University of Alberta

Assessing the Working Memory Abilities of ADHD Children Using the Stanford-Binet Intelligence Scales, Fifth Edition

by

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Introduction

First described by physician George Still in 1902, attention-deficit/hyperactivity disorder (ADHD) is now recognized as one of the most common disorders diagnosed in children (Barkley, 1998). It is estimated to affect between 3 and 7 percent of school-age children (APA, 1994) from diverse cultures and geographical regions (Tannock, 1998). ADHD is a chronic disorder impacting the child's peer and family relations, self-esteem, academic achievement, and cognitive functioning (Barkley, 1998; Biederman, Faraone, & Milberger, 1996). The symptoms of ADHD are considered to be due to deficits in behavioural inhibition, leading to secondary impairments in executive function (Barkley, 1997b).

One of the most researched of these executive functions is working memory (Carroll, 1993); the ability to temporarily store and manipulate information in mind (Baddeley, 1986; Roid, 2003b). Studies of working memory deficits associated with ADHD have brought many conflicting results (Barkley, 1998). For example, working memory abilities of children with ADHD have been found to vary from the average range (e.g., Kaplan, Crawford, Dewey, & Fisher, 2000) to the below average range (e.g., Mayes, Calhoun, & Crowell, 1998) depending on the measures used and population studied (Barkley, 1998).

The confusion surrounding the precise nature of working memory abilities in ADHD may be due to the inconsistent conceptualization and definition of working memory across research studies (Tannock, 1998). While researchers have frequently searched for working memory deficits in ADHD, many studies have been atheoretical or unsystematic in their approach (Karatekin, 2004). Similarly, numerous memory tasks have been utilized without a unifying theory to explicate the results.

Framing this research within Baddeley's (1986) Working Memory Model may help to clarify the conflicting results and add meaning to their interpretation (see Roodenrys, Koloski, & Grainger, 2001). Within this model, Baddeley posits a three-component system, comprised of two subsidiary systems (responsible for the storage and rehearsal of verbal and spatial information) and the *central executive* system (responsible for attentional control and the coordination of the subsidiary systems; Baddeley & Hitch, 1974). Assessing these components separately may indicate the nature of working memory deficits. Measures that require the simple storage and rehearsal of verbal and spatial information assess the subsidiary systems, while measures that require the concurrent storage and processing of information are considered indicators of central executive functioning (Baddeley, 1996b).

In general, the research suggests that neither verbal nor spatial subsidiary systems are impaired in ADHD (Barkley, DuPaul, & McMurray, 1990; Karatekin & Asarnow, 1998; Mariani & Barkley, 1997). Instead, discrepancies appear in tasks which require the simultaneous storage and processing of information, suggesting central executive impairments (Barnett et al., 2001; Karatekin, 2004; Roodenrys et al., 2001). In other words, the working memory deficits proposed by Barkley (1997b) may be best assessed through measures of the central executive.

One important limitation in this research is that the two measures of memory most commonly used in both research and assessment (digit span and mental arithmetic; Barkley, 1998) are dependent upon academic knowledge and skill (Carroll, 1993). This is especially pertinent to ADHD, as many of these children have difficulties in math achievement or comorbid learning disabilities in mathematics (Barkley et al., 1990; Cantwell & Baker, 1991). Additional limiting factors in this line of research are due to the methodological inconsistencies inherent in many of the studies. These problems include sample selection issues, changing diagnostic criteria, absence of control groups, and the failure to control for comorbid diagnoses (Barkley, 1998; Carlson, Shin, & Booth, 1999; Lahey & Carlson, 1991). These inconsistencies have made the interpretation of the data difficult, and limited the generalizability of the results.

These measurement issues have important implications in the cognitive testing of ADHD children. The numerous deficits associated with ADHD often lead to the referral of these children to a variety of mental health services. The high prevalence of ADHD children in the mental health system is emphasized by the finding that children with ADHD represent between 50-75% of the referrals to child psychological services (Cantwell, 1996). Intelligence testing is often an integral component in the assessment of these children, playing a major role in determining the cognitive difficulties and learning needs associated with this disorder (Barkley, 1998; Naglieri, Goldstein, Iseman, & Schwebach, 2003). It is essential that appropriate assessment tools be used, so that valid estimates of cognitive ability and learning needs are provided (Barkley, 1998; Marshall, Hynd, Handwerk, & Hall, 1997).

The recent publication of the Stanford-Binet Intelligence Scales – Fifth Edition (SBV; Roid, 2003a) provides a promising tool for the assessment of intellectual functioning in ADHD. The Working Memory (WM) factor of the SBV is based on Baddeley's (1986) model of working memory (Roid, 2003c), therefore, it may provide a more clear measure of working memory relative to its executive functioning and role within Barkley's model. Otherwise stated, WM does not solely measure the rehearsal and recall of information; rather, in theory, it assesses the central executive. In addition, the WM factor does not rely upon math ability or reading comprehension skills, thus providing a more pure measure of working memory abilities.

Research Purpose and Objectives

No literature addressing the performance of ADHD children on the SBV is currently available. Similarly, there is little research supporting the validity of the WM factor as a measure of working memory. There are two main objectives of this research. First, this study will add to the literature on the nature of working memory deficits associated with ADHD. Both verbal and nonverbal working memory processes will be assessed using tasks which require the simultaneous storage and manipulation of information. This research will build upon previous research by controlling for comorbid diagnoses, assessing ADHD subtypes separately, using consistent diagnostic criteria (i.e., DSM-IV), and including a control group for comparison.

Additionally, there is growing evidence to suggest that Baddeley's (1986) model of working memory may provide important contributions to ADHD research. Still, few studies have used this model as a framework to organize and guide their research (e.g., Karatekin, 2004; Roodenrys et al., 2001). As the WM factor is based on Baddeley's model (Roid, 2003c), this study may add to the evidence supporting the use of the Working Memory Model in ADHD research.

Second, it is hoped this study will add validity to the SBV construct of working memory. Children with ADHD are hypothesized to have deficits in their working memory abilities compared to other children. Lower WM scores on the SBV will provide evidence to support to the claim that the WM factor does indeed assess working memory abilities (Roid, 2003c).

