



## Executive functions in Asperger's syndrome: An empirical investigation of verbal and nonverbal skills<sup>☆</sup>

Adam W. McCrimmon<sup>a\*</sup>, Vicki. L. Schwan<sup>b</sup>, Donald H. Saklofske<sup>a</sup>, Janine M. Montgomery<sup>c</sup>, Danielle I. Brady<sup>a</sup>

<sup>a</sup> Educational Studies in School Psychology, University of Calgary, 2500 University Drive, Calgary, Alberta, Canada T2N-1N4

<sup>b</sup> Faculty of Education, University of Western Ontario, London, Ontario, Canada

<sup>c</sup> Department of Psychology, University of Manitoba, Winnipeg, Manitoba, Canada

### ARTICLE INFO

#### Article history:

Received 7 May 2011

Accepted 10 May 2011

Available online 6 June 2011

#### Keywords:

Asperger's syndrome

Adolescents

Executive functioning

Neuropsychological functioning

### ABSTRACT

Deficits in executive functioning (EF) have been proposed to underlie the behavioural patterns of individuals with an autism spectrum disorder. Researchers have shown that the Asperger's syndrome (AS) population performs more poorly than typically developing controls on many EF tasks. However, the research literature is inconsistent in identifying the specific features or aspects of EF that are affected in this population. This study investigated EF in AS using a bottom-up empirical method. Four visually mediated and three verbally mediated EF tasks from the Delis–Kaplan Executive Functioning System were administered to 33 adolescents with AS and 33 age- and gender-matched controls. Two-step cluster analysis was then used to derive subgroups. Diagnostic composition of these subgroups (AS versus control) was examined to provide empirical evidence of a performance bias towards verbal EF for the AS group. A two cluster solution best fits the data with 73% of the AS participants being classified into one cluster and 64% of the control participants classified into another. Assignment into cluster A was based primarily upon low performance on the four visual EF tasks whereas assignment into cluster B was based primarily upon good performance on the four visual EF tasks and one verbal EF task.

© 2011 Elsevier Ltd. All rights reserved.

### 1. Introduction

Researchers have focused on a description and characterization of executive functions (EFs) in individuals with Asperger's syndrome (AS) (e.g., Ozonoff, Rogers, & Pennington, 1991). Despite reports documenting EF deficits, there are no consistent findings describing the specific EF abilities of individuals with AS, nor is there unequivocal evidence differentiating AS from related disorders, such as Autistic Disorder and Pervasive Developmental Disorder – Not Otherwise Specified, based on EF dysfunction. This study investigated EF abilities in adolescents and young adults with AS via a bottom-up empirical design to understand better the specific EF strengths and weaknesses of these individuals.

<sup>☆</sup> This research was supported in part by a grant from the Alberta Center for Child, Family, and Community Research (ACFCRCR). The funding agency had no involvement in study design, data collection, data analysis, data interpretation, writing of this report, or publication.

\* Corresponding author. Tel.: +1 403 220 7573; fax: +1 403 282 9244.

E-mail addresses: [a.mccrimmon@ucalgary.ca](mailto:a.mccrimmon@ucalgary.ca), [awmccrim@ucalgary.ca](mailto:awmccrim@ucalgary.ca) (A.W. McCrimmon).

### 1.1. Asperger's syndrome: diagnostic criteria

Both the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision* (DSM-IV-TR; American Psychiatric Association, 2000) and *International Classification of Diseases, Tenth Edition* (ICD-10; World Health Organization, 1994) clinical classification systems currently recognize AS as a separate and distinct diagnostic disorder. AS is clinically described by impairments in social interaction and repetitive and stereotyped behavioural patterns, with no significant delay in language, cognitive, or adaptive development. Additionally, the criteria for another autism spectrum disorder (ASD) cannot be met for a diagnosis of AS. The prevalence rate of AS is conservatively reported to be 2.5–2.6 per 10,000 children (Fombonne, 2003, 2005).

### 1.2. Neuropsychological Functioning

A common definition of intelligence (IQ) is “the aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment” (Wechsler, 1944). Asperger's original accounts (Asperger, 1944/1991) described his cases as possessing normal cognitive intelligence and being capable of gainful employment. However, researchers have found that individuals with AS manifest higher verbal (VIQ) and lower performance (PIQ) skills (Ehlers et al., 1997; Ghaziuddin & Mountain-Kimchi, 2004; Klin, Volkmar, Sparrow, Cicchetti, & Rourke, 1995; Koyama, Tachimori, Osada, Takeda, & Kurita, 2007; Lincoln, Allen, & Killman, 1995; Lincoln, Courchesne, Allen, Hanson, & Ene, 1998; Miller & Ozonoff, 2000; Ozonoff, South, & Miller, 2000). Furthermore, relative strengths in the verbally mediated cognitive subtests of the Wechsler scales (e.g., Information, Vocabulary, Comprehension, Similarities, and Arithmetic) (Ehlers et al., 1997; Ghaziuddin & Mountain-Kimchi, 2004; Ozonoff et al., 2000) and relative weaknesses in perceptually mediated subtests (e.g., Block Design, Object Assembly, Coding) (Ehlers et al., 1997) have been reported. In line with this is evidence of concordance between the cognitive profiles of AS and Nonverbal Learning Disability (NLD), with strengths in verbally mediated skills (e.g., vocabulary, rote knowledge, verbal memory, and verbal output) and a resulting right hemisphere dysfunction (Klin et al., 1995). However, other researchers have reported no modality differences (Ambery, Russell, Perry, Morris, & Murphy, 2006; Manjiviona & Prior, 1999; Ozonoff, Rogers, et al., 1991; Szatmari, Tuff, Finlayson, & Bartolucci, 1990).

Although finding a distinct IQ profile of AS (especially in light of the concordance with NLD) is thought to be an effective description of their skills and abilities and compelling evidence of a taxonomical distinction between AS and other clinical disorders within the ASD category, this line of evidence cannot be used to describe or differentiate AS from the other ASDs, due to the current diagnostic criteria for these disorders. Indeed, researchers have pointed out that as many as 20% of individuals with AS do not fit this profile, yet still meet the diagnostic criteria for AS (Klin, Pauls, Schultz, & Volkmar, 2005; Klin et al., 1995). Specifically, the diagnostic criteria for AS require that normal language developmental milestones be met. It is therefore not surprising that the majority of individuals with AS demonstrate relative strengths on verbal intelligence tasks. In other words, the diagnostic criteria specify the cognitive, linguistic, and behavioural parameters, resulting in a self-fulfilling prophecy when these factors are examined in research. As such, research investigating the specific skills and abilities of individuals with AS should focus on aspects other than a differentiation in functioning related to verbal intellectual ability.

Several models have been proposed to further investigate the specific skills and abilities of individuals with an ASD, such as AS. One such model used to provide an account of the core symptoms of such disorders is executive functioning.

