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Attention Deficits in Children With Combined Autism and ADHD: A CPT Study

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Abstract

Objective: To investigate characteristics of attention in children with the combination of autism spectrum disorder (ASD) and ADHD. **Method:** Four groups of 8- to 10-year-old children were compared on the Conners' Continuous Performance Test–Second Edition (CCPT-II): (a) ASD + ADHD (*n* = 11), (b) ASD only (*n* = 9), (c) ADHD only (*n* = 38), and (d) no diagnosis (*n* = 134). **Results:** There was an overall effect of group on the Continuous Performance Test (CPT) index and measures of hit reaction time, accuracy, response style, variability, and consistency. The ASD + ADHD group, much like the ADHD only group, had a more risky response style, a higher variability, and a lower consistency than the ASD only group. The impact of intellectual function on CCPT-II performance was considerable in children within the ASD subgroups. **Conclusion:** The findings underscore the importance of including measures of attention and intellectual function when assessing children with the combination of ASD and ADHD. *(J. of Att. Dis. 2016; 20(7) 599-609)*

Keywords

autism spectrum disorder, ADHD, attention, Continuous Performance Test, inhibition, variability

Background

Autism spectrum disorder (ASD) and ADHD are two neurodevelopmental disorders that are mutually exclusive in the current diagnostic systems (International Classification of Diseases–Tenth Edition [ICD-10] and *Diagnostic and Statistical Manual of Mental Disorders* [4th ed.; *DSM-IV*; American Psychiatric Association, 1994]). However, several studies have shown high rates of co-occurrence of ASD and ADHD (Kadesjo & Gillberg, 2001; Rommelse, Franke, Geurts, Hartman, & Buitelaar, 2010), similarities regarding genetics (Lichtenstein, Carlstrom, Raastam, Gillberg, & Anckarsater, 2010; Rommelse et al., 2009), and aspects of cognitive function (Nydén et al., 2010; Rommelse et al., 2009). Earlier studies have shown that children with "comorbid" ASD and ADHD tend to be more functionally impaired and more often receive treatment than those with only one of the disorders (Frazier, Demaree, & Youngstrom, 2004; Gillberg et al., 2004; Holtmann et al., 2006). Still, very limited attention has been paid to cognitive characteristics of the combined group.

Problems related to executive function (EF) and attention have been described as core cognitive deficits of children with ASD (Hill, 2004; Mahone et al., 2006) and ADHD (Barkley, 2010; Geurts, Verte, Oosterlaan, Roeyers, & Sergeant, 2004). However, the characteristics of these problems are different in the two groups. Children with ASD have been characterized by an inability to flexibly shift and disengage attention within and between sensory modalities (Pascualvaca, Fantie, Papageorgiou, & Mirsky, 1998), showing more problems with planning and fluid reasoning than children with ADHD (Semrud-Clikeman, Walkowiak, Wilkinson, & Butcher, 2010). The cognitive problems of children with ADHD have often been described as a deficit of inhibition (Geurts et al., 2004). In one study (Sinzig, Morsch, Bruning, Schmidt, & Lehmkuhl, 2008), a group of children with ADHD was compared with two ASD groups, one with comorbid ADHD and one without, on a set of tests of

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response inhibition, flexibility, working memory, and planning. The results confirmed impairments of inhibition and working memory in the ADHD group, and deficits in planning and flexibility in the ASD group. Although children in the comorbid group showed comparable deficits as children in the ADHD group on measures of response inhibition, the two ASD groups differed from the "ADHD only" group with regard to working memory. Furthermore, the comorbid group was more similar to the "ASD only" group on measures of planning and flexibility. Another study (Corbett & Constantine, 2006) compared results of children with ASD with those of children with ADHD and a control group on an integrated visual and auditory Continuous Performance Test (CPT). The ASD group showed significant ADHD-like deficits, with some of the children with ASD showing an even higher level of impulsivity than the children with ADHD. However, a recent study of adults failed to replicate findings of dissociations in executive/attention function across the diagnostic groups with ASD, ADHD, and comorbid ASD with ADHD (Nydén et al., 2010).

The Conners' Continuous Performance Test–Second Edition (CCPT-II) has frequently been used to assess EF and attention (Epstein et al., 2003), including measures of reaction time (RT), accuracy, response style, variability, consistency, and vigilance. These measures have been included in many studies aiming to differentiate between individuals with and without ADHD (Advokat, Martino, Hill, & Gouvier, 2007; McGee, Clark, & Symons, 2000; Newcorn et al., 2001), and showing lower accuracy, with more errors of omissions and commissions, and a more variable RT in individuals with ADHD (Ehlers et al., 1997). Studies of children with ASD have not consistently reported impairment on CCPT-II. Sinzig et al. (2008) explained this by the insensitivity of the test to detect the characteristic deficit in flexibility of attention that characterizes this group of children.

General intellectual function (IQ) is known to be depressed or to show an uneven profile in ASD and ADHD (Cederlund & Gillberg, 2004; Ehlers et al., 1997; Nydén et al., 2010). Therefore, when examining results on a cognitive test in children with a neurodevelopmental disorder (such as ASD or ADHD), the question arises as to whether IQ may confound the results (Frazier et al., 2004). Function on tests and everyday tasks that are dependent on attention tends to be related to intellectual abilities, as indicated by findings of a low to moderate negative correlation between Wechsler's Full Scale IQ (FSIQ) scores and CCPT-II scores (Conners, 2000; Jepsen, Fagerlund, & Mortensen, 2009). Correlations between measures of IQ and attention have been widely investigated in studies of children with ADHD. In a review, Jepsen et al. (2009) concluded that the influence of IQ on attention and visa versa was best described as rather small. Studies of ASD have indicted a stronger influence of IQ on attention (and on everyday functioning in more general terms; Liss et al., 2001). One study, using the Wisconsin Card Sorting Test as a measure of EF, showed a high correlation with IQ even among those with an above average IQ score (Arffa, Lovell, Podell, & Goldberg, 1998).