Study Limitations and Delimitations

While there are many cognitive abilities assessed by the SBV that could be measured, this study will focus on working memory. Theoretically, this construct should be most significantly impaired in children with ADHD (Barkley, 1997b). Additionally, of the five factors tested during the standardization process of the SBV, WM was reportedly the most impaired in ADHD children (Roid, 2003c). Additionally, this assessment of working memory will not elucidate specific aspects of central executive deficits, or clarify how or why these deficits occur. This study will only indicate whether or not these deficits occur in ADHD, as measured by the SBV.

This study is also delimited by the decision to use data from the Education Clinic at the University of Alberta. These children were referred to the clinic for a variety of academic, behavioural, and emotional concerns, and as such, may not be considered a random sample. The results of this study are intended to apply only to clinic-referred children, and do not reflect the full range of abilities of children with ADHD. While this sample may not accurately represent the ADHD population as a whole, or even a typical child with the disorder, this sample may be more indicative of cases seen in treatment and assessment (Carlson et al., 1999). As such, this study may provide important information concerning the assessment and research of clinic-referred children.

Study Overview

Chapter II contains a review of the literature in three main topics relevant to this study. First, a brief description of ADHD is provided, including a review of the cognitive deficits associated with ADHD, and a discussion of the limitations of previous research. An outline of one of the prevalent models of ADHD is also provided. Second, a brief theoretical overview of the measurement of working memory is examined, and the measurement of working memory in ADHD is reviewed. Third, the SBV is described with particular focus on the WM factor. These three topics are integrated, leading to the rationale of the study and generation of hypotheses.

Chapter III outlines the research design and procedure used to answer these hypotheses. Descriptions of the participants, instruments, procedures, and statistical analyses utilized in this study are provided. Study limitations and delimitations of the study are also outlined.

Chapter IV presents the results of this study, organized by research question. A discussion of these results is presented in Chapter V, along with implications of the study and suggestions for future research.

Literature Review

Attention Deficit Hyperactivity Disorder

ADHD is the most commonly diagnosed disorder in childhood and adolescents (Cantwell, 1996). It is comprised of three primary symptoms; poor sustained attention, impulsiveness, and hyperactivity (Barkley, 1997b). These symptomatic behaviours typically arise in early childhood and are persistent over the course of the child's development (Hinshaw, 1994). They are considered developmentally inappropriate, and significantly impair the daily functioning of the children. For example, during their development children with ADHD are more likely to experience academic failure or poor academic achievement, delinquency, poor family relations, rejection by peers, mood disorders, conduct problems, as well as poor self-esteem (Barkley, Fischer, Edelbrock, & Smallish, 1990; Biederman et al., 1996; Carlson, Lahey, Frame, & Walker, 1987; Hinshaw, 1994). Many of these challenges in daily functioning persist into adulthood, evidenced by difficulties in social relationships, marriage and employment (Weiss & Hechtman, 1993).

Epidemiology

The prevalence of ADHD in the general population is estimated to be between 3 and 7 percent of school-age children (APA, 1994). Current estimates of incidence in the United States range from 3.5 million to 17 million children and adults with ADHD (Cantwell, 1996). The trend in the incidence is increasing as more diagnoses are continually made. One study found the number of ADHD diagnoses in the United States nearly tripling in the early 1990's—from 947 208 diagnoses made in 1990, to 2 357 833 diagnoses made in 1995 (Robinson, Sclar, Skaer, & Galin, 1999).

Several factors are likely to play a role in the varying prevalence rates found in this disorder. First, there has been a recent increase in the public awareness of the disorder, resulting in more children being referred for testing (Barkley, 1998). Second, prevalence rates vary considerably depending on the diagnostic criteria used. The prevalence of ADHD as defined by the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) may be greater than the prevalence based on DSM, Third Edition Revised (DSM-III-R) criteria as the DSM-IV included two subtypes of ADHD which were not included in the earlier edition (APA, 1994). Children meeting the DSM-IV criteria for these two subtypes would not have met the DSM-III-R criteria. Third, prevalence is influenced by factors such as health problems, developmental disorders, and low socio-economic status (SES; Barkley, 1998).

ADHD is more likely to be diagnosed in boys than in girls, although the magnitude of this difference depends on the population sampled and type of ADHD. For example, in the general population the ratio of males to females is 4 to 1, while in clinical samples, this ratio is more than double at 9 to 1 (Cantwell, 1996). This difference may be attributed to a referral bias in which boys (who demonstrate more severe aggressive/impulsive conduct problems) are referred more often than girls (who have primarily inattentive and cognitive problems; Wolraich, Hannah, Pinnock, Baumgaertel, & Brown, 1996). The male to female ratio is also less pronounced for the Inattentive Type of ADHD where the average ratio is approximately 2.2 to 1 compared to an average of 3.2 to 1 for the Combined Type of ADHD (Carlson et al., 1999). Additionally, low

SES appears to be correlated with gender, as females with ADHD trended towards lower family SES compared to males with ADHD (Gaub & Carlson, 1997).

Clinical Criteria

Individuals with ADHD are described as having "chronic difficulties" with inattention, hyperactivity, and impulsivity (Barkley, 1998, p. 57). To meet a diagnosis of ADHD these symptoms are required; to emerge before the age of seven, be considered developmentally inappropriate for the child's age or developmental level, persist across two or more settings (i.e., school and home), persist for six months or longer, and significantly impair the child's social or academic functioning (APA, 1994; see Appendix). Additionally, children must meet a required number of inattentive and/or hyperactive/impulsive symptoms (see Table 2.1).