### 1.3. Executive functioning in Asperger's disorder

Executive functions (EFs) are defined as “the ability to maintain an appropriate problem-solving set for attainment of a future goal” (Ozonoff, Pennington, & Rogers, 1991). They refer to higher mental processes including a number of interacting, yet theoretically distinct, processes including inhibition, working memory, selective attention, planning, and cognitive and behavioural flexibility (Joseph & Tager-Flusberg, 2004). Executive dysfunction has been proposed to potentially explain restricted interests and repetitive behaviours commonly displayed by individuals diagnosed with an ASD (Lopez, Lincoln, Ozonoff, & Lai, 2005; Pennington, 2002; Turner, 1997, 1999). EF variables commonly investigated in individuals with AS include mental flexibility, planning, and inhibition (Pennington, 1997).

Mental flexibility, or set shifting, is the ability to perceive things in a different manner, respond in unique ways and/or to make necessary cognitive adjustments to assist goal attainment, whereas planning is defined as the ability to form a strategy for goal attainment and see it through regardless of the number of required steps (Calhoun, 2006). Individuals with AS have been observed to perform significantly below typically developing matched controls on measures of mental flexibility and planning such as the Wisconsin Card Sorting Task (Ambery et al., 2006; Ozonoff, Rogers, et al., 1991; Verte, Guerts, Roeyers, Oosterlaan, & Sergeant, 2006), Tower of Hanoi (Ozonoff, Rogers, et al., 1991), and the Tower of London (Verte et al., 2006). It has been suggested that this pattern of reduced mental flexibility and planning could be more commonly displayed as an inability to disengage from an object and shift from an external to an internal point of reference (perseveration) resulting in difficulties relating to people and engaging in conversation where the topic of discussion often changes over time (Hughes & Russell, 1993; Russel, Mauthner, Sharpe, & Tidswell, 1991). However, it should be noted that some researchers have reported no EF deficits in individuals with AS on a local–global shifting task (Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2001) and the WCST (Miller & Ozonoff, 2000; Nyden, Gillberg, Hjelmquist, & Heiman, 1999).

Inhibition is the ability to control a response that will not support goal attainment and instead activate an appropriate alternative (Calhoun, 2006). Researchers using the Opposite Worlds task of the Test of Everyday Attention for Children have reported that children with AS experienced greater difficulties with inhibition on this task as compared to typical control children (Verte et al., 2006). Moreover, deficits on both verbal and visual go-no-go tasks have also been reported (Nyden et al., 1999). However, measures of inhibition, such as the classic Stroop task, have shown no difference in performance of AS and typically developing children (Ambery et al., 2006).

The limited research literature indicates inconsistent evidence in favour of an EF deficit in mental flexibility, planning, and inhibition in individuals with AS. Whereas some researchers have found a difference in performance between individuals with AS and typically developing controls on common EF tasks (Ozonoff, Rogers, et al., 1991; Verte et al., 2006), others have reported no difference (Manjiviona & Prior, 1999; Miller & Ozonoff, 2000).

In one departure from the more commonly used EF tasks, Kleinhans, Akshoomoff, and Delis (2005) investigated EF in a combined group of AS and High-Functioning Autism (HFA) using four subtests of the Delis–Kaplan Executive Functioning System (DKEFS). This group performed significantly below typically matched controls on a composite EF measure (created for the research study) despite average IQ, although this discrepancy was generally small. When individual subtests were examined, the combined participant group performed in the Below Average range on letter fluency and switching fluency, two aspects of the Verbal Fluency subtest. These researchers indicated that this finding, in combination with performance within the Average range on Design Fluency (a non-verbal EF task), suggests that AS and HFA populations may be associated with a modality-specific EF deficit, specifically a verbal EF deficit. However, the results of this study are potentially unrepresentative of individuals with AS as a mixed sample was utilized. Specifically, given that HFA individuals are clinically differentiated by the presence of a language delay in early childhood (before the age of three), and further difficulties in language processing later in life, this delay could also be represented by reduced performance on verbally mediated EF measures. Together with a very small sample size, combining individuals with HFA and AS into the same study sample may have resulted in erroneous conclusions regarding a potential verbal EF deficit in individuals with AS.

#### 1.4. Summary and critique

Although some studies have shown that individuals with AS exhibit deficits in various aspects of EF, research investigating more specific features of EF in this population has yet to be conducted. As well, more research should be focused on older adolescent and adult populations, given the trajectory of executive functioning development, which continues to develop into late adolescence (Blakemore & Choudhury, 2006).

The present study investigated the theorized modality-specific deficit in EFs in individuals with AS proposed by Kleinhans et al. (2005). Adolescents and young adults with AS and typically developing controls were compared on seven subtests of the DKEFS using cluster analysis to provide empirically based evidence of a modality-specific EF deficit in AS. The composition of subgroups was then examined in terms of diagnostic characteristics and specific EF performance.

Based upon research evidence showing an overall EF deficit in individuals with AS, it was hypothesized that one cluster of participants would be comprising primarily individuals with AS and a second cluster would be comprising primarily typically developing matched control participants. Further, it was hypothesized that the clusters would be differentiated by performance on verbally mediated versus visually mediated EF tasks. Thus, cluster A, comprising primarily individuals with AS, would demonstrate better performance on verbally mediated EF tasks than the individuals in cluster B. In contrast, cluster B, comprising primarily typically developing control participants, would demonstrate better performance on visually mediated EF tasks.

## 2. Methods

### 2.1. Participants

Participant recruitment for the AS sample occurred through community supportive agencies. Forty-one participants diagnosed with AS initially participated in the study. Eight participants were removed for 1 of 2 reasons: six due to a confirmed clinical diagnosis of Autistic Disorder (HFA) and two due to failure to meet the IQ inclusion criteria described below. The final clinical sample included 33 adolescents or young adults diagnosed with AS ( $M = 18.83$  years, range 16–21 years, 78.8% male) and 33 age- and gender-matched typically developing controls ( $M = 18.86$  years, range 16–21 years, 78.8% male).

The diagnosis of the individuals with AS was confirmed using DSM-IV-TR (American Psychiatric Association, 2000) diagnostic criteria. A clinical diagnosis of AS made by a licensed professional not associated with the current study (e.g., Psychologist, Psychiatrist, and Developmental Pediatrician) in addition to a documented history of qualitative impairment in social interaction, repetitive or stereotypical patterns of behaviour, and intact language development in early childhood was required. All AS participants were required to provide documentation specifying the professional who provided their diagnosis as well as information pertaining to their developmental history. This information was subsequently reviewed by three of the authors to ensure adherence to DSM-IV criteria for AS prior to inclusion into the study. A more strict diagnostic process such as the Autism Diagnostic Interview – Revised (Lord, Rutter, & Le Couteur, 1994) was not possible as appropriate

individuals (e.g., parents) were unavailable to complete this measure for the majority of the participants. Participant demographic characteristics are described in Table 1.

In accordance with DSM-IV-TR diagnostic criteria, all AS participants were required to demonstrate verbal (VIQ), nonverbal (PIQ), and full scale intelligence (FSIQ) in the Average or higher ranges (85 or greater). Consistent with many findings in the research literature (e.g., Ehlers et al., 1997; Ghaziuddin & Mountain-Kimchi, 2004; Klin et al., 1995), the participants with AS demonstrated significantly greater VIQ than PIQ ( $t(32) = 2.727, p = 0.01$ ).