To the best of our knowledge, no studies have reported CCPT-II results in a group of children with the combination of ASD and ADHD, nor has anyone investigated possible correlations between IQ and CCPT-II results in children with this combination of diagnoses.

Aims of the Study

The aim of the study was to characterize aspects of EF and attention (as assessed by the CCPT-II) in children with combined ASD and ADHD. We wanted to know whether their performance could be differentiated from that of children with either diagnosis and of children with no diagnosis, expecting to find the most severe deficits in children with an ADHD diagnosis. We also wanted to investigate the association between IQ and CCPT-II performance in the combined group, and to examine whether any association found would differ from associations found in the other groups.

Method

The Bergen Child Study (BCS)

All children included in the present study were participants in the third phase of the first wave of the BCS. The BCS is an ongoing longitudinal study of mental health and development. The first wave started in October 2002 and included the total population of 9,430 children attending second to fourth grade (7-9 years old) in all public, private, and special schools in Bergen, and 222 children from a small municipality (Sund) outside Bergen. During the initial screening phase, the four-page BCS questionnaire (BCSQ) was given to the parents and teachers of the target population, including—among other scales—the Strengths and Difficulties Questionnaire (SDQ, Goodman, 1999), the Swanson, Nolan, and Pelham Questionnaire–Fourth Edition (SNAP-IV; Swanson et al., 2001), and the Autism Spectrum Screening Questionnaire (ASSQ; Ehlers, Gillberg, & Wing, 1999). A child was defined as screen positive in the screening phase if (a) the SDQ total difficulties score exceeded the 90th percentile cutoff according to parents or teachers, (b) there was a severe impairment according to parents or teachers on the SDQ impact section, or (c) the score on one of the other scales included in the questionnaire exceeded the 98th percentile cutoff. In a second phase of the first wave of the BCS, parents of all screen-positive children and a random sample of screen-negative children were interviewed using the Development and Well-Being Assessment (DAWBA; Goodman, Ford, Richards, Gatward, & Meltzer, 2000).

The data analyzed in the present study originated from the third phase of the first wave of the BCS, designed to resemble a clinical psychiatric examination, including a diagnostic interview—the Kiddie Schedule of Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime Version (K-SADS-PL; Kaufman et al., 1997)—and measures of cognitive function, including the Wechsler Intelligence Scale for Children–Third Edition (WISC-III, Wechsler, 2003) and the CCPT-II (Conners, 2000). As part of the ASD diagnostic process, the Diagnostic Interview for Social and Communication Disorders–Tenth Edition (DISCO; Wing, Leekam, Libby, Gould, & Larcombe, 2002) was administered to the ASD screen-positive children (i.e., an ASSQ score above the 98th percentile on either parent or teacher reports). A total of 48 ASSQ screen-positive children and a random selection of ASSQ screen-negative children (n = 14) were interviewed. In addition, two other ASSQ screen-negative children were assigned for the interview, based on suspected social difficulties as measured by the K-SADS-PL. We have argued elsewhere that the children with ASD and ADHD examined in the third phase of the first wave of the BCS are largely representative of children with these disorders in the general Bergen child population (Posserud, Lundervold, Lie, & Gillberg, 2011). Sample protocols of the first wave have been described in previous publications (Heiervang et al., 2007; Lundervold, Posserud, Ullebø, Sørensen, & Gillberg, 2011).

Definitions of ASD and ADHD

For the purpose of the present study, the concept of ASD comprised autistic disorder/childhood autism, Asperger's disorder/syndrome, and pervasive developmental disorder–not otherwise specified/atypical autism (*DSM-IV*, ICD-10) as diagnosed by the DISCO. Children with marked observational autistic traits, but for whom there was conflicting evidence of symptom levels between the parental DISCO report and the clinical observation (symptoms reported were too few or vaguely described to motivate a clear DISCO ASD diagnosis), were classified as atypical autism in the present context.

ADHD was defined as a "definite" ADHD diagnosis according to the K-SADS-PL interview. Children with "probable" (n = 28) or "in remission" (n = 1) ADHD were excluded from the study.

Participants in the Present Study

The ASD only group. Nine children (one girl) were included in the ASD only group: autistic disorder (n = 2) and atypical autism (n = 7).

The ADHD only group. The ADHD only group included 38 children (6 girls) with a definite ADHD diagnosis according to the K-SADS-PL interview, but no ASD diagnosis according to the DISCO.

The ASD + ADHD group. The combined group included 11 boys with a dual diagnosis of ADHD and ASD: autistic disorder (n = 2), Asperger's syndrome (n = 5), and atypical autism (n = 4).

The no diagnosis comparison group. The no diagnosis comparison group included the 134 children, 42.5% girls, with no diagnosis present according to the K-SADS-PL and the DISCO interviews.

The project was approved by the National Committee for Medical and Health Research Ethics–Western Norway and the Norwegian Social Science Data Services (NSD).

Instruments

K-SADS-PL (Kaufman et al., 1997) is a semistructured diagnostic interview used to evaluate present and past episodes of psychopathology in children according to the *DSM-IV*. For the purpose of the present study, one or both of the parents were first interviewed, and the child was interviewed in a separate session later during the same day. A combined sum of scores was calculated for each of the participant. The derived information was coded into four different categories: diagnosis not present, probable diagnosis (meeting 75% or more of the diagnostic criteria), diagnosis in remission, and definite clinical diagnosis.

The DISCO (Wing et al., 2002) is a structured interview and was used to systematically gather information to aid the process of diagnosing children with ASD. The DISCO involves a diagnostic algorithm according to the diagnostic criteria of the ICD-10 and DSM-IV. The interviewer scores the items on the basis of all available information, including observations of the child. The DISCO also provides indications of level of functioning, as measured by items related to early development and items on activities of daily living.

The WISC-III (Wechsler, 1999) is a standardized test of intellectual function in children 7 to 16 years old. The test provides a FSIQ score, derived from a subset of verbal and nonverbal tasks. Scaled scores of the FSIQ were age-adjusted according to Swedish norms (Sonnander, Ramund, & Smedler, 1998) and included in the study.