Table 2.1

Behavioural Symptoms for the Diagnosis of ADHD in the DSM-IV

Inattention
Often fails to give close attention to details or makes careless mistakes
Often has difficulty sustaining attention in tasks or play activities
Often does not seem to listen when spoken to directly
Often does not follow through on instructions and fails to finish tasks
Often has difficulty organizing tasks and activities
Often avoids, dislikes, or is reluctant to engage in tasks requiring sustained mental effort
Often loses things necessary to tasks and activities
Is often easily distracted by extraneous stimuli
Is often forgetful in daily activities
Hyperactivity
Often fidgets with hands or feet or squirms in seat
Often leaves seat in class or in other situations in which remaining seated is expected
Often runs about or climbs excessively in situations in which it is inappropriate
Often has difficulty playing or engaging in leisure activities quietly
Is often "on the go" or often acts as if "driven by a motor"
Often talks excessively
Impulsivity
Often blurts out answers before questions have been completed
Often has difficulty awaiting turn
Often interrupts or intrudes on others

Inattention. Children with ADHD display difficulties maintaining attention relative to other children of the same developmental level and gender (Barkley, 1997b). Difficulties sustaining attention do not appear to be due to heightened distractibility (Barkley, 1998) as research suggests that children with ADHD are no more distractible than other children in response to interfering stimuli (Rosenthal & Allen, 1980). Instead, difficulties sustaining attention are demonstrated by the "diminished persistence of effort to tasks that have little intrinsic appeal or minimal immediate consequences for completion" Barkley, 1998, p. 57). When alternate activities are available which offer immediate gratification or reward, a child with ADHD is likely to appear distracted and engage in the more rewarding activity (Barkley, 1998; Douglas, 1983). As such, problems with attention are most commonly seen in situations which require increased cognitive effort (Bayliss & Roodenrys, 2000) or sustained attention during dull, repetitive tasks, with little immediate reinforcement (Barkley, DuPaul et al., 1990) such as schoolwork, homework, or performing chores (Barkley, 1998). These difficulties in sustained attention are reflected in the DSM-IV criteria for inattention (APA, 1994; see Table 2.1).

Hyperactivity. Hyperactivity involves developmentally inappropriate levels of both motor and vocal activity (Barkley, 1997a). ADHD children are characteristically more active, restless, and fidgety when compared to non-diagnosed children (Barkley & Cunningham, 1979). These children are often described by their parents and teachers as "always up and on the go", acts as if driven by a motor", and "often hums or makes odd noises" (Barkley, 1998, p. 60). Some researchers suggest it is not an excess in absolute levels or hyperactivity that differentiate ADHD children from non-ADHD or other clinic-referred children (Firestone, & Martin, 1979). Rather, the inability to regulate activity level to meet task or situational requirements seems to be the primary concern in ADHD (Routh, 1978; Barkley, 1998). Current DSM criteria for hyperactivity is listed in Table 2.1 (APA, 1994).

Impulsivity. Impulsivity refers to a "deficiency in inhibiting behaviour in response to situational demands" (Barkley, 1998, p. 58). In children with ADHD, impulsivity is most often demonstrated in the inability to delay a response or delay gratification or reward, and the inability to inhibit dominant behavioural responses (Barkley, 1997a).

Clinical observations of these children reflect this behavioural disinhibition; for example, they respond to situations without waiting for instructions, demonstrate difficulties in situations that require restraint, and interrupt others conversations (Barkley, 1998). Impulsivity or behavioural disinhibition is considered the hallmark of ADHD (Barkley, 1997a) and is, in fact, the behaviour which best distinguishses children with ADHD from other clinical disorders (Barkley, 1998; Barkley, Grodzinsky, & DuPaul, 1992). Current DSM criteria for impulsivity is listed in Table 2.1 (APA, 1994)

Diagnosing ADHD. The presence or absence of these symptom clusters is assessed through clinical interviews and behavioural rating scales. Clinical interviews such as the Structured Interview for Diagnostic Assessment of Children-Revised (SIDAC-R) directly assess ADHD symptomatology by assessing the presence or absence of each individual DSM symptom. Clinical interviews are considered the most valid tool in assessment (Barkley, 1998); however, behavioural rating scales are also important tools in assessing ADHD as they are easy and economical to administer, and provide important information concerning attention, hyperactivity, impulsivity, and other related symptoms (Manning & Miller, 2001; Elliot, Busse, & Gresham, 1993). Evaluations have, in the past, relied on parent reports in the diagnosis of ADHD (Biederman, Keenan, & Faraone, 1990). However, because ADHD symptoms are often "most clearly and consistently observed in the school", teacher observations are important components of both clinical evaluation (Barkley, 1998, p.60) and research studies (Wolraich et al., 1996).

One rating scale frequently used in the assessment of a child's behaviour is the Behavior Assessment System for Children (BASC; Reynolds & Kamphaus, 1992). The

BASC is a multidimensional measure of a child's behaviour across a variety of settings (i.e. home and school), which assesses social, emotional, and behavioural functioning. These behaviours can be rated by different observers using the Child Rating Scale (CRS), the Parent Rating Scale (PRS), and the Teacher Rating Scale (TRS). Additionally, the behaviours can be compared to norm groups at differing age levels—preschool (4-5), child (6-11), and adolescent (12-18).

The BASC is considered a valid and reliable diagnostic tool for ADHD when used as part of a multi-modal assessment (Manning & Miller, 2001; Ostrander, Weinfurt, Yarnold, & August, 1998). Specifically, the *Hyperactivity* and *Attention Problems* scales are useful in evaluating the DSM-IV diagnostic criteria (Ostrander et al., 1998; Vaughn, Riccio, Hynd, & Hall, 1997). Inattentive symptomatology is well represented by the BASC, with the TRS assessing five out of nine, and the PRS assessing six of the nine DSM-IV symptoms of inattention (see Table 2.2 below). Hyperactive/impulsive symptomatology is also well represented by the BASC; the TRS assesses five out of nine, and the PRS assesses seven of the nine DSM-IV symptoms of hyperactivity/impulsivity (see Table 2.3 below).