Individuals in the control group were recruited primarily through secondary and post-secondary school systems. None indicated a history of or present concern with mental health consistent with a DSM-IV-TR diagnosis. Control participants were matched to participants with AS on the basis of age and gender based upon initial demographic data collected prior to their participation in the study. The clinical and control participants were not matched according to VIQ, PIQ, or FSIQ; however, it should be noted that the participant groups did not differ with respect to VIQ ( $t(64) = 1.796, p = 0.077$ ), PIQ ( $t(64) = 0.112, p = 0.911$ ), or FSIQ ( $t(64) = 1.303, p = 0.197$ ).

## 2.2. Measures

### 2.2.1. Verbal, nonverbal, and full-scale intelligence

VIQ, PIQ, and FSIQ were assessed using the Wechsler Abbreviated Scales of Intelligence (WASI; Wechsler, 1999), an individually administered abbreviated test of cognitive intelligence linked to both the Wechsler Intelligence Scale for Children (WISC-III; Wechsler, 1991) and the Wechsler adult Intelligence Scale (WAIS-III; Wechsler, 1997). It is appropriate for assessing the general intellectual ability of adults or children (aged 8–89 years). The VIQ domain comprised the Similarities and Vocabulary subtests while the PIQ domain includes the Block Design and Matrix Reasoning subtests.

### 2.2.2. Executive functioning

The Delis–Kaplan Executive Function System (DKEFS) (Delis, Kaplan, & Kramer, 2001) is a comprehensive measure of cognitive functions related to executive processes including planning, reasoning, mental flexibility, and inhibition. The nine subtests may be administered individually or in combination with others. Seven subtests were selected for this study.

**2.2.2.1. Trail Making task.** Trail-Making measures flexibility of thinking with five tasks. The primary EF task is TM4: Number–Letter Switching where the examinee is asked to connect visually depicted numbers and letters in alternating ascending order. Performance on this task can then be compared to the other (and simpler) tasks to evaluate cognitive flexibility and motor speed.

**2.2.2.2. Verbal Fluency task.** The Verbal Fluency subtest is a measure of fluency of production and cognitive flexibility in which examinees are required to generate verbal labels fitting within provided categories. It comprises three tasks. The primary EF task is VF3 Category Switching where examinees provide words sequentially belonging to two alternating categories (e.g., articles of clothing and musical instruments) within a time limit.

**2.2.2.3. Design Fluency task.** The Design Fluency task measures fluency of production, as well as cognitive flexibility. The examinee is presented with a row of boxes, each of which contains an array of dots and is asked to connect the dots using only four lines, making a different design in each box, for 60 s. The primary EF task is the DF3 Switching task where the examinee connects empty and filled dots in alternating fashion.

**2.2.2.4. Color–Word Interference task.** The Color–Word Interference subtest is a modification of the classic Stroop test which measures inhibition of an automatic response. The primary EF task for this study is the CW3 Inhibition task. The examinee says the color of ink in which a word denoting a contrasting color is printed.

**2.2.2.5. Word Context task.** The Word Context (WC) subtest assesses verbal evaluative ability, and deductive reasoning and flexibility of thinking. Examinees are required to determine the meaning of the made-up word based upon five sentence clues, each providing increasingly direct hints as to the meaning of the word.

**Table 1**  
Participant demographic information.

	Asperger's syndrome ( $n = 33$ )	Controls ( $n = 33$ )
Age	18.83 (1.55)	18.86 (1.59)
Gender (% male)	78.8	78.8
VIQ	114.09 (12.15)	109.03 (10.69)
PIQ	108.94 (9.85)	108.67 (10.01)
FSIQ	113.18 (10.61)	110.06 (8.76)

*Note.* Age is reported in decimalized format (e.g., 19 years, 6 months is 19.5 years). The Wechsler Abbreviated Scale of Intelligence (WASI) is from Wechsler, 1999. VIQ refers to verbal intelligence quotient, PIQ refers to performance intelligence quotient, and FSIQ refers to full scale intelligence quotient. Mean and standard deviation performance for each of these measures is reported in standard score units.

**2.2.2.6. Tower task.** The Tower (T) subtest is a modification and improvement of the Tower of Hanoi (Borys, Spitz, & Dorans, 1982) and Tower of London (Morris, Ahmed, Syed, & Toone, 1993), commonly used measures of planning ability and mental flexibility. Examinees are shown a display consisting of three pegs with several disks in a pre-arranged format. The objective is to transfer the entire tower to one of the other pegs, moving only one disk at a time and never a larger piece onto a smaller.

**2.2.2.7. Proverb task.** The Proverb subtest measures verbal abstraction ability in which eight proverbial sayings are presented, both common and uncommon. The primary EF task is the Free Inquiry (PFI) condition in which the proverbs are read to the examinee who is then asked to interpret them without assistance.

### 2.3. Procedure

Participants were administered the WASI at the onset of the testing session to establish the IQ criteria. If met, participants were administered all of the selected subtests of the DKEFS. However, only performance on the primary EF tasks was analyzed. Based upon the abilities evaluated by these tasks as described in the technical manual, subtests deemed to be verbally mediated were the VF3, WC, and PFI tasks whereas visually mediated tasks were the TM4, DF3, CW3, and T tasks.

## 3. Results

Exploratory factor analysis (EFA) was initially used to determine if the subtests grouped together into verbally mediated and visually mediated categories. The overall data for the TM4, CW3, and WC tasks were negatively skewed and the WC task was quite leptokurtic. As such, the principle axis factoring method, which is robust to violations of the assumption of normality (Fabrigar, Wegener, MacCallum, & Strahan, 1999), was utilized. The direct oblimin rotation method was selected to allow the EF task variables to be correlated. The pattern (indicating the contribution of each variable to each factor) and structure (represents the correlation between the factors) matrices are reported in Table 2.

In determining factor composition, the guidelines established by Tabachnick and Fidell (2007) were used; a factor loading of 0.32 with no cross-factor loading of this amount or greater is indicative of factor membership. Two factors underlie the EF tasks. The first factor comprised the visually mediated tasks (TM4, DF3, CW3, and T) whereas the second comprised verbally mediated tasks (VF3, WC, and PFI). Examination of the structure matrix suggests that the four visually mediated tasks in factor 1 and the 3 verbally mediated tasks in factor 2 are not significantly correlated.

Two-step cluster analysis was then used to determine if subgroups of participants could be empirically derived on the basis of performance on these specific tasks. The two-step cluster analysis procedure is a multivariate technique designed to reveal natural groupings within a data set and the goal is to maximize the variability between the clusters relative to the variability within clusters. No *a priori* designation of number of clusters allowed the analysis to determine the optimum number and pattern of clusters arising from the data.

The final cluster solution was based upon the following parameters: two-step cluster analysis using Schwarz's Bayesian Criterion (BIC), the log-likelihood distance measurement, and automatic generation of the optimum number of clusters. The results indicated an optimum two-cluster solution as indicated by the BIC. Thirty-six individuals were classified into cluster A and 30 into cluster B. Cluster A comprised 24 individuals with AS (66.6%) and 12 control individuals (33.3%) whereas cluster B comprised 9 individuals with AS (30%) and 21 control individuals (70%). Overall, 72.7% of AS participants were classified into cluster A whereas 63.6% of control participants were classified into cluster B. Cluster A was labelled "low performers" and cluster B was labelled "high performers". Cognitive and performance information of the participants in these clusters appear in Table 3.