The CCPT-II is a computerized test characterized by high signal-to-noise ratio (90% target stimuli and 10% nontarget stimuli) and an adequate reliability (Conners, 2000). The participants are asked to respond to all stimuli presented on the computer screen (letters), except for the nontarget letter X. Target and nontarget letters appear randomly on the computer screen for 250 ms each. The test consists of 360 trials, distributed across six blocks. Each block is divided into three sub-blocks. The time interval between each presented letter varies within each block. For the three sub-blocks within each block, the interstimulus interval (ISI) is 1, 2, or 4 s; the order of the different ISI sub-blocks varies from block to block. The CCPT-II takes 14 min to

Table 1. Definitions of Variables.

Concepts	Variables	Definitions
RT	Hit RT	RT for correct responses across the test
Accuracy	Hits	Number of correct responses
	Omissions	Number of omissions
	Commissions	Number of commissions
Response style	Response-style (β)	Trade-off between speed and accuracy. High score indicates a risky style
Variability	Variability *SE*	The amount of variability the individual shows in relation to his or her own *SE*
Sustained attention	Block change	Change in hit RT across the different blocks
Consistency	Hit RT *SE*	*SE* of hit RT across the test
	SE Block change	*SE* of block change across the different blocks
	Hit RT ISI change	Change in *SE* of RT at different ISI
	Hit *SE* ISI change	ISI in face of changing task demands

Note. RT = reaction time; ISI = interstimulus interval.

complete and generates measures of RT, accuracy, variability, consistency, and vigilance. The included measures and their definitions are listed in Table 1.

Procedure

The clinical examination was performed at the Department of Biological and Medical Psychology, division of Clinical Neuropsychology at the University of Bergen, Norway. The K-SADS-PL interviews were conducted and scored by psychologists or psychiatrists, trained in using the interview before the participants were included and blind to the screening protocols when conducting the interviews. Meetings for discussion of complex cases were arranged on a regular basis, and the final decisions were always given to the senior psychologist who had the main responsibility for the K-SADS part during the assessment period.

All DISCO interviews were conducted and scored by Maj-Britt Posserud, who is a licensed DISCO interviewer, trained for the reliable use of the instrument in clinical practice and research. All cases were discussed individually in detail with Christopher Gillberg before final diagnoses were made.

Trained test technicians administrated the tests of cognitive function (WISC-III and CCPT-II) as part of a larger test battery. The CCPT-II was individually administered on a stationary computer (17 inches screen). The participants were given the instruction to press the spacebar whenever a letter appeared on the screen (target letters), except when the letter X appeared (nontarget letter). The instruction was standardized according to the CCPT-II manual. The research technician was present in the test room during the administration of the test.

Statistical Analysis

The PAWS 18 statistical package was used for data analyses. We used univariate ANOVA to investigate the distribution of age, FSIQ, and the separate CCPT-II variables across the four groups. Covariates were included in case of significant overall results. Multiple paired group differences were explored by Tukey post hoc tests when equal variance was assumed and Games–Howell test when not assumed. A Dunnetts two-tailed *t* test with the ASD + ADHD as a reference was run to investigate its contrast to the other groups on the CCPT-II measures. Finally, we ran correlation analyses between the FSIQ and the CCPT-II measures, for each group separately. Significant ($p < .05$) results (and some trends) are reported in the text.

Results

Age and Intellectual Function

The sample's distribution of age and FSIQ by group is shown in Table 2. A one-way ANOVA showed a statistically significant difference between the groups in age, $F(3, 191) = 4.4$, $p = .005$. A groupwise Games–Howell corrected comparison showed that the combined ASD + ADHD group was significantly older than the comparison group ($p = .004$). This was confirmed by the contrast analysis ($p = .006$).

A one-way ANOVA showed that the group difference in FSIQ score was statistically significant, $F(3, 191) = 11.11$, $p < .001$. A Tukey corrected post hoc test showed that the ADHD group obtained a significantly lower score than the comparison group ($p < .001$), and there was a trend toward a significantly lower score in the ASD group ($p = .055$).

The severity of symptoms in the ADHD and the combined group was assessed by including symptom reports from teachers and parents on the Hyperactivity subscale from the SDQ (R. Goodman, 1999) and the oppositional defiant disorder (ODD), Inattention and Hyperactivity subscales from the SNAP scale (Swanson et al., 2001). An independent-samples *t* test showed no statistically significant differences in these respects across the two groups.

Table 2. Demographic Variables in the Four Groups.

	Comparison group	ADHD only	ASD only	ADHD + ASD
	n = 134	*n* = 38	*n* = 9	*n* = 11
Age	9.7 (0.9)	10.0 (0.9)	10.3 (0.9)	10.6 (0.7)
IQ total score	93.8 (14.1)	78.1 (16.2)	92.2 (17.7)	87.1 (17.9)

Note. ASD = autism spectrum disorder.

Table 3. CCPT-II Results in the Four Groups.

Concepts	Variables	Comparison *n* = 134	ADHD only *n* = 38	ASD only *n* = 9	ASD + ADHD *n* = 11
Overall index	CPT index	8.5 (7.3)	11.0 (6.7)	7.7 (7.4)	13.5 (8.3)
RT	Hit RT	374.03 (58.53)	415.16 (105.81)	349.22 (93.44)	368.12 (115.09)
Accuracy	Hits	307.75 (12.9)	297.21 (19.4)	309.67 (13.2)	302.82 (15.4)
	Omission	16.25 (12.9)	26.79 (19.42)	14.33 (13.2)	21.18 (15.08)
	Commission	24.62 (7.8)	25.02 (6.5)	26.00 (5.6)	24.81 (6.5)
Response style	Response-style (β)	0.87 (5.6)	0.46 (0.23)	9.9 (28.5)	0.87 (5.9)
Variability	Variability *SE*	24.86 (22.3)	33.86 (19.07)	12.2 (5.5)	34.3 (25.6)
Sustained attention	RT block change	−11.3 (19.2)	−7.2 (23.0)	4.5 (18.3)	−8.8 (25.6)
Consistency	Hit RT *SE*	11.62 (6.59)	0.115.24 (8.12)	8.04 (3.77)	14.44 (8.29)
	SE Block change	0.07 (0.11)	0.10 (0.12)	0.04 (0.06)	0.12 (0.13)
	Hit RT ISI change	0.07 (0.06)	0.08 (0.06)	0.05 (0.04)	0.10 (0.08)
	Hit *SE* ISI change	0.08 (0.19)	0.14 (0.21)	−0.04 (0.15)	0.19 (0.21)

Note. CCPT-II = Conners' Continuous Performance Test -Second Edition; ASD = autism spectrum disorder; CPT = Continuous Performance Test; RT = reaction time; ISI = interstimulus interval.