Table 2.2

DSM Criteria for Inattention and Corresponding Questions on the BASC Rating Scales

DSM-IV Diagnostic Criteria	BASC PRS Items	BASC TRS Items
Often fails to give close attention to details; makes careless mistakes	—	Does not pay attention to lectures
Has difficulty sustaining attention	—	Has a short attention span
Often does not seem to listen when spoken to directly	Listens attentively Listens to directions	Listens attentively Listens to directions
Does not follow through on instructions and fails to finish schoolwork or other duties	Completes homework from start to finish without taking a break	—
Has difficulty organizing tasks and activities	—	—
Avoids or dislikes tasks that require sustained mental effort	Gives up easily when learning something new	Gives up easily when learning something new
Loses things necessary for tasks or activities	—	—
Easily distracted by extraneous stimuli	Is easily distracted	Is easily distracted from classwork
Forgetful in daily activities	Forgets things	Forgets things
—	Completes work on time	—
—	—	Has trouble concentrating

Table 2.3

DSM Criteria for Hyperactivity/Impulsivity and Corresponding Questions on the BASC Rating Scales

DSM-IV Diagnostic Criteria	BASC PRS Items	BASC TRS Items
Often leaves seat in classroom or in other situations in which remaining seated is expected	Leaves seat during meals	—
Often runs about or climbs excessively in situations in which it is inappropriate	Climbs on things	—
Has difficulty playing or engaging in leisure activities quietly	Makes loud noises when playing	Makes loud noises when playing
Is often "on the go" or often acts as if "driven by a motor"	Is overly active	Is overly active
Often talks excessively	—	Talks too loud
Often blurts out answers before questions have been completed	—	Calls out in class
Often has difficulty awaiting turn	Cannot wait to take a turn	Cannot wait to take a turn
Often interrupts or intrudes on others	Interrupts others when they are speaking	Interrupts others when they are speaking
Often fidgets with hands or feet or squirms in seat	Fiddles with things while at meals Is restless during movies	—
—	Throws tantrums	—
—	Needs too much supervision	—
—	—	Hurries through assignments
—	—	Rushes through assigned work
—	—	Bothers other children when they are working
—	—	Acts silly
—	—	Acts without thinking
—	—	Seeks attention while doing schoolwork

Diagnostically, the BASC is considered superior to other rating scales in its ability to distinguish ADHD children from non-ADHD children (Vaughn et al., 1997; Ostrander et al., 1998). Still, approximately 80% of the children were correctly classified using the BASC as a sole diagnostic tool, leaving some degree of measurement error. Therefore, results of the BASC should not be the exclusive diagnostic measure of ADHD. Additionally, although ADHD children scored significantly higher as a group than non-diagnosed children, many children with ADHD scored in the average range on the hyperactive and attention problems subscales (Manning & Miller, 2001).

Intelligence tests have also been routinely used in the assessment of ADHD (Naglieri et al., 2003) with several authors suggesting that the disorder can be distinguished by analyzing specific patterns of subtest performance (Kaufman, 1994; Bowers, Risser, Suchanec, & Tinker, 1992; see Schwean & Saklofske, 1998). The validity of this method of evaluation has been widely debated (Schwean & Saklofske) and the predominant current view is that intelligence tests are best utilized as part of a diagnostic assessment. Intelligence tests provide important information concerning the current cognitive functioning of children with ADHD, but it is recommended they not be used for the purpose of diagnosis (Barkley, 1998).

Types of ADHD

The current classification system utilized in the DSM-IV was based in part on the field trials of Leahy et al. (1994) and other factor analytic studies (see Lahey & Carlson, 1991), which demonstrated two distinct symptom clusters—inattention and hyperactivity/impulsivity (Carlson et al., 1999). Depending on the presence or absence of these symptom clusters, children are diagnosed with differing subtypes of ADHD (see table 2.1 for diagnostic criteria). To meet the criteria for ADHD Predominantly Inattentive Type (ADHD-I), a child must meet six or more of the nine inattentive symptoms. Six or more of the nine hyperactive/impulsive symptoms are required for a diagnosis of ADHD Predominantly Hyperactive-Impulsive Type (ADHD-H). Six or more of both inattentive and hyperactive/impulsive symptoms are required for a diagnosis of ADHD Combined Type (ADHD-C).

Researchers have debated the validity of the three subtypes of ADHD. Specifically, they have struggled to determine whether the ADHD-I subtype "represents a single disorder with common attentional problems but varying activity levels or whether [it is], in fact, a distinct disorder" (Lockwood, Marcotte, & Stern, 2001, p. 318). Research has varied on this point with some researchers arguing for a common disorder (Chhabildas, Pennington, & Willcutt, 2001; Gaub, & Carlson, 1997; Lockwood et al., 2001) while others argue it is a distinct disorder, both neurologically and behaviourally (Barkley et al., 1997; Lahey, Schaughency, Strauss, & Frame, 1984; Milich, Balentine, & Lynam, 2001). While this debate remains largely unresolved, the current study will consider both ADHD-I and ADHD-C to be two related subtypes of ADHD, differing in the severity of hyperactive behaviours. The remaining literature review will focus on the ADHD-I and ADHD-C subtypes, as the majority of research has been done on these groups (Carlson et al., 1999) and they appear to be more prevalent in both general and clinical samples of children with ADHD (Baumgaertel, Wolraich, & Dietrich, 1995; Goodyear & Hynd, 1992; Wolraich et al., 1996).

Cognitive and Academic Abilities in ADHD

Some researchers have suggested that children with ADHD have normally distributed IQ scores, and do not appear to have generalized cognitive impairment (Douglas, 1988; Kaplan et al., 2000; Shue & Douglas, 1992). In other words, ADHD children represent the entire spectrum of cognitive ability from giftedness to mental disabilities (Barkley, 1998). However, it has also been suggested that ADHD children seen in clinics display cognitive deficits relative to their same-age peers (Barkley, 1998; Cantwell & Baker, 1992; Carlson, Lahey, & Neeper, 1986). Although the differences in IQ scores were often statistically significant, all mean IQ scores fell within the average range (see Table 2.4).

The only report of ADHD children assessed with the SBV was from the standardization sample (Roid, 2003c). ADHD children were found to score significantly lower than non-ADHD children. Again, these scores were still within the average range although they were statistically lower than their same age peers (see Table 2.4).