Inspection of the variable importance plots revealed that performance on the following DKEFS tasks were important in differentiating participants in either cluster (listed in order of importance):

Cluster A ( $n = 36$ ) (low performers) : DF3, CW3, T, TM4  
 Cluster B ( $n = 30$ ) (high performers) : TM4, CW3, DF3, WC, T

**Table 2**  
 Pattern and structure matrices from the EFA.

Variable	Pattern Matrix		Structure Matrix	
	Factor 1	Factor 2	Factor 1	Factor 2
TM4	0.693	-0.141	0.646	0.089
VF3	0.200	0.344	0.315	0.411
DF3	0.729	0.150	0.779	0.393
CW3	0.737	0.090	0.767	0.336
WC	0.245	0.742	0.492	0.824
T	0.495	0.017	0.501	0.182
PFI	-0.125	0.566	0.064	0.525

**Table 3**  
Cluster demographic information.

Variable	Total sample ( <i>n</i> = 66)	Cluster A ( <i>n</i> = 36)	Cluster B ( <i>n</i> = 30)	Performance differential	Significance ( <i>p</i> value)
Diagnosis (# AS)	33	24	9		
Age	18.85 (1.56)	18.50 (1.50)	19.26 (1.54)		
Gender (# male)	52	28	24		
VIQ	111.56 (11.64)	108.42 (11.20)	115.33 (11.18)	6.91	0.015
PIQ	108.80 (9.85)	104.81 (7.57)	113.60 (10.23)	8.79	<0.001
FSIQ	111.62 (9.78)	107.72 (8.06)	116.30 (9.73)	8.58	<0.001
TM4	9.88 (3.26)	8.11 (3.40)	12.00 (1.15)	3.89	<0.001
VF3	10.74 (3.11)	9.58 (2.89)	12.13 (2.81)	2.55	<0.001
DF3	12.33 (3.49)	10.00 (2.45)	15.13 (2.29)	5.13	<0.001
CW3	9.77 (3.90)	7.58 (3.76)	12.40 (1.99)	4.82	<0.001
WC	11.00 (2.13)	10.11 (2.10)	12.07 (1.66)	1.96	<0.001
T	11.08 (2.84)	9.81 (2.14)	12.60 (2.57)	2.79	<0.001
PFI	9.44 (3.46)	8.89 (3.55)	10.10 (3.28)	1.21	0.158

Note. Mean and standard deviation performance for VIQ, PIQ, and FSIQ is reported in standard score units ( $M = 100$ ,  $SD = 15$ ). Mean and standard deviation performance for the TM3, VF3, DF3, CW3, WC, T, and PFI tasks is reported in scaled score units ( $M = 10$ ,  $SD = 3$ ).

The significance of each task in determining which cluster participants were assigned was calculated via *t*-tests (Bonferonni correction set at  $p = 0.007$  for multiple testing). Performance on the DF3 task ( $M = 10.00$ ,  $SD = 2.50$ ) was the largest contributor to assignment into cluster A ( $t(64) = -5.72$ ,  $p < 0.001$ ). Subsequent to this, performance on the CW3 ( $M = 7.58$ ,  $SD = 3.76$ ;  $t(64) = -3.49$ ,  $p < 0.001$ ), T ( $M = 9.81$ ,  $SD = 2.14$ ;  $t(64) = -3.16$ ,  $p < 0.001$ ), and TM4 ( $M = 8.11$ ,  $SD = 3.40$ ;  $t(64) = -3.12$ ,  $p < 0.001$ ) tasks was a significant contributor to classification into cluster A.

Conversely, the TM4 performance of the participants in cluster B ( $M = 12.00$ ,  $SD = 1.15$ ) was the largest contributor to assignment into that cluster ( $t(64) = 10.15$ ,  $p < 0.001$ ). Subsequent to this, performance on the CW3 ( $M = 12.40$ ,  $SD = 1.99$ ;  $t(64) = 7.22$ ,  $p < 0.001$ ), DF3 ( $M = 15.13$ ,  $SD = 2.29$ ;  $t(64) = 6.71$ ,  $p < 0.001$ ), WC ( $M = 12.07$ ,  $SD = 1.66$ ;  $t(64) = -3.12$ ,  $p < 0.001$ ), and T ( $M = 12.60$ ,  $SD = 2.57$ ;  $t(64) = 3.25$ ,  $p < 0.001$ ) tasks was a significant contributor to classification into cluster B.

Although the purpose of cluster analysis is to separate and classify participants based upon differences in performance, and thus maximize the likelihood of differential performance between the groups, it was of interest to determine the significance of differential performance of participants in cluster A and B. Two-sample *t*-tests were calculated with a Bonferonni correction (significance value set at  $p = 0.005$ ) for multiple testing. VIQ performance did not differ between the groups ( $t(64) = -2.5$ ,  $p = 0.015$ ) although PIQ ( $t(64) = -4.008$ ,  $p < 0.001$ ) and FSIQ ( $t(64) = -3.919$ ,  $p < 0.001$ ) performance did significantly differ. Performance on the majority of EF tasks differed. Specifically, performance on the TM4 ( $t(64) = -5.976$ ,  $p < 0.001$ ), VF3 ( $t(64) = -3.611$ ,  $p < 0.001$ ), DF3 ( $t(64) = -8.738$ ,  $p < 0.001$ ), CW3 ( $t(64) = -6.311$ ,  $p < 0.001$ ), WC ( $t(64) = -4.142$ ,  $p < 0.001$ ), and T ( $t(64) = -4.551$ ,  $p < 0.001$ ), tasks significantly differed between cluster A and cluster B. Only performance on the PFI task ( $t(64) = -1.427$ ,  $p = 0.158$ ) did not significantly differ.

Of interest was determining if diagnostic status affected the performance of the participants in each cluster. To this effect, *t*-tests compared performance on the cognitive and EF tasks of the AS and control participants within each cluster (Bonferonni correction,  $p = 0.005$  for multiple testing) as shown in Table 4. Regarding cluster A, only the DF3 task indicated a significant difference ( $t(34) = -3.479$ ,  $p = 0.001$ ), indicating that the control group performed better than the AS group on this task. Regarding cluster B, the AS group demonstrated significantly better performance on both VIQ ( $t(28) = 3.537$ ,  $p = 0.001$ ) and FSIQ ( $t(28) = 3.622$ ,  $p = 0.001$ ). However, EF task performance did not differ between these groups in cluster B.

Analyses were conducted to examine the performance of the participants with AS in each cluster. The nine “high performer” participants with AS had higher cognitive and EF task performance than did the 24 “low performer” participants.