CCPT-II Results

Descriptive statistics on the separate CCPT-II variables are listed in Table 3. All contrast analyses were run with the combined ASD + ADHD group as the reference. Due to significant group differences in age and FSIQ, these variables were included in separate ANCOVAs in case of statistically significant results.

CPT index. A one-way ANOVA showed a trend toward a group effect for the CPT index, $F(3, 191) = 2.57$, $p = .055$. None of the Tukey corrected group comparisons were statistically significant, but the contrast analysis showed a weak trend toward a higher index in the combined than in the comparison group ($p = .067$).

RT. There was an overall group effect for the hit RT, that is, the speed of RT across the task, $F(3, 191) = 3.59$, $p = .015$. A Games–Howell corrected groupwise comparison showed a significant difference between the ADHD and the comparison group, indicating that the former was slower ($p = .016$).

Accuracy measures. Analyses of the accuracy measures revealed a significant overall effect of group on the number of hits, $F(3, 191) = 5.5$, $p = .001$, and the number of omissions, $F(3, 191) = 5.5$, $p = .001$. The Games–Howell corrected groupwise comparisons showed that the combined group was not significantly different from any other group, but the number of hits was lower and the number of omissions higher in the ADHD only than in the comparison group, $p = .014$.

Response-style (β). On the response-style indicator, a measure of the trade-off between speed and accuracy, the overall effect of group was significant, $F(3, 191) = 4.07$, $p = .008$. A Games–Howell corrected groupwise comparison showed no significant differences between the groups, but the contrast analysis showed that the combined group obtained a statistically significant lower score—indicating a more risky response style—than the ASD only group ($p = .017$).

Variability. The overall effect of group was significant on the measure of variability, $F(3, 191) = 3.58$, $p = .015$. A Games–Howell corrected groupwise comparison showed that the ASD only group was less variable than the ADHD only ($p > .001$) and the comparison group ($p > .001$). The contrast analysis showed a trend that the combined group was significantly more variable than the ASD only group ($p = .052$).

Sustained attention. There were no significant group effects in respect of sustained attention or vigilance, as measured by Block change.

Consistency. The standard error (*SE*) of hit RT, a measure of the consistency of RT throughout the task, showed an overall effect of group, $F(3, 191) = 4.37$, $p = .005$. The Tukey corrected groupwise comparisons showed that the combined group was not significantly different from any of the other groups, but the ADHD only group was less consistent than the comparison group ($p = .020$) and the ASD only group ($p = .025$). The contrast analysis showed a nonsignificant trend toward a less consistent RT in the combined than in the ASD only group ($p = .089$).

There was a trend toward an overall group effect on the "*SE* Block change" measure, $F(3, 191) = 2.36$, $p = .073$, but no significant groupwise results. The hit *SE* ISI change, the *SE* measure of consistency as the time between the targets increased, showed a significant overall group effect, $F(3, 191) = 3.36$, $p = .020$. The Tukey corrected groupwise comparisons and contrast analysis showed that the combined ASD + ADHD group was significantly less consistent in adjusting to presentation speed than the ASD only group, $p = .044$ and $p = .021$, respectively.

Age and FSIQ as Covariates

Two significant results were retained when age and FSIQ were included as covariates in ANCOVAS: on the measure of response-style (β), $F(3, 191) = 4.08$, $p = .008$, and the *SE* measure of consistency as the time between the targets increased (hit *SE* ISI change), $F(3, 191) = 3.24$, $p = .023$. Post hoc tests confirmed that the combined ASD + ADHD group used a less cautious response style and were less consistent than the ASD only group.

Correlations Between FSIQ and CCPT Measures

The Pearson correlation between the FSIQ and the CPT index was low in the ADHD only group ($r = -.031$), intermediate in the comparison group ($r = -.111$) and the combined ASD + ADHD group ($r = -.359$), and strong and statistically significant in the ASD only group ($r = -.732$, $p = .025$). Moderate correlations within the combined group were found on measures of hit RT ($r = -.416$), accuracy (hits, $r = .489$), variability ($r = -.540$), and the hit RT ISI change measure of consistency ($r = -.576$), but the only statistically significant results were found on the response-style measure ($r = -.613$, $p = .017$) and the consistency measure hit *SE* ISI change ($r = -.616$, $p = .044$). In the ASD only group, this was true for the measure of accuracy ($r = .852$, $p \leq .001$), the consistency measures of hit RT *SE* ($r = -.833$, $p = .005$), and hit RT ISI change ($r = -.799$, $p = .010$), whereas the only significant correlation in the ADHD only group was found on the hit RT measure ($r = -.424$, $p = .008$).

Discussion

Children with the combination of ASD and ADHD differed as regards CCPT-II results from those with ASD "only" and from children with neither ASD nor ADHD. Children in the combined group were different from those in the ASD only group on the response-style measure, indicating that they were less cautious, more variable, and less consistent as time between targets increased. The ASD only group showed a trend toward overall better performance on the test measures than any of the other three groups included in the study. The ADHD only group, on the other hand, did less well than the comparison group on measures of RT, accuracy, variability, and consistency. No significant differences were revealed between the ADHD only and the combined group.

