13.07)	5.86	.006
C-INA	67.00	(12.05)	70.53	(9.45)	50.80	(14.38)	9.11	.001
C-HYP	65.93	(16.98)	77.87	(8.93)	55.27	(15.39)	9.51	.000
C-ADH	69.40	(10.16)	74.73	(6.20)	53.13	(14.13)	14.25	.000
BASC								
B-ATT	69.67	(11.53)	75.33	(7.87)	50.00	(12.27)	17.98	.000
B-HYP	66.80	(16.95)	75.67	(11.91)	51.00	(21.11)	7.21	.002
B-INT	54.47	(11.78)	64.47	(11.63)	49.53	(15.35)	5.03	.011
B-ADP	41.87	(8.24)	42.93	(8.91)	50.47	(12.10)	2.51	.094

Note. ADH = ADHD Index, ADP = Adaptive, ATT = Attention, B = BASC Monitor, C = Conners' Parent Rating Scale, HYP = Hyperactivity, INA = Inattentive, INT = Internalizing, OPP = Oppositional.

Table 3. Means and Standard Deviations for the Dependent Measures.

Variable	ASD		ADHD		TYP	
	M	(SD)	M	(SD)	M	(SD)
FSRQ	54.27	(21.68)***	78.40	(14.95)	93.73	(18.56)
ARCQ	65.27	(27.44)	75.60	(17.08)	93.13	(18.08)
VRCQ	53.93	(17.81)***	86.33	(17.60)	95.93	(17.52)
FSAQ	60.27	(20.81)**	61.67	(19.33)	92.13	(21.36)
AAQ	68.20	(21.96)*	67.53	(19.37)	95.60	(22.09)
VAQ	60.73	(22.08)*	63.13	(20.47)	90.27	(22.89)

Note. Two-tailed tests of significance where, *p<0.05, **p<.01, **p<.001

Table 4. Results of MANCOVA for the Dependent Measures.

Variable	F	P
FSRQ	10.44	.000
ARCQ	3.20	.051
VRCQ	16.47	.000
FSAQ	6.66	.003
AAQ	4.85	.013
VAQ	4.49	.017

Table 5. Discriminant Function Analysis

Variable	Function 1		Function 2	
	Structure Coefficients	Standardized Coefficients	Structure Coefficients	Standardized Coefficients
FSRQ	.80*	1.37	.07	-.96
ARCQ	.47*	-.95	.32	.86
VRCQ	.93*	.19	-.26	-.11
FSAQ	.52	1.48	.83*	.24
AAQ	.43	-.54	.77*	.42
VAQ	.46	-.82	.68*	.36

Note. *Largest absolute correlation between each variable and any discriminant function.

Table 6. DFA Classification Results[a].

Diagnosis	Predicted Group Membership Percentage			Total Percentage
%	TYP	ADHD	ASD	
TYP	73.3	26.7	0.0	100.0
ADHD	13.3	66.7	20.0	100.0
ASD	6.7	6.7	86.7	100.0

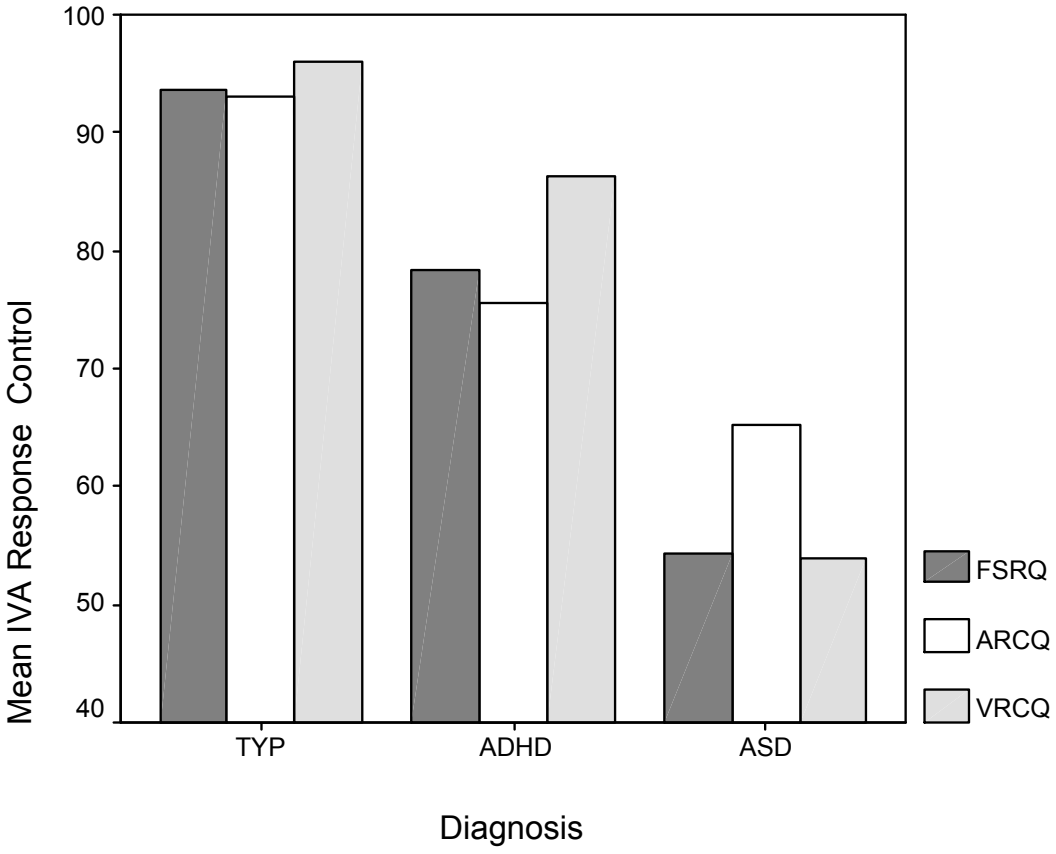
Note. a. 75.6% of original grouped cases correctly classified.