**Table 4**  
Cognitive and EF performance for participants in cluster A and B.

Variable	Cluster A AS ( <i>n</i> = 24)	Cluster A control ( <i>n</i> = 12)	Cluster B AS ( <i>n</i> = 9)	Cluster B control ( <i>n</i> = 21)	Significance
VIQ	110.13 (10.34)	105.00 (12.51)	124.67 (10.48)	111.33 (9.02)	** +
PIQ	105.29 (7.17)	103.83 (8.57)	118.67 (9.68)	111.43 (9.89)	** +
FSIQ	108.92 (7.32)	105.33 (9.22)	124.56 (9.80)	112.76 (7.42)	+
TM4	7.88 (3.58)	8.58 (3.12)	11.67 (1.32)	12.14 (1.06)	+
VF3	9.63 (2.70)	9.50 (3.37)	13.56 (1.51)	11.52 (3.04)	+
DF3	9.13 (2.42)	11.75 (1.36)	15.89 (2.67)	14.81 (2.09)	* +
CW3	7.21 (4.05)	8.33 (3.11)	12.11 (2.85)	12.52 (1.57)	+
WC	10.04 (2.16)	10.25 (2.05)	12.89 (1.62)	11.71 (1.59)	+
T	9.29 (2.31)	10.83 (2.37)	13.44 (3.54)	12.24 (2.02)	+
PFI	9.67 (3.56)	7.33 (3.11)	12.67 (2.40)	9.00 (3.02)	

Note. Single asterisk denotes statistical significance within cluster A. Dual asterisk denotes statistical significance within cluster B. Single + denotes statistical significance between AS participants.

Specifically, VIQ ( $t(64) = -3.585, p = 0.001$ ), PIQ ( $t(64) = -4.333, p < 0.001$ ), and FSIQ ( $t(64) = -4.979, p < 0.001$ ) performance significantly differed. Moreover, performance on the TM4 ( $t(64) = -3.074, p = 0.004$ ), VF3 ( $t(64) = -4.107, p < 0.001$ ), DF3 ( $t(64) = -6.962, p < 0.001$ ), CW3 ( $t(64) = -3.319, p = 0.002$ ), WC ( $t(64) = -3.587, p < 0.001$ ), and T ( $t(64) = -3.96, p < 0.001$ ), tasks significantly differed between cluster A and cluster B. Only the PFI task ( $t(64) = -2.327, p = 0.027$ ) did not significantly differ between clusters.

Finally, it was of interest to determine if cognitive ability was indicative of performance on the EF tasks. Correlations were calculated within each diagnostic group in each cluster to determine the nature and extent of the relationship between VIQ and the verbally mediated EF tasks, and PIQ and the visually mediated EF tasks. Again, a Bonferroni correction was utilized for each group of comparisons (significance value set at  $p = 0.0124$  for verbal comparisons and  $p = 0.0166$  for nonverbal comparisons). Regarding the AS participants in cluster A, only VIQ and PFI task performance was significantly correlated ( $r = 0.514, p = 0.01$ ). Cluster A control participants did not demonstrate any significant relationships among these variables. Regarding the AS participants in cluster B, no significant relationships were indicated. Cluster B control participants demonstrated a significant correlation between VIQ and performance on the WC task ( $r = 0.587, p = 0.005$ ).

#### 4. Discussion

Consistent with the hypothesized differentiation of EF tasks based upon modality, results of the EFA indicated two factors: visually mediated (TM4, DF3, CW3, and T) and verbally mediated (VF3, WC, and PFI) EF tasks. Despite the variability of task requirements in the verbally mediated tasks, the results from the factor analysis provide the framework from which to investigate EF performance in adolescents and young adults with AS and controls. However, as factor analysis procedures are sensitive to the effects of small sample sizes (Comrey & Lee, 1992), and general consensus regarding minimal sample size for cluster analysis is  $2^k$  participants ( $k$  = number of variables) to achieve sufficient power and confidence in the statistical conclusions (Formann, 1984), the results from the current analyses should be considered exploratory.

As expected, individuals with AS demonstrate better developed VIQ compared to PIQ. Overall, lower performance on the four visually mediated tasks (DF3, CW3, T, and TM4) was a significant contributor to assignment into cluster A, where the majority of participants with AS were classified, whereas higher performance on the verbal tasks was a significant contributor to classification into cluster B, where the majority of control participants were classified. Of note was the fact that, although participants in cluster A performed within the Average range on the DF3 task, their performance was significantly lower than that of the participants in cluster B. Indeed, this performance difference was the largest contributor to the final clustering solution.

One possible argument regarding the performance differential of the AS and control participants pertains to IQ and its relationship to EF performance. Although argued to be different cognitive constructs (Kolb & Whishaw, 1990; Pennington & Ozonoff, 1996), a high degree of overlap between IQ and EF is often cited in the research literature (Sternberg, 1985; Sternberg & Gardner, 1982). Here,  $g$  (or general intelligence) represents an individual's overall intellectual functioning and underlies individual differences in EF. Corollaries of this hypothesis have been explored and three lines of evidence have been put forward to challenge this notion of EF/IQ interdependence (Crinella & Yu, 2000).

First, if such a direct relationship exists, then tasks with a higher  $g$  loading will necessarily draw more upon EF than tasks with low  $g$  loadings. Although a positive relationship may exist between IQ and EF, the correlations are quite low (Ardila, Pineda, & Rosselli, 2000; Arffa, 2007; Welsh, Pennington, & Grossier, 1991). Moreover, this relationship appears to be most related to one aspect of  $g$ , fluid intelligence. In addition, several researchers have reported that individuals affected by some childhood disorders, such as Learning Disorders, Autism, phenylketonuria, and Attention-Deficit/Hyperactivity Disorder, demonstrate poor performance on measures of fluid intelligence and EF, but relatively intact crystallized and overall intelligence (Barkley, 1997; Berlin, 2003; Diamond, Prevor, Callendar, & Druin, 1997; McLean & Hitch, 1999; Pennington & Ozonoff, 1996; Stanovich, Siegel, & Gottardo, 1997; Swanson, 1999).

Second, if a direct relationship between IQ and EF exists, then individuals with a deficit in one area should necessarily demonstrate a deficit in the other. There is ample research evidence that many individuals, such as those with Attention-Deficit/Hyperactivity Disorder (ADHD), demonstrate consistent EF deficits (Barkley, 1995, 1997; Pennington, Grossier, & Welsh, 1993); however, their mean full scale IQ scores do not reflect this deficit. Although individuals with ADHD often display deficits on common measures of intelligence such as the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003), the effect size of this difference is not large nor is it commensurate with their demonstrated EF deficits (Mayes & Calhoun, 2006; Schwean & McCrimmon, 2008; Schwean & Saklofske, 2005).

Third, the frontal lobes of the brain are clearly responsible for EF (Cummings & Benson, 1990; Luria, 1966). However, minor insult to sections of the frontal lobes of the brain frequently results in deficits to EF but not IQ (Hebb, 1945, 1949; Stuss & Benson, 1984; Teuber, 1959). Indeed, as succinctly pointed out by Duncan, Burgess, and Emslie (1995, p. 262), “frontal patients have impaired ‘planning’, ‘problem solving’, etc. but preserved ‘intelligence’”.

In general, EF typically requires a base level of cognitive ability in order to succeed and vice versa. However, EF is but one information processing component necessary for problem solving. The results of the present study reflect this finding in that VIQ was significantly related to performance on only one verbal EF task (PFI) for the AS participants in cluster A and the WC task for control participants in cluster B. PIQ performance was not significantly related to visual EF task performance for any participants.

Overall, the results are consistent with the hypothesized modality-specific EF bias in individuals with AS. Participants with AS demonstrated some difficulty with the verbally mediated EF tasks but had an even a greater deficit on the visually mediated tasks. This finding is counter to the results reported by Kleinmans et al. (2005) but as suggested earlier, this may be due to the small sample size and use of a combined diagnostic sample which may have led to unrepresentative findings.