As expected, the findings confirmed that inconsistency and variability are core cognitive symptoms associated with ADHD (see, for example, Hervey et al., 2006; McGee et al., 2000; Perry, Sagvolden, & Faraone, 2010). The combination of slow RT and a high number of omission errors probably reflects problems related to inattention.

Overall, the combined ASD and ADHD group was more similar to the ADHD only than the ASD only group on the CCPT-II measures. The relatively strong performance of the ASD only group in the present study could be taken to indicate that the group mainly included "high-functioning" individuals within the autism spectrum, but could alternatively be explained by insensitivity of the CCPT-II to deficits in the ability to flexibly shift attention within or across modalities, dysfunctions that could be detected by other test or daily life functioning measures (Sinzig et al., 2008). The mean IQ value in the ASD only and the combined ASD and ADHD group did not support the first of these alternatives, whereas the latter would seem reasonable as previous ASD research has shown that problems related to shifting attention focus may coexist with normal scores on the CCPT-II (Pascualvaca et al., 1998). High-functioning children with ASD have also shown poor performance on measures of cognitive flexibility as assessed by the Wisconsin Card Sorting Test (Kaland, Smith, & Mortensen, 2008). However, closer inspection of the test results showed that it was only the subscore "failure to maintain set" that was significantly lower in the ASD group. This finding was interpreted as a failure of attention focusing in children with ASD. The lower scores on the CPT index in the combined group shown in this study may be interpreted as a failure in the ASD group to focus attention, but this failure was only evident in children with a co-occurring ADHD diagnosis.

A low IQ level has been found in some, but not all, studies of individuals with ADHD. Performance on IQ tests has been associated with and also partly explained by other aspects of neurocognitive function (Adolfsdottir, Sørensen, & Lundervold, 2008; Tillman, Bohlin, Sørensen, & Lundervold, 2009). More recent studies have more consistently reported low to moderate correlations between IQ and performance on neurocognitive tests in children and adolescents with ADHD (Jepsen et al., 2009), and that also ADHD symptoms (e.g., Bezdjian, Baker, Lozano, & Raine, 2009) and symptoms associated with affective disorders (Nigg & Casey, 2005; Sobanski et al., 2010; Sørensen, Plessen, Nicholas, & Lundervold, 2011) are crucial to understand characteristics of cognition in children. Associations between intellectual and neurocognitive function have also been demonstrated in children with ASD where the most distinguishing feature of intellectual function seems to be an uneven rather than low function (Cederlund & Gillberg, 2004; Gilchrist, Green, Cox, Burton, Rutter, & Couteur, 2001). In a recent study, Nydén et al. (2010) demonstrated that adults in a combined ASD + ADHD group showed distractibility at the same level as the ADHD group on a CPT test (Test of Variables of Attention [TOVA]). Distractibility is relying on the ability to focus attention and therefore confirms the finding in the present study of an altered attention function to be present in children with ASD who also fulfill the criteria for an ADHD diagnosis. The authors showed that intellectual dysfunction was—as in our study—most pronounced in the ADHD group, but the authors did not analyze correlations as in the present study.

The finding of group dependence regarding the association between test performance and FSIQ has important implications. For the ASD only and the combined ASD and ADHD group, performances on several CCPT-II measures were found to be strongly correlated with FSIQ, whereas a significant correlation was only found on the RT measure in the ADHD group. These findings are highly relevant to the debate whether IQ should be controlled for in studies of cognitive function in children with neurocognitive disorders. Children with ASD as a group represent a wide variety of intellectual functioning. Moreover, a recent review article suggested that the observed differences in symptoms across ASD subgroups can be explained by IQ levels (Happé, Booth, Charlton, & Hughes, 2006).

The present study emphasizes the importance of taking intellectual function into account when interpreting CCPT-II results in these groups of children. Our findings indicate that CPT results in general should be interpreted very cautiously in ASD children. A normal CPT test score in an ASD child cannot be interpreted as absence of ADHD, and a child with ASD and low intellectual ability may well have low performance on the CPT without having ADHD. This positive association could suggest that high level of intellectual function is protective against developing clinically significant attention problems in children with ASD. The importance of IQ as predictor of outcome in children and adults with ASD supports this hypothesis. The low correlation between results on the CCPT-II and intellectual function in the ADHD group, indicating independence between the two variables, was less expected. However, the finding may at least partly be explained by characteristics of the present ADHD group. First of all, the group included only children with a definite ADHD diagnosis aaccording to K-SADS-PL. Second, no child was excluded due to low IQ level. Several studies have excluded those children, and by doing so, they may have excluded a specific subgroup of children (Frazier et al., 2004). The impact of high IQ on CPT performance in children with ADHD was recently shown in a Korean study (Park et al., 2011).

The presence of co-occurring ASD and ADHD seems to be critical to recognize because of the impact of associated problems and the exponential risk associated with comorbidity (D. W. Goodman, Lasser, Babcock, Pucci, & Solanto, 2011). To date, however, little is known about the associated features of comorbid ASD and ADHD diagnosis, and whether it represents a qualitatively distinct phenotype separate from the ASD and ADHD group, a more severe form of ASD and ADHD deficits, or merely similar deficits to either one of the individual disorders alone (Rommelse et al., 2010). The present study gives no clear indications as to these alternatives, although our study supports earlier studies indicating phenotypic overlap between the two diagnostic categories (e.g., Gillberg, 2010; Lichtenstein et al., 2010; Sinzig, Walter, & Doepfner, 2009).

Issues related to the coexistence between the two disorders also arise from nosological considerations. For instance, it has been suggested that ASD and ADHD may share common underlying genetic factors (Rommelse et al., 2009). Furthermore, it has been argued that there seems to be an overlap in the diagnostic criteria and functional deficits associated with ASD and ADHD, in that inattention and social impairments have been recognized as associated features of both in the current diagnostic manuals (Rommelse et al., 2010). In sum, a growing amount of studies during the last decades have consistently reported high prevalence rates of co-occurring symptoms of ASD and ADHD. This should have implications for future editions of the diagnostic manuals, clinical practice, and treatment. In regard to clinical practice, this highlights the need of broad approaches in the assessment and evaluation of childhood psychiatric disorders addressing comorbid conditions. It has been suggested that a dimensional approach might be more appropriate than the current categorical approach to assess and classify childhood psychiatric disorders (Lundström et al., 2012), and arguably also the use of CPT tests for identifying a category of children with ADHD-like symptoms. More research is needed to address the possible associated features and cognitive function in co-occurring ASD and ADHD, and the dimensional nature of the symptoms characterizing individuals within and in the gray zone of the two diagnostic categories.