Table 2.4

IQ Scores for Children Diagnosed with ADHD from Various Studies

	N	IQ Measure	FSIQ		PIQ		VIQ	
			M	SD	M	SD	M	SD
Kaplan et al. (2000)	131	WISC-III	103.83	12.6	—	—	—	—
Seidman et al. (1997)	0/36	WISC-R	106.0	13.1	—	—	—	—
Mahone et al. (2003)	61	WISC-III	—	—	102.2	11.4	109.8	13.2
	61	WISC-R	—	—	107.9	15.5	109.7	11.0
Naglieri et al. (2003)	21/4	WISC-III	102.3	13.9	101.1	14.6	102.6	15.2
Assesmany et al. (2001)	32/8	WISC-III	98.20	13.1	97.80	15.0	99.33	12.5
Snow (2000)	30/5	WISC-III	97.8	—	96.5	—	99.0	—
Mayes et al. (1998)	13	WISC-III	105.9	—	—	—	—	—
Saklofske et al. (1996)	21	WISC-III	98.14	14.7	102.90	14.5	94.62	15.6
Anastopolous et al. (1994)	40	WISC-III	102.4	13.3	102.9	12.0	101.9	15.8
Saklofske et al. (1994)	40/5	WISC-III	97.96	12.6	101.36	13.9	95.51	13.0
	40/5	SB-IV	102.0	11.3	—	—	—	—
Morgan et al. (1996)	22/4	WISC-III	100.82	17.1	101.23	17.4	100.45	17.7
Mariani et al. (1997)	34/0	SB-IV	107.8	13.2	—	—	—	—
Carlson et al. (1986)	15/5	WISC-III	90.70	—	95.20	—	85.40	—
Prifitera et al. (1983)	65	WISC-III	101.0	—	102.9	—	99.5	—
Schwean et al. (1993)	45	WISC-III	98.0	—	101.4	—	95.5	—
Roid (2003c)	104	SBV	92.2	—	93.1	—	92.3	—

The specific nature of these relative intellectual deficits has remained a source of debate, and it is unclear whether these differences exist due to real cognitive deficits, or whether they are related to an impulsive response style (Barkley, 1998) or comorbid conditions such as Learning Disabilities (LD; Bohline, 1985) or Tourette's Disorder (Brand et al., 2002). Several studies have found a relationship between hyperactive/impulsive behaviour and measures of intelligence (Hinshaw, 1992; McGee, Williams, & Silva, 1984) suggesting that the relationship between IQ and ADHD is specific to the hyperactive/impulsive symptom cluster (Barkley, 1998; Hinshaw, 1992). This hypothesis would predict a greater impairment in the IQ of the ADHD-C subtype compared to ADHD-I. This has been found in some studies (Carlson et al., 1986) but not replicated in others (Morgan et al., 1996). Impairments on intelligence tests often appear to be most significant in the assessment of working memory (Anastopolous, Spisto, & Maher, 1994). The differences in working memory abilities will be discussed in more detail in the review of literature on working memory.

Because tasks which require persistent cognitive effort are difficult for many children with ADHD (Bayliss & Roodenrys, 2000), school often provides a significant challenge for these children (Barkley, 1998). As a result, academic performance and learning problems are two of the difficulties most commonly associated with ADHD (Barkley & Gordon, 2002; Campbell & Baker, 1991). Academic problems have been consistently found in ADHD children in reading, writing, and mathematics, when compared to children with no diagnosis (August & Garfinkel, 1990; Barkley, DuPaul et al., 1990; Fischer, Barkley, Edelbrock, & Smallish, 1990; Saklofske, Schwean, &

O'Donnell, 1996) and children with conduct problems (Rapport, Scanlan, & Denney, 1999).

Academic difficulties are also highlighted by findings that children with ADHD are more likely to have a comorbid LD (Cantwell & Baker, 1991)—a condition wherein children perform academically below the level expected for their age and IQ (APA, 1994). Estimates of the comorbidity of ADHD and LD are relatively high, ranging from 10% (August & Holmes, 1984) to above 80% (McGee & Share, 1988). Additionally, it is estimated that up to 50% of children with ADHD may require tutoring, 30-40% may be placed in special academic programs, up to 40% may be suspended from school, approximately 30% may repeat a grade in school, and 10-35% may fail to complete high school (Barkley, 1998; Barkley, Fischer et al., 1990; Weiss & Hechtman, 1993).

Some researchers suggest that children with ADHD-I are at a higher risk for academic problems compared to children with ADHD-C, even when IQ is statistically controlled (Carlson et al., 1986; Marshall et al., 1997). Specific deficits in ADHD-I appear to be in math achievement where children perform significantly lower than both controls and the ADHD-C subtype on measures of mathematical ability (Marshall et al., 1997; Carlson et al., 1986). These studies relied on clinical samples and this pattern of performance may not be found in the general population of ADHD children (Carlson et al., 1999). Nevertheless, children with ADHD seen in a clinic setting—especially the ADHD-I subtype—appear to have significant deficiencies in mathematics.

Gender Differences

The majority of ADHD research has been completed with male samples (Arnold, 1996) and few studies have included a sufficient number of female participants to allow for the analysis of female manifestations of ADHD or gender based comparisons (Gaub & Carlson, 1997; Hinshaw, 2002). The current findings do show trends that when compared to non-ADHD girls, those with ADHD demonstrated impairments in cognitive and academic functioning, disruptive behaviours, and difficulties in peer and social relationships (Hinshaw, 2002).

Compared to clinic-referred males, clinic-referred females with ADHD show lower levels of hyperactivity, fewer conduct disorder diagnoses, fewer executive function impairments, and greater intellectual impairment (Gaub & Carlson, 1997; Seidman, Biederman, Faraone, & Weber, 1997). However, because only girls with significant impairments are referred to clinics (Hinshaw, 2002), the lower level of intellectual functioning found in females may be restricted to clinic-referred children (Barkley, 1989; Gaub & Carlson, 1997). Non-referred females tend to show less impairment in all respects compared to males (Seidman et al., 1997).

Issues in Researching ADHD

In recent years, ADHD has become the most researched childhood behavioural disorder (Weiss & Hechtman, 1993). However, even with the vast amount of research compiled, there still exists a substantial variability in the findings. These discrepant results may be due, in large part, to methodological inconsistencies inherent in the research studies (Barkley et al., 1992; Schwean & Saklofske, 1998) and result in difficulty interpreting the various studies. Several of these inconsistencies include: discrepant sampling criteria (i.e., referral bias and failure to control for comorbid diagnoses) and failure to clearly define the diagnostic criteria (i.e., varied DSM criteria, failure to control for ADHD subtypes, and failure to operationally define the ADHD criteria).