Two findings in this study raise further questions. First, what performance characteristics did the nine participants with AS in cluster B demonstrate that resulted in cross-classification? Second, given the propensity of individuals with AS to demonstrate difficulty in understanding and utilizing non-literal forms of speech, why was the performance differential between cluster A and cluster B on the PFI task the smallest of all the EF tasks and why was this task not a significant contributor to cluster assignment?

The cognitive and EF performance of the cluster B AS participants was higher than their cluster A counterparts. As is frequently mentioned in the research literature, individuals with AS often possess well-developed cognitive and information processing skills, particularly in the verbal domain (Ambery et al., 2006; Klin et al., 2005, 1995; Miller & Ozonoff, 2000; Tager-Flusberg & Joseph, 2003). It is their difficulties with social interaction and behavioural management that are the hallmark characteristics of the disorder. Thus, many individuals with AS demonstrate high intellectual abilities, typically in the verbal domain. However, a proportion of individuals with AS demonstrate cognitive abilities in the Average to Low-Average ranges. Similarly, performance on EF tasks is not universal. Thus, there is a degree of heterogeneity in the IQ and EF abilities of individuals within this population. Although a small proportion of individuals with AS possess well-developed IQ and EF abilities, a greater proportion demonstrate an EF deficit, particularly a visually based one. They have difficulties in fluidly changing mental state, or set-shifting (as evaluated by the TM4 task), struggle with inhibitory skills (as evaluated by the CW3 and T tasks), and find fluency of production challenging (as measured by the DF3 task). Although this finding could be related to their relatively stronger verbal information processing abilities, results of this study indicate little to no correlation between IQ and EF performance of these individuals.

The PFI task was not a significant contributor to cluster assignment. This finding is particularly remarkable given the well-documented difficulty of individuals with AS in interpreting and understanding non-literal language. Indeed, this difficulty with non-literal social communication exists despite intact speech and language and is a hallmark feature of AS (Adachi et al., 2006, 2004; Baron-Cohen, 1988; Boucher, 2003; Eales, 1993; Kjelgaard & Tager-Flusberg, 2001; Martin & McDonald, 2003; Ozonoff & Miller, 1996; Rajendran, Mitchell, & Rickards, 2005; Tager-Flusberg, 1981, 1996, 2006). However, despite the considerable amount of literature on the pragmatic difficulties of individuals with AS, there is a paucity of research on pragmatic reasoning or the ability to make inferences that go beyond the linguistic meaning of utterances (Pijnacker, Hagoort, Buitelaar, Teunisse, & Guerts, 2009). Despite this, some researchers have recently reported similar findings to those reported in this study (Towgood, Meuwese, Gilbert, Turner, & Burgess, 2009). One potential reason for the current findings is that the PFI task does not accurately represent the everyday scenarios and encounters people experience with non-literal language. That is, typical examples of non-literal language use may include simile and metaphor, exaggeration, hyperbole, irony, sarcasm, humour, and other subtle implied nuances associated with the pragmatics of language. For example, the phrase, "Can you answer the phone?" implies a request to engage in the action rather than the literal interpretation of inquiry into a person's physical capability to engage in the action. Although individuals with AS typically interpret these forms of figurative language literally (Dennis, Lazenby, & Lockyer, 2001; Emerich, Creaghead, Grether, Murray, & Grasha, 2003; Happe, 1993; Martin & McDonald, 2004), they appear to be able to understand and interpret proverbs, or at least the eight items in the PFI task, at a level commensurate with typically developing controls. This result could be because the initial five items on this task are relatively common proverbs that would likely have been heard in everyday conversation. Essentially, the PFI task does not appear to be an effective method by which to evaluate and interpret the social-communicative skills of individuals with AS.

Limitations of the present study include the relatively small sample used to draw conclusions. The general consensus regarding minimal sample size is 10 participants per variable being investigated to achieve sufficient power and confidence in the statistical conclusions. As this study examined seven D-KEFS tasks, the overall sample size of 66 falls slightly short of this requirement. In addition, the age range of the participants was 16–21, a time when the pre-frontal cortex is developing and maturing which would affect EF performance. As such, the results may not be indicative of performance of older individuals whose brains have undergone such development or younger individuals whose brains have yet to develop to the same extent.

Overall, the results of this study indicate that individuals with AS demonstrate low performance on the visually mediated EF tasks and relatively better performance on the verbally mediated EF tasks of the DKEFS. Essentially, individuals with AS demonstrate a modality specific EF bias in favour of verbally-based tasks. This information may provide important information regarding the current skills and abilities of individuals with AS, particularly in terms of cognitive flexibility, inhibition, and set shifting. As such, the use of EF measures in a comprehensive multi-method assessment process for AS may be of benefit.

### Conflict of interest

The authors report no conflict of interest in the publication of this article.



## Acknowledgements

Kind acknowledgement to research team members: Keoma Thorne, Jo-Anne Burt, Yvonne Hindes, & Candace Kosack.