Strengths and Limitations

The main strength of the present study is the selection of participants from a population-based sample, although small sample sizes and large standard deviations in the subgroups, especially in the ASD and the combined ASD + ADHD group, are limitations that may have increased the likelihood of Type II errors.

Results were not reported separately according to gender and diagnostic subgroups due to small sample sizes. However, we know that boys typically outnumber girls in prevalence rates in the ASD and ADHD populations of children, and studies have also shown that neuropsychological deficits in ADHD (O'Brien, Dowell, Mostofsky, Denckla, & Mahone, 2010) and ASD (Nydén, Hjelmquist, & Gillberg, 2000) are partly modulated by gender. Moreover, gender differences in CPT performances have been reported, with boys performing more poorly than girls (Conners, Epstein, Angold, & Klaric, 2003).

Furthermore, there are reasons to believe that the results may have been different if it had been possible to analyze CCPT-II results within diagnostic subgroups of ADHD (Egeland, Johansen, & Ueland, 2009), although this is not supported by all studies (Chhabildas, Pennington, & Willcutt, 2001). The ASD diagnostic category in the present study included children within a broad autism spectrum. ASD subgroups typically represent a wide variety of features (Witwer & Lecavalier, 2008), and it is unknown whether subtype performance on the CCPT-II might vary.

Other limitations are related to the fact that the diagnostic evaluations in the present study were solely based on information from child and parent reports, and that cognitive function was assessed by a single neuropsychological test of different aspects of attention. The exact behavioral correlates of the various components of the CCPT-II remain unclear (Edwards et al., 2007; Epstein et al., 2003), and the results in the present study must therefore be interpreted with caution.

Conclusion

We found CCPT-II performance in children with combined ASD and ADHD to be more similar to performance in the ADHD only than in the ASD only group. Moreover, the results from the present study add to other studies highlighting the importance of investigating RT variability and consistency as indicators of attention deficits. The question of whether combined ASD and ADHD represents a distinct phenotype or merely overlapping phenotypes remains unresolved, and further research is needed in this respect. Finally, we found that the associations between overall CCPT-II performance and FSIQ varied substantially between the diagnostic groups in the sample, with the highest correlation between CPT performance and IQ in the ASD group. In this regard, we suggest that high IQ could be a protective factor for the development of *clinically significant* attention problems in ASD. The finding highlights the need for a differentiated and integrative approach to cognition and neuropsychiatry in clinical practice and research.

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References

Adolfsdottir, S., Sørensen, L., & Lundervold, A. J. (2008). The attention network test: A characteristic pattern of deficits in children with ADHD. *Behaviour Brain Functions, 4*, 9.

Advokat, C., Martino, L., Hill, B. D., & Gouvier, W. (2007). Continuous Performance Test (CPT) of college students with ADHD, psychiatric disorders, cognitive deficits, or no diagnosis. *Journal of Attention Disorders, 10*, 253-256.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Arffa, S., Lovell, M., Podell, K., & Goldberg, E. (1998). Wisconsin Card Sorting Test performance in above average and superior school children: Relationship to intelligence and age. *Archives Clinical Neuropsychology, 13*, 713-720.

Barkley, R. A. (2010). Differential diagnosis of adults with ADHD: The role of executive function and self-regulation (2010). *Journal of Clinical Psychiatry, 71*, e17.

Bezdjian, S., Baker, L. A., Lozano, D. I., & Raine, A. (2009). Assessing inattention and impulsivity in children during the Go/NoGo task. *British Journal of Developmental Psychology, 27*(Pt 2), 365-383.

Cederlund, M., & Gillberg, C. (2004). One hundred males with Asperger syndrome: A clinical study of background and associated factors. *Developmental Medicine & Child Neurology, 46*, 652-660.

Chhabildas, N., Pennington, B. F., & Willcutt, E. G. (2001). A comparison of the neuropsychological profiles of the *DSM-IV* subtypes of ADHD. *Journal of Abnormal Child Psychology, 29*, 529-540.

Conners, C. K. (2000). *CPT-II. Continuous Performance Test II. Computer program for Windows techincal guide and software manual*. Toronto, ON: Multi-Health Systems.inc.

Conners, C. K., Epstein, J. N., Angold, A., & Klaric, J. (2003). Continuous performance test performance in a normative epidemiological sample. *Journal of Abnormal Child Psychology, 31*, 555-562.

Corbett, B. A., & Constantine, L. J. (2006). Autism and attention deficit hyperactivity disorder: Assessing attention and response control with the integrated visual and auditory continuous performance test. *Child Neuropsychology, 12*(4-5), 335-348.

Edwards, M. C., Gardner, E. S., Chelonis, J. J., Schulz, E. G., Flake, R. A., & Diaz, P. F. (2007). Estimates of the validity and utility of the Conners' Continuous Performance Test in the assessment of inattentive and/or hyperactive-impulsive behaviors in children. *Journal of Abnormal Child Psychology, 35*, 393-404.

Egeland, J., Johansen, S. N., & Ueland, T. (2009). Differentiating between ADHD sub-types on CCPT measures of sustained attention and vigilance. *Scandinavian Journal of Psychology, 50*, 347-354.

Ehlers, S., Gillberg, C., & Wing, L. (1999). A screening questionnaire for Asperger syndrome and other high-functioning autism spectrum disorders in school age children. *Journal of Autism and Developmental Disorders, 29*, 129-141.