Sampling. Two samples of children are typically used in ADHD research: clinic-referred (clinical) and nonreferred samples. Clinical samples are comprised of children seen by psychologists, educators, physicians, or other mental health professionals for evaluation or treatment. Non-referred samples are gathered from the general population, typically through the school setting (e.g., Rohde et al., 1999) or birth records (e.g., Todd et al., 2002). Generally, only those children with substantial impairments in academic or cognitive functioning, conduct, or peer and family relationships, are referred to clinics (Hinshaw, 2002). This *referral bias* leads to significant differences between these types of samples (Carlson et al., 1999). Compared to nonreferred samples, clinic samples have inflated rates of comorbidity (Caron & Ruter, 1991) a higher male to female ratio (Cantwell, 1996), greater social impairment (Lahey et al., 1994), and poorer academic achievement (Carlson et al., 1999).

The differing composition of these two groups has important implications on both the research questions that can be appropriately addressed by each group, and also the generalizability of the research findings. Because nonreferred samples are more representative of the ADHD population as a whole, prevalence rates, patterns of comorbidity, gender ratio and other characteristics of the general ADHD population are most suitably researched with a nonreferred sample (Carlson et al., 1999). Although clinic samples may not validly represent characteristics of the general ADHD population, clinic samples may be more indicative of cases seen in treatment and assessment (Carlson et al., 1999). Clinic samples may be used as valid indicators of the demographic information of a clinical population, as well as the academic, social, emotional, and behavioural functioning of ADHD children seen in assessments or treatment.

Generalizations or inferences from one type of sample to the other should be made with caution (Hinshaw, 2002). The majority of previous research investigating achievement, gender-differences, and intellectual ability, have used clinical samples (Carlson et al., 1999; Gaub & Carlson, 1997) and may not represent the full range of abilities found in ADHD. For example, in a nonreferred sample, IQ scores of ADHD children are normally distributed (Kaplan et al., 2000) while IQ scores in clinical samples may be significantly lower (Barkley, 1998).

Failure to control for comorbid diagnoses has also placed limits on the validity of much of the research. ADHD, especially in clinic-referred children, is consistently associated with high rates of comorbid diagnoses (Caron & Rutter, 1991). Many of these comorbid diagnoses (i.e., LD, Tourette's Disorder, Conduct Disorder) may be associated with particular impairments in behavioural, academic, social, and cognitive functioning (Bohline, 1985; Brand et al., 2002; McGee et al., 1984) Many researchers have included children with comorbid diagnoses in the research samples (Barkley, 1998), and as a result, deficits associated with comorbid disorders may be falsely attributed to ADHD symptoms (Caron & Rutter, 1991)

Defining ADHD in Research. As mentioned previously, as a result of continuing research, the clinical criteria for ADHD has changed with the publications of the DSM-Third Edition (DSM-III; APA, 1980), DSM-Third Edition Revised (DSM-III-R; 1987), and the DSM-IV. Because the definition of ADHD has changed over time, the results of the various research studies utilizing differing definitions may not be comparable (Lahey & Carlson, 1991). Neither DSM-IV subtype ADHD-I nor ADHD-H would have warranted a diagnosis under DSM-III-R criteria. Comparisons of DSM-III and DSM-IV definitions of ADHD may also not be valid, even though both editions distinguish between the three subtypes. Conceptual differences exist between the two editions, and many of the current diagnostic criteria have been changed or added (Power, Costigan, Eiraldi, & Leff, 2004).

Related to the issue of changing diagnostic criteria, many studies have failed to control for ADHD subtypes (Barkley, 1998). Although significant differences appear to exist between the ADHD subtypes (Carlson et al., 1986), the subtypes often remain unseparated in studies. This can result in a blurring of the impairments associated with ADHD (Barkley, 1998).

The method of diagnosis utilized in research studies also limits the generalizability of the various research. While clinical interviews are the preferred and most reliable method of assessing for ADHD (Barkley, 1998) they are also costly and require considerable time for training and interviewing (Ostrander et al., 1998). Behavioural rating scales provide a valuable alternative to efficiently assess ADHD in research studies; however, the criteria for ADHD (e.g., cut-off value) have not been consistently operationally defined. For example, the Achenbach Child Behavior Checklist

(CBC; Achenbach & Edelbrock, 1983), Revised Behavior Problem Checklist (RBPC; Quay & Peterson, 1983), Conners Rating Scales (CRS; Conners, 1989), and BASC have all been utilized in research to diagnose ADHD. Differing conceptualizations of ADHD symptoms may result in different diagnoses and varying results (Power et al., 2004). As a consequence, it is essential that children in various tests meet consistent criteria, and the DSM-IV serves as the current standard; its criteria are the most representative of numerous factor analytic studies (Lahey et al., 1994).

Executive Functioning in Children with ADHD

Although ADHD is diagnosed largely due to behavioural symptomatology, its core deficits appear to be cognitive in nature. In Barkley's Behavioural Disinhibition Model of ADHD (1997b), he suggested that *behavioural inhibition* is the central problem of this disorder. Behavioral inhibition refers to the process of inhibiting the initial response to an event or stopping an ongoing response or response pattern (Barkley, 1998). This impulse control results in a period of delay between an event and the decision to respond to the event, and sets the occasion for *executive functions* to occur (Barkley, 1997b).

Executive functions refer to a domain of self-directed cognitive abilities that are used for self-regulation. In this context, executive functions shift the source of behavioural control from a typically external (and immediate) one to one that is typically internal (and future oriented; Barkley, 1998). Additionally, executive functions determine how various mental processes will work together while performing a task, and are required to "choose, construct, execute, and maintain optimal strategies for performing a task" (Scharchar & Logan, 1990, p. 710). Several executive functions are considered particularly relevant to ADHD: the ability to guide one's behaviour through internal speech; the self regulation of affect, motivation, and arousal; the analysis and synthesis of behaviour; and working memory.