## References

- Adachi, T., Hirabayashi, S., Shiota, M., Suzuki, S., Wakamiya, E., Kitayama, S., et al. (2006). Study of situational recognition of attention deficit/hyperactivity disorders, Asperger's disorder and high functioning autism with the Metaphor and Sarcasm Scenario Test (MSST). *No To Hattatssu*, 38, 177–181.
- Adachi, T., Koeda, T., Hirabayashi, S., Maeoka, Y., Shiota, M., Wright, E., et al. (2004). The metaphor and sarcasm scenario test: A new instrument to help differentiate high functioning pervasive developmental disorder from attention deficit/hyperactivity disorder. *Brain & Development*, 26, 301–306.
- Ambery, F., Russell, A., Perry, K., Morris, R., & Murphy, D. (2006). Neuropsychological functioning in adults with Asperger syndrome. *Autism*, 10, 551–564.
- American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders, 4th ed., text revised*. Washington, DC: Author.
- Ardila, A., Pineda, D., & Rosselli, M. (2000). Correlation between intelligence test scores and executive function measures. *Archives of Clinical Neuropsychology*, 15, 31–36.
- Arffa, S. (2007). The relationship of intelligence to executive function and non-executive function measures in a sample of average, above average, and gifted youth. *Archives of Clinical Neuropsychology*, 22, 969–978.
- Asperger, H. (1991). Autistic psychopathologies in childhood. Translated and annotated by U. Frith. In: U. Frith (Ed.), *Autism and Asperger's Syndrome*. New York, NY, US: Cambridge University Press.
- Barkley, R. A. (1995). Linkages between attention and executive functions. In G. R. Lyon & N. A. Krasnegor (Eds.), *Attention, memory and executive function* (pp. 307–328). Baltimore: Paul H. Brookes.
- Barkley, R. A. (1997). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin*, 121, 65–94.
- Baron-Cohen, S. (1988). Social and pragmatic deficits in autism: Cognitive or affective? *Journal of Autism and Developmental Disorders*, 18, 379–402.
- Berlin, L. (2003). The role of inhibitory control and executive functioning in hyperactivity/ADHD: Comprehensive summaries of Uppsala dissertations from the Faculty of Social Sciences 120. Acta Universitatis Upsaliensis.
- Blakemore, S., & Choudhury, S. (2006). Development of the adolescent brain: Implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry*, 47, 296–312.
- Borys, S. V., Spitz, H. H., & Dorans, B. A. (1982). Tower of Hanoi performance of retarded young adults and nonretarded children as a function of solution length and goal state. *Journal of Experimental Child Psychology*, 33, 87–110.
- Boucher, J. (2003). Language development in autism. *International Journal of Pediatric Otorhinolaryngology*, 67(Suppl. 1), 159–163.
- Calhoun, J. (2006). Executive functions: A discussion of the issues facing children with autism spectrum disorders and related disorders. *Seminars in Speech & Language*, 27, 60–71.
- Comrey, A. L., & Lee, H. B. (1992). *A first course in factor analysis* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Crinella, F., & Yu, J. (2000). Brain mechanisms and intelligence. Psychometric g and executive function. *Intelligence*, 27, 299–327.
- Cummings, J. L., & Benson, D. F. (1990). Subcortical mechanisms and human thought. In J. L. Cummings (Ed.), *Subcortical dementia* (pp. 251–260). New York: Oxford University Press.
- Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *Delis-Kaplan Executive Functioning System (D-KEFS) examiners manual*. San Antonio, TX: The Psychological Corporation.
- Dennis, M., Lazenby, A. L., & Lockyer, L. (2001). Inferential language in high-functioning children with autism. *Journal of Autism and Developmental Disorders*, 31, 47–54.
- Diamond, A., Prevor, M. B., Callendar, G., & Druin, D. P. (1997). Prefrontal cognitive deficits in children treated early and continuously for PKU. *Monographs of the Society for Research in Child Development* 62(4) Serial No. 252.
- Duncan, J., Burgess, P., & Emslie, H. (1995). Fluid intelligence after frontal lobe lesions. *Neuropsychologia*, 33, 261–268.
- Eales, M. J. (1993). Pragmatic impairments in adults with childhood diagnoses of autism or developmental receptive language disorder. *Journal of Autism and Developmental Disorders*, 23, 593–617.
- Ehlers, S., Nyden, A., Gillberg, C., Sandberg, A. D., Dahlgren, S., Hjelmquist, E., et al. (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.
- Emerich, D. M., Creaghead, N. A., Grether, S. M., Murray, D., & Grasha, C. (2003). The comprehension of humorous materials by adolescents with high-functioning autism and Asperger's syndrome. *Journal of Autism and Developmental Disorders*, 33, 253–257.
- Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods*, 4, 272–299.
- Fombonne, E. (2003). Epidemiological surveys of autism and other pervasive developmental disorders: An update. *Journal of Autism and Developmental Disorders*, 33, 365–382.
- Fombonne, E. (2005). The changing epidemiology of autism. *Journal of Applied Research in Intellectual Disabilities*, 18, 281–294.
- Formann, A. K. (1984). *Die Latent-Class-Analyse: Einführung in die Theorie und Anwendung*. Weinheim: Beltz.
- Ghaziuddin, M., & Mountain-Kimchi, K. (2004). Defining the intellectual profile of Asperger Syndrome: Comparison with high-functioning autism. *Journal of Autism and Developmental Disorders*, 34, 279–284.
- Happe, F. (1993). Communicative competence and theory of mind in autism: A test of relevance theory. *Cognition*, 48, 101–119.
- Hebb, D. O. (1945). Man's frontal lobes: A critical review. *Archives of Neurology and Psychiatry*, 54, 10–24.
- Hebb, D. O. (1949). *The organization of behavior*. New York: John Wiley & Sons.
- Hughes, C., & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology*, 29, 498–510.
- Joseph, R. M., & Tager-Flusberg, H. (2004). The relationship of theory of mind and executive functions to symptom type and severity in children with autism. *Development and Psychopathology*, 16, 137–155.
- Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An investigation of language impairment in autism: Implications for genetic subgroups. *Language and Cognitive Processes*, 16, 287–308.
- Kleinhaus, N., Akshoomoff, N., & Delis, D. (2005). Executive functions in autism and Asperger's Disorder: Flexibility, fluency, and inhibition. *Developmental Neuropsychology*, 27, 379–401.
- Klin, A., Pauls, D., Schultz, R., & Volkmar, F. (2005). Three diagnostic approaches to Asperger Syndrome: Implications for research. *Journal of Autism and Developmental Disorders*, 35(2), 221–234.
- Klin, A., Volkmar, R., Sparrow, S., Cicchetti, D., & Rourke, B. (1995). Validity and neuropsychological characterization of Asperger Syndrome: Convergence with Nonverbal Learning Disabilities Syndrome. *Journal of Child Psychology and Psychiatry*, 36, 1127–1140.
- Kolb, B., & Whishaw, I. (1990). *Fundamentals of human neuropsychology*. New York: WH Freeman and Company.
- Koyama, T., Tachimori, H., Osada, H., Takeda, T., & Kurita, H. (2007). Cognitive and symptom profiles in Asperger's Syndrome and high-functioning autism. *Psychiatry and Clinical Neurosciences*, 61, 99–104.
- Lincoln, A., Allen, M., & Killman, A. (1995). The assessment and interpretation of intellectual abilities in people with autism. In E. Schopler & G. Mesibov (Eds.), *Learning and cognition in autism. Current issues in autism* (pp. 89–117). New York: Plenum Press.
- Lincoln, A., Courchesne, E., Allen, M., Hanson, E., & Ene, M. (1998). Neurobiology of Asperger syndrome: Seven case studies and quantitative magnetic resonance imaging findings. In E. Schopler, G. B. Mesibov, & L. J. Kunch (Eds.), *Asperger syndrome or high functioning autism?* (pp. 145–166). New York: Plenum Press.