Ehlers, S., Nydén, A., Gillberg, C., Sandberg, A. D., Dahlgren, S. O., Hjelmquist, E., & Oden, A. (1997). Asperger syndrome, autism and attention disorders: A comparative study of the cognitive profiles of 120 children. *Journal of Child Psychology and Psychiatry, 38*, 207-217.

Epstein, J. N., Erkanli, A., Conners, C. K., Klaric, J., Costello, J. E., & Angold, A. (2003). Relations between Continuous Performance Test performance measures and ADHD behaviors. *Journal of Abnormal Child Psychology, 31*, 543-554.

Frazier, T. W., Demaree, H. A., & Youngstrom, E. A. (2004). Meta-analysis of intellectual and neuropsychological test performance in attention-deficit/hyperactivity disorder. *Neuropsychology, 18*, 543-555.

Geurts, H. M., Verte, S., Oosterlaan, J., Roeyers, H., & Sergeant, J. A. (2004). How specific are executive functioning deficits in attention deficit hyperactivity disorder and autism? *Journal of Child Psychology and Psychiatry, 45*, 836-854.

Gilchrist, A., Green, J., Cox, A., Burton, D., Rutter, M., Couteur, A. L. (2001). Development and current functioning in adolescents with Asperger syndrome: A comparative study. *Journal of Child Psychology and Psychiatry, 42*, 227-240.

Gillberg, C. (2010). The ESSENCE in child psychiatry: Early symptomatic syndromes eliciting neurodevelopmental clinical examinations. *Research in Developmental Disabilities, 31*, 1543-1551.

Gillberg, C., Gillberg, I. C., Rasmussen, P., Kadesjo, B., Soderstrom, H., Rastam, M., . . . Niklasson, L. (2004). Co-existing disorders in ADHD—Implications for diagnosis and intervention. *European Child & Adolescent Psychiatry, 13*(Suppl. 1), i80-i92.

Goodman, D. W., Lasser, R. A., Babcock, T., Pucci, M. L., & Solanto, M. V. (2011). Managing ADHD across the lifespan in the primary care setting. *Postgraduate Medicine, 123*(5), 14-26.

Goodman, R. (1999). The extended version of the Strengths and Difficulties Questionnaire as a guide to child psychiatric caseness and consequent burden. *Journal of Child Psychology and Psychiatry, 40*, 791-799.

Goodman, R., Ford, T., Richards, H., Gatward, R., & Meltzer, H. (2000). The Development and Well-Being Assessment: Description and initial validation of an integrated assessment of child and adolescent psychopathology. *Journal of Child Psychology and Psychiatry, 41*, 645-655.

Happé, F., Booth, R., Charlton, H., & Hughes, C. (2006). Executive function deficient in autism spectrum disorders and attention-deficit/hyperactivity disorder: Examining profiles across domains and ages. *Brain and Cognition, 61*, 25-39.

Heiervang, E., Stormark, K. M., Lundervold, A. J., Heimann, M., Goodman, R., Posserud, M., . . . Gillberg, C. (2007). Psychiatric disorders in Norwegian 8- to 10-year-olds: An epidemiological survey of prevalence, risk factors, and service use. *Journal of American Academy of Child & Adolescent Psychiatry, 46*, 438-447.

Hervey, A. S., Epstein, J. N., Curry, J. F., Tonev, S., Arnold, L. E., Conners, C. K., . . . Hechtman, L. (2006). Reaction time distribution analysis of neuropsychological performance in an ADHD sample. *Child Neuropsychology, 12*, 125-140.

Hill, E. L. (2004). Executive dysfunction in autism. *Trends in Cognitive Science, 8*, 26-32.

Holtmann, M., Matei, A., Hellmann, U., Becker, K., Poustka, F., & Schmidt, M. H. (2006). Rolandic spikes increase impulsivity in ADHD—A neuropsychological pilot study. *Brain Development, 28*, 633-640.

Jepsen, J. R. M., Fagerlund, B., & Mortensen, E. L. (2009). Do attention deficits influence IQ assessment in children and adolescents with ADHD? *Journal of Attention Disorders, 12*, 551-562.

Kadesjo, B., & Gillberg, C. (2001). The comorbidity of ADHD in the general population of Swedish school-age children. *Journal of Child Psychology and Psychiatry, 42*, 487-492.

Kaland, N., Smith, L., & Mortensen, E. L. (2008). Brief report: Cognitive flexibility and focused attention in children and adolescents with Asperger syndrome or high-functioning autism as measured on the computerized version of the Wisconsin Card Sorting Test. *Journal of Autism and Developmental Disorders, 38*, 1161-1165.

Kaufman, J., Birmaher, B., Brent, D., Rao, U., Flynn, C., Moreci, P., . . . Ryan, N. (1997). Schedule for Affective Disorders and Schizophrenia for School-Age Children–Present and Lifetime version (K-SADS-PL): Initial reliability and validity data. *Journal of American Academy of Child & Adolescent Psychiatry, 36*, 980-988.

Lichtenstein, P., Carlstrom, E., Raastam, M., Gillberg, C., & Anckarsater, H. (2010). The genetics of autism spectrum disorders and related neuropsychiatric disorders in childhood. *American Journal of Psychiatry, 167*, 1357-1363.

Liss, M., Harel, B., Fein, D., Allen, D., Dunn, M., Feinstein, C., . . . Rapin, I. (2001). Predictors and correlates of adaptive functioning in children with developmental disorders. *Journal of Autism and Developmental Disorders, 31*, 219-230.

Lundervold, A. J., Posserud, M., Ullebø, A. K., Sørensen, L., & Gillberg, C. (2011). Teacher reports of hypoactivity symptoms reflect slow cognitive processing speed in primary school children. *European Child & Adolescent Psychiatry, 20*, 121-126.

Lundström, S., Chang, Z., Råtestam, M., Gillberg, C., Larsson, H., Anckersäter, H., & Lichtenstein, P. (2012). Autism spectrum disorders and autistic like traits: Similar etiology in the extreme end and in the normal variation. *Archives of General Psychiatry, 69*, 46-52.