Deficits in these executive functions are considered unique to ADHD (Barkley, 1997b; Berlin, Bohlin, & Rydell, 2003; Clark, Prior, & Kinsella, 2002; Weyandt & Willis, 1994). It is postulated that children with ADHD should demonstrate deficiencies in measures of these four executive functions in comparison to non-ADHD children. Some research has supported this hypothesis. For example, executive functioning deficits do not appear to be shared by other disorders such as ODD or reading disabilities (Klorman et al., 1999), and are useful in distinguishing ADHD children from non-ADHD controls (Berlin, Bohlin, Nyberg, & Janols, 2004).

One limitation of Barkley's model is that these executive functions and inhibitory problems are not well defined. Similarly, their measurement has varied across research studies leading to conflicting results (Tannock, 1998). The following section will review how working memory has been conceptualized and researched, and how children with ADHD perform on working memory tasks.

Working Memory

Working memory is defined as a class of memory processes which involve the simultaneous storage and processing or manipulation of information (Baddeley, 1986; Roid, 2003b). These two interrelated processes are necessary for academic tasks such as reading fluency and comprehension (Baddeley, Logie, & Ellis, 1988; Daneman &

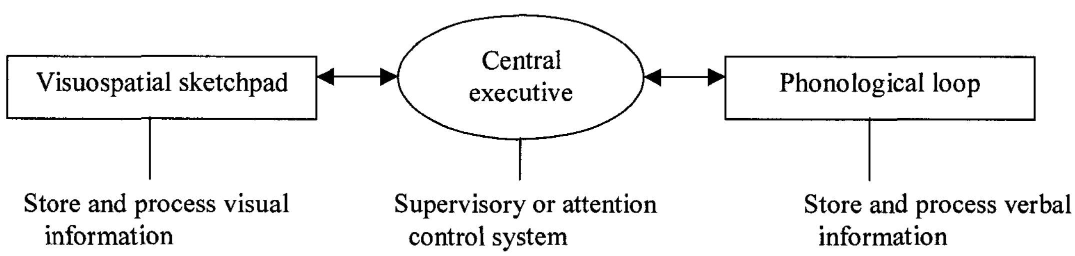
Carpenter, 1980), mathematical problem solving (Logie, Gilhooly, & Wynn, 1994), and learning (Baddeley, 2000), as well as higher order cognitive processes such as logical reasoning and planning (Baddeley, 1986; Baddeley, 1996a). It is also within the construct of working memory that "goals and intentions to act are retained" and that "action plans are formulated and used to guide the performance of the goal-directed responses" (Barkley, 1997b, p. 75; see also Fuster, 1989). In other words, working memory plays a role in guiding behaviour as the information that is temporarily stored in mind is used to guide subsequent responses.

Barkley (1997b) suggested that behavioural inhibition sets the occasion for working memory to occur. In other words, children who are able to inhibit inappropriate behavioural responses are better able to store and process information (Stevens, Quittner, Zuckerman, & Moore, 2002). However, the precise nature of this executive function is still not well understood (Barkley, 1997b) due, in part, to variations in its conceptualization and definition across research studies (Tannock, 1998). Framing working memory within Baddeley's (1986; Baddeley & Hitch, 1974) Working Memory Model may permit a more focussed examination of working memory deficits in ADHD (Roodenrys et al., 2001). The Working Memory Model replaces the previous theories of a single short-term memory system with a three-component system of working memory responsible for the processing and temporary storage of information (Baddeley, 2000).

This model is comprised of two subsidiary systems, the *visuospatial sketchpad* and the *phonological loop*, and an attentional control system, the *central executive* (see Figure 2.1). The function of the visuospatial sketchpad is to store and manipulate visual and spatial information, while the function of the phonological loop is to store and manipulate speech-based information (Baddeley, 1986). In these terms, the visuospatial sketchpad reflects nonverbal working memory abilities, and the phonological loop reflects verbal working memory abilities. The central executive acts as an attentional control system (Baddeley, 2002) and is responsible for tasks such as coordinating information from the two subsidiary systems, and integrating information within one subsidiary system (Baddeley, 1986; Roodenrys, et al., 2001). Breaking down working memory into the simultaneous processes of storing and processing information, the subsidiary systems primarily store information (with minor processing roles), while the central executive coordinates the processing of the information (with minor storage abilities; Baddeley, 1992).

Figure 2.1

The Three-Component Model of Working Memory



In addition to increasing the number of components of working memory, this theory also differs from theories of short-term memory in the functions associated with the memory systems (Baddeley & Hitch, 1994). Short-term memory generally refers to the simple storage and subsequent recall of information from the short-term memory store. This function differs significantly from the simultaneous processes of storing and processing information that is seen in working memory models. The processing of information requires some manipulation or operation to be performed (Baddeley, 1986; Roid, 2003c; Wechsler, 2003), such as reversing the information or separating the information into categories.

Synthesising the Working Memory Model with the Behavioural Disinhibition Model provides a useful framework with which to view the working memory deficits in ADHD (see Roodenrys et al., 2001). The central executive is conceptually similar to working memory as an executive function, in that both are involved in the allocation of attentional control and the integration of mental processes in the role of controlling behavioural responses (see Baddeley, 1992; Barkley, 1997b). Within this framework, deficits associated with ADHD are expected in measures of the central executive, while functioning within the visuospatial sketchpad and phonological loop should remain unimpaired (Roodenrys et al., 2001; Shue & Douglas, 1992).

Measurement of Working Memory

As with the other executive functions, neuropsychological theories suggest that working memory is dependent on response inhibition—the delay in responding providing the time necessary for memory traces to be formed and retained (Fuster, 1989). During this time, there are a number of sources of interference (both internally and externally), which can distort or disrupt the memory from forming (Barkley, 1997). Holding information in memory requires effort and attention, and the working memory system is often "prone to failure" especially when the information load or other cognitive demands are high (Gathercole, 1999, p. 410). Individual differences in working memory abilities have received substantial attention in psychological research (Carroll, 1993).