Table 7. IVA Procedural Guidelines Classification Results

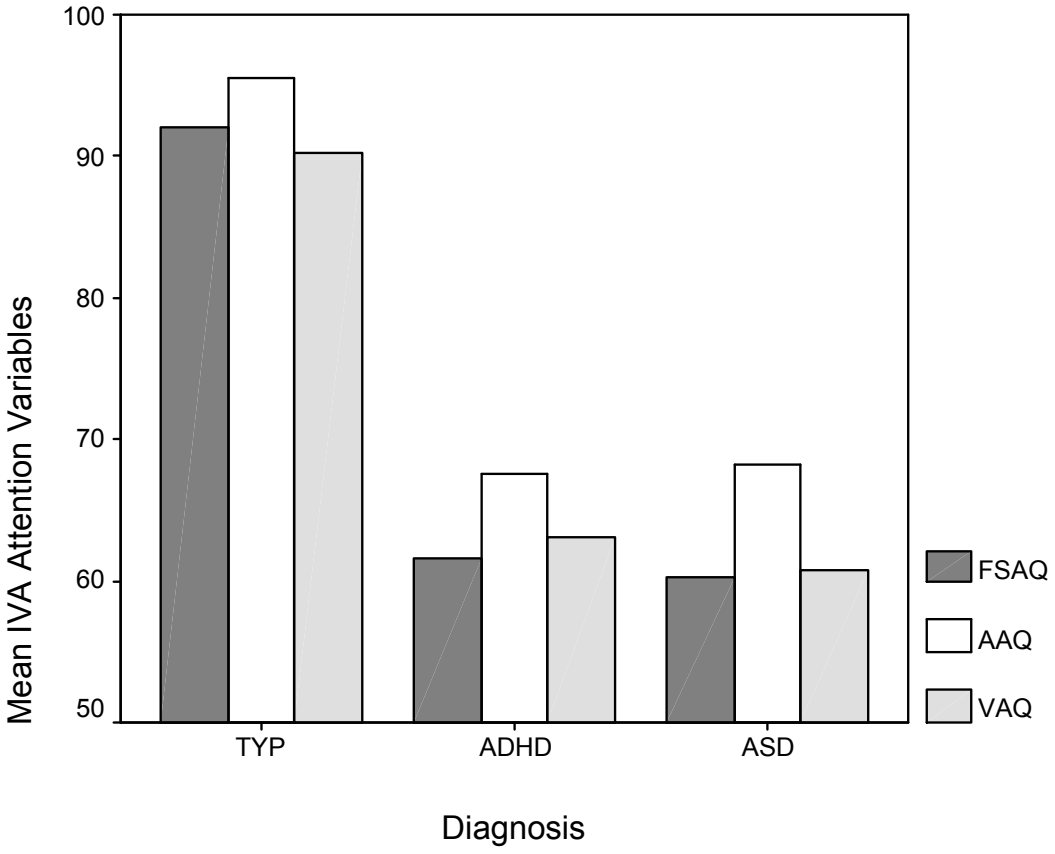
GROUP	ADHD-INA	ADHD-HYP	ADHD-COM	No DX
TYP	3 20%	0 0%	3 20%	9 60%
ADHD	5 33%	2 13%	8 54%	0 0%
ASD	1 7%	2 13%	11 73%	1 7%

Note: 93% of ASD sample falling in ADHD, 100% of ADHD classified, 40% of TYP falling in ADHD.

Graph 1. Response Control Quotients Across Groups.



Graph 2. IVA Attention Quotients Across Groups



Captions

Table 1. Descriptive statistics of age and IQ for three groups of children (autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD) and typically developing (TYP)).

Table 2. Means and standard deviations for the diagnostic measures across the three groups. The measures include: the Conners' Parent Rating Scale-Revised (short) and BASC Monitor

Table 3. Means and standard deviations for the dependent measures across the three groups. Six variables of attention and response control are shown.

Table 4. The results of the MANCOVA for the dependent measures across the three attention and three response control variables.

Table 5. Discriminant function analysis for the six IVA measures. The structure coefficients and standardized coefficients are presented across the two generated functions, which include: Function 1 (response control) and Function 2 (attention).

Table 6. DFA classification results. The predicted group membership across the three groups based on the IVA dependent variables.

Table 7. IVA procedural guidelines classification results. Classification of the three groups into the ADHD diagnostic subtypes to include predominantly inattentive, predominantly hyperactive-impulsive, and combined type, based on the IVA manual guidelines.

Graph 1. Response control quotients across groups. Mean performance across the three groups on the IVA visual, auditory and full scale response quotients.

Graph 2. Attention quotients across groups. Mean performance across the three groups on the IVA visual, auditory and full scale attention quotients.