Mahone, E. M., Powell, S. K., Loftis, C. W., Goldberg, M. C., Denckla, M. B., & Mostofsky, S. H. (2006). Motor persistence and inhibition in autism and ADHD. *Journal of International Neuropsychological Society, 12*, 622-631.

McGee, R. A., Clark, S. E., & Symons, D. K. (2000). Does the Conners' Continuous Performance Test aid in ADHD diagnosis? *Journal of Abnormal Child Psychology, 28,* 415-424.

Newcorn, J. H., Halperin, J. M., Jensen, P. S., Abikoff, H. B., Arnold, L. E., Cantwell, D. P., . . . Vitiello, B. (2001). Symptom profiles in children with ADHD: Effects of comorbidity and gender. *Journal of American Academy of Child & Adolescent Psychiatry,* 40, 137-146.

Nydén, A., Hjelmquist, E., & Gillberg, C. (2000). Autism spectrum and attention-deficit disorders in girls: Some neuropsychological aspects. *European Child & Adolescent Psychiatry, 9*, 180-185.

Nydén, A., Niklasson, L., Stahlberg, O., Anckarsater, H., Wentz, E., Rastam, M., & Gillberg, C. (2010). Adults with autism spectrum disorders and ADHD neuropsychological aspects. *Research in Developmental Disabilities, 31*, 1659-1668.

O'Brien, J. W., Dowell, L. R., Mostofsky, S. H., Denckla, M. B., & Mahone, E. M. (2010). Neuropsychological profile of executive function in girls with attention-deficit/hyperactivity disorder. *Archives of Clinical and Neuropsychology, 25*, 656-670.

Park, M. H., Kweon, Y. S., Lee, S. J., Park, E. J., Lee, C., & Lee, C. U. (2011). Differences in performance of ADHD children on a Visual and Auditory Continuous Performance Test according to IQ. *Psychiatry Investigation, 8*, 227-233.

Pascualvaca, D. M., Fantie, B. D., Papageorgiou, M., & Mirsky, A. F. (1998). Attentional capacities in children with autism: Is there a general deficit in shifting focus? *Journal of Autism and Developmental Disorders, 28*, 467-478.

Perry, G. M. L., Sagvolden, T., & Faraone, S. V. (2010). Intraindividual variability (IIV) in an animal model of ADHD—The spontaneously hypertensive rat. *Behavioral and Brain Functions, 6*, 56.

Posserud, M., Lundervold, A. J., Lie, S. A., & Gillberg, C. (2011). The prevalence of autism spectrum disorders: Impact of diagnostic instrument and non-response bias. *Social Psychiatry and Psychiatric Epidemiology, 45*, 319-327.

Rommelse, N. N. J., Altink, M. E., Fliers, E. A., Martin, N. C., Buschgens, C. J. M., Hartman, C. A., . . . Oosterlaan, J. (2009). Comorbid problems in ADHD: Degree of association, shared endophenotypes, and formation of distinct subtypes. Implications for a future *DSM. Journal of Abnormal Child Psychology, 37*, 793-804.

Rommelse, N. N. J., Franke, B., Geurts, H. M., Hartman, C. A., & Buitelaar, J. K. (2010). Shared heritability of attention-deficit/hyperactivity disorder and autism spectrum disorder. *European Child & Adolescent Psychiatry, 19*, 281-295.

Semrud-Clikeman, M., Walkowiak, J., Wilkinson, A., & Butcher, B. (2010). Executive functioning in children with Asperger syndrome, ADHD-combined type, ADHD-predominately inattentive type, and controls. *Journal of Autism and Developmental Disorders, 40*, 1017-1027.

Sinzig, J., Morsch, D., Bruning, N., Schmidt, M. H., & Lehmkuhl, G. (2008). Inhibition, flexibility, working memory and planning in autism spectrum disorders with and without comorbid ADHD-symptoms. *Child and Adolescent Psychiatry and Mental Health, 2*, 4.

Sinzig, J., Walter, D., & Doepfner, M. (2009). Attention deficit/hyperactivity disorder in children and adolescents with autism spectrum disorder: Symptom or syndrome? *Journal of Attention Disorders, 13*, 117-126.

Sobanski, E., Banaschewski, T., Asherson, P., Buitelaar, J., Chen, W., Franke, B., . . . Faraone, S. V. (2010). Emotional lability in children and adolescents with attention deficit/hyperactivity disorder (ADHD): Clinical correlates and familial prevalence. *Journal of Child Psychology and Psychiatry, 51*, 915-923.

Sonnander, S., Ramund, B., & Smedler, A.-C. (1998). *WISC-III Manual*. Stockholm:Psykologiförlaget AB.

Sørensen, L., Plessen, K. J., Nicholas, J., & Lundervold, A. J. (2011). Is behavioral regulation in children with ADHD aggravated by comorbid anxiety disorder? *Journal of Attention Disorders, 15*, 56-66.

Swanson, J. M., Kraemer, H. C., Hinshaw, S. P., Arnold, L. E., Conners, C. K., Abikoff, H. B., . . . & Wu, M. (2001). Clinical relevance of the primary findings of the MTA: Success rates based on severity of ADHD and ODD symptoms at the end of treatment. *Journal of the American Academy of Child & Adolescent Psychiatry, 40*, 168-179.

Tillman, C. M., Bohlin, G., Sørensen, L., & Lundervold, A. J. (2009). Intellectual deficits in children with ADHD beyond central executive and non-executive functions. *Archives of Clinical Neuropsychology, 24*, 769-782.

Wechsler, D. (2003). Wechsler Intelligence Scale for Children - III (Norwegian Version). Stockholm Harcourt Assessment.

Wing, L., Leekam, S. R., Libby, S. J., Gould, J., & Larcombe, M. (2002). The diagnostic interview for sand communication disorders: Background, inter-rater reliability and clinical use. *Journal of Child Psychology and Psychiatry, 43*, 307-325.

Witwer, A. N., & Lecavalier, L. (2008). Examining the validity of autism spectrum disorder subtypes. *Journal of Autism and Developmental Disorders, 38*, 1611-1624.

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