- Lopez, B., Lincoln, A., Ozonoff, S., & Lai, Z. (2005). Examining the relationship between executive functions and restricted, repetitive symptoms of autistic disorder. *Journal of Autism and Developmental Disorders*, 35, 445–460.
- Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism Diagnostic Interview – Revised. A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders*, 24, 659–685.
- Luria, A. (1966). *Higher cortical functions in man*. New York, NY, US: Basic Books Inc.
- Manjiviona, J., & Prior, M. (1999). Neuropsychological profiles of children with Asperger's Syndrome and autism. *Autism*, 3, 327–356.
- Martin, I., & McDonald, S. (2003). Weak coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. *Brain and Language*, 85, 451–466.
- Martin, I., & McDonald, S. (2004). An exploration of causes of nonliteral language problems in individuals with Asperger syndrome. *Journal of Autism and Developmental Disorders*, 34, 313–328.
- Mayes, S., & Calhoun, S. (2006). WISC-IV and WISC-III profiles in children with ADHD. *Journal of Attention Disorders*, 9, 486–493.
- McLean, J. F., & Hitch, G. J. (1999). Working memory impairments in children with specific arithmetic learning difficulties. *Journal of Experimental Child Psychology*, 74, 240–260.
- Miller, J., & Ozonoff, S. (2000). The external validity of Asperger Disorder: Lack of evidence from the domain of neuropsychology. *Journal of Abnormal Psychology*, 109, 227–238.
- Morris, R. G., Ahmed, S., Syed, G. M., & Toone, B. K. (1993). Neural correlates of planning ability: Frontal lobe activation during the Tower of London test. *Neuropsychologia*, 31, 1367–1378.
- Nyden, A., Gillberg, C., Hjelmquist, E., & Heiman, M. (1999). Executive function/attention deficits in boys with Asperger syndrome, attention disorder, and reading/writing disorder. *Autism*, 3, 213–228.
- Ozonoff, S., & Miller, J. N. (1996). An exploration of right hemisphere contributions to the pragmatic impairments of autism. *Brain and Language*, 52, 411–434.
- Ozonoff, S., Pennington, B., & Rogers, S. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry*, 32, 1081–1105.
- Ozonoff, S., Rogers, S., & Pennington, B. (1991). Asperger's Syndrome: Evidence of an empirical distinction from high-functioning autism. *Journal of Child Psychology and Psychiatry*, 32, 1107–1122.
- Ozonoff, S., South, M., & Miller, J. (2000). DSM-IV-Defined Asperger Syndrome: Cognitive, behavioral and early history differentiation from high-functioning autism. *Autism*, 4, 29–46.
- Pennington, B. (1997). *Dimensions of executive functions in normal and abnormal development*. Baltimore, MD, US: Paul H Brookes Publishing.
- Pennington, B. (2002). *The development of psychopathology: Nature and nurture*. New York, NY, US: Guilford Press.
- Pennington, B., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry*, 37, 51–87.
- Pennington, B. F., Grossier, D., & Welsh, M. C. (1993). Contrasting cognitive deficits in attention deficit hyperactivity disorder versus reading disability. *Developmental Psychology*, 29, 511–523.
- Pijnacker, J., Hagoor, P., Buitelaar, J., Teunisse, J. P., & Guerts, B. (2009). Pragmatic inferences in high-functioning adults with autism and Asperger Syndrome. *Journal of Autism and Developmental Disorders*, 39, 607–618.
- Rajendran, G., Mitchell, P., & Rickards, H. (2005). How do individuals with Asperger syndrome respond to nonliteral language and inappropriate requests in computer-mediated communication? *Journal of Autism and Developmental Disorders*, 35, 429–443.
- Rinehart, N., Bradshaw, J., Moss, S., Brereton, A., & Tonge, B. (2001). A deficit in shifting attention present in high-functioning autism but not Asperger's Disorder. *Autism*, 5, 67–80.
- Russel, J., Mauthner, N., Sharpe, S., & Tidswell, T. (1991). The windows task as a measure of strategic deception in preschoolers and autistic subjects. *British Journal of Developmental Psychology*, 9, 331–349.
- Schwean, V. L., & McCrimmon, A. W. (2008). Attention-deficit/hyperactivity disorder: Using the WISC-IV to inform intervention planning. In A. Priftera, D. H. Saklofske, & L. G. Weiss (Eds.), *WISC-IV clinical assessment and intervention 2e*. San Diego: Elsevier Academic Press.
- Schwean, V. L., & Saklofske, D. H. (2005). Assessment of attention deficit hyperactivity disorder with the WISC-IV. In A. Priftera, D. H. Saklofske, & L. G. Weiss (Eds.), *WISC-IV clinical use and interpretation*. Burlington: Elsevier Academic Press.
- Stanovich, K. E., Siegel, L. S., & Gottardo, A. (1997). Converging evidence for phonological and surface subtypes of reading disability. *Journal of Educational Psychology*, 89, 114–127.
- Sternberg, R. (1985). *Beyond IQ: A triarchic theory of human intelligence*. New York: Cambridge University Press.
- Sternberg, R., & Gardner, H. (1982). A componential interpretation of the general factor in human intelligence. In H. J. Eysenck (Ed.), *A model for intelligence* (pp. 231–254). Berlin: Springer Verlag.
- Stuss, D. T., & Benson, D. F. (1984). Neuropsychological studies of the frontal lobes. *Psychological Bulletin*, 95, 3–28.
- Swanson, H. L. (1999). Reading comprehension and working memory in learning-disabled readers: Is the phonological loop more important than the executive system? *Journal of Experimental Child Psychology*, 72, 1–31.
- Szatmari, P., Tuff, L., Finlayson, M., & Bartolucci, G. (1990). Asperger's Syndrome and autism: Neurocognitive aspects. *Journal of the American Academy of Child & Adolescent Psychiatry*, 29, 130–136.
- Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics* (5th ed.). Boston: Allyn and Bacon.
- Tager-Flusberg, H. (1981). On the nature of linguistic functioning in early infantile autism. *Journal of Autism and Developmental Disorders*, 11(1), 45–56doi:10.1007/BF01531340.
- Tager-Flusberg, H. (1996). Brief report: Current theory and research on language and communication in autism. *Journal of Autism and Developmental Disorders*, 26, 169–171.
- Tager-Flusberg, H. (2006). Defining language phenotypes in autism. *Clinical Neuroscience Research*, 6(3–4), 219–224.
- Tager-Flusberg, H., & Joseph, R. M. (2003). Identifying neurocognitive phenotypes in autism. *Philosophical Transactions: Biological Sciences*, 358, 303–314.
- Teuber, H. L. (1959). Some alterations in behaviour after cerebral lesions in man. In D. A. Bass (Ed.), *Evolution of nervous control from primitive organisms to man* (pp. 157–194). Washington, DC: America Association for the Advancement of Science.
- Towgood, K. J., Meuwese, J. D. I., Gilbert, S. J., Turner, M. S., & Burgess, P. W. (2009). Advantages of the multiple case series approach to the study of cognitive deficits in autism spectrum disorder. *Neuropsychologia*, 47, 2981–2988.
- Turner, M. (1997). Towards an executive dysfunction account of repetitive behavior in autism. In J. Russel (Ed.), *Autism as an executive syndrome*. New York, NY, US: Oxford University Press.
- Turner, M. (1999). Repetitive behavior in autism: A review of psychological research. *Journal of Child Psychology and Psychiatry*, 40, 839–849.
- Verte, S., Guerts, H., Roeyers, H., Oosterlaan, J., & Sergeant, J. (2006). Executive functioning in children with an autism spectrum disorder: Can we differentiate within the spectrum? *Journal of Autism and Developmental Disorders*, 36, 351–372.
- Wechsler, D. (1944). *The measurement of adult intelligence*. Baltimore: Williams & Wilkins.
- Wechsler, D. (1991). *Manual for the Wechsler intelligence scale for children* (3rd ed.). San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (1997). *Wechsler adult intelligence scale* (3rd ed.). San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (1999). *Wechsler abbreviated scale of intelligence*. San Antonio, TX: The Psychological Corporation.
- Wechsler, D. (2003). *Wechsler intelligence scale for children* (4th ed.). San Antonio, TX: NCS Pearson Inc.
- Welsh, M. C., Pennington, B. F., & Grossier, D. B. (1991). A normative-developmental study of executive function: A windows on prefrontal functions in children. *Developmental Neuropsychology*, 7, 131–149.
- World Health Organization. (1994). *International classification of diseases* (10th ed.). Geneva, Switzerland: Author.