Operationally, studies of memory focus on the "amount of information… that is retained after a given amount of exposure to the learning situation, and after a given amount of time after the exposure is discontinued" (Carroll, 1993, p. 248). Baddeley (1986) suggests that working memory can be measured by simple tasks which require the "temporary storage of information that is being processed in any of a range of cognitive tasks" (p. 34.). Typically, this has involved utilizing tasks such as the oral repetition of digit spans, mental arithmetic, locating stimuli within spatial arrays of information, and holding sequences of information in memory to properly execute a task (Barkley, 1997).

Both visual and verbal memory processes, as well as central executive functioning, have been assessed in a number of different ways. In Carroll's factor analytic study (1993), 251 factors were found relating to the measurement of memory ability. These included 72 factors interpreted as Memory Span, 43 interpreted as Associative Memory, and 17 factors interpreted as General Memory. The following review of the measurement of memory abilities will focus on memory span tasks as they are utilized most frequently in research (Carroll, 1993) and in intelligence testing (see Wechsler, 1991; Thorndike, Hagen, & Sattler, 1987; Roid, 2003b).

Memory Span as a Measure of Working Memory. Memory span techniques were first devised by a London schoolmaster in the 1890's (Baddeley, 1986) and included in the first measures of cognitive functioning (Binet & Simon, 1905). Memory span is defined as the maximum number of items that a person can recall after a single presentation, either visually or auditorily. Here a distinction should be made between memory span and working memory span. The concept of a working memory span was developed by Daneman and Carpenter (1980), and based on the assumption that working memory involves the simultaneous storage and processing of information. They argued that memory span is not a valid indicator of working memory as it assesses only the storage of information, ignoring the processing component. This contrast is similar to the difference between short-term memory and working memory discussed previously.

This distinction is important, especially in the current study, as measures of working memory span appear to be more valid indicators of the capacity of both the central executive (Baddeley, 1986) and working memory as an executive function (Barkley, 1998). In disorders with hypothesised deficits in executive functioning, measures of working memory span appear to be more sensitive to the working memory deficits associated with the disorders. This pattern can be seen in studies of aging (Baddeley, 1986); Alzheimer's disease (Baddeley et al.,1999; Baddeley & Hitch, 1994), multiple sclerosis (Lengenfelder, Chiaravalloti, Ricker, & DeLuca, 2003), traumatic brain injury (Kimberg & Farah, 1993), and ADHD (Barkley, 1998).

Many researchers have not differentiated between these two indicators of memory, and some memory span tasks may be better described as working memory span (see Carroll, 1993). For the purposes of the current research study, memory span will refer to measures of storage only, and working memory span will refer to measures of concurrent storage and processing. There are many tests of memory span and working memory span, which are frequently utilized in both research and assessment practices (Carroll, 1994). The measure of working memory and short-term memory most frequently utilized in ADHD research is digit span (Barkley, 1998).

Tests of digit span involve the repetition of a series of random digits presented by an examiner at the rate of one number per second. At the end of the presented sequence, the examinee recalls the items in order—with digit span represented by the maximum number of digits recalled correctly (e.g., Wechsler, 1991). Digit span tests generally assess the functioning of the phonological loop. Even if digits are presented visually, they are typically encoded sub-vocally and stored and processed in the phonological loop (Baddeley, 1986).

Digit span is a measure of memory span, and arguably not a valid indicator of working memory abilities (Daneman & Carpenter, 1980). In one variation of the digit span test, the examinee is required to recall the numbers in reverse order (e.g., Wechsler, 1991). The memory process involved with backward recall or backward digit span are considered distinct from forward recall (Reynolds, 1997) and may reflect the simultaneous storage and processing characteristic of working memory span tasks. As a measure of working memory span, backward recall likely relies on the central executive (Karatekin, 2004), and therefore may be a more valuable measure of working memory processes in ADHD. Discrepancies between forward and backward recall performance do seem to be manifest most clearly in individuals with executive functioning deficits such as Traumatic Brain Injury and ADHD (Barkley, 1998; Reynolds, 1997).

An additional verbal working memory span test was developed by Daneman and Carpenter (1980), and designed to test both storage and processing. In this task, the examinee reads a series of sentences, and is then required to recall the last word of each sentence. Working memory span is operationally defined as the number of sentences the examinee can read while correctly recalling the last words. One weakness of this approach is that the task relies heavily on reading recognition and reading comprehension abilities, and may not provide a clear measure of working memory (Baddeley, 1986).

Letter-number span tests (e.g., Wechsler, 2003) were first developed by Gold and colleagues (1997) as a measure of working memory span. Here, the examiner first reads aloud a series of numbers and letters. The examinee is next required to recall the numbers first in numerical order, then the letters in alphabetical order. This test involves both the processing (sorting the letters and numbers into groups) and storage of information (recalling the correct letters and numbers).

Nonverbal measures of memory have also been developed to assess memory span. For example, Knox (1913) developed the Knox Cube Imitation Test to diagnose "mental retardation" in illiterate or non-English speaking individuals[1]. The test consists of four identical cubes, which are tapped by the examiner in a particular sequence. The examinee is then required to tap the identical sequence. As only storage is measured, this test is likely a valid measure of short-term memory (Vecchi & Richardson, 2001) but not a valid measure of working memory. Nonverbal measures of working memory span will be discussed later in relation to the SBV.

Working Memory Performance in Children with ADHD

Barkley's (1997b) model of ADHD, and neuropsychological theories in general (Fuster, 1989), suggest that working memory is dependent on behavioural or response inhibition. Therefore, individuals with deficits in response inhibition—such as ADHD—should show deficits in measures of working memory, specifically in measures of central

[1] This measure was originally intended as a substitute for the Simon-Binet scale when assessing illiterate and non-English speaking individuals (Knox, 1913).

executive functioning. Additionally, deficits should not be observed in simple memory span tasks, which assess only the visuospatial sketchpad or phonological loop.

Supporting this hypothesis are several studies that utilized digit span tasks. A consistent finding in these studies is that children with ADHD show no impairment in forward recall when compared to non-ADHD children, but demonstrate significant deficits in backward recall tasks (Karatekin & Asarnow, 1998; Korkman & Posenen, 1994; Mariani & Barkley, 1997; McInnes, Humphries, Hogg-Johnson, & Tannock, 2003; Roodenrys et al., 2001). In other words, the simple storage and recall of auditory information—functions of the Phonological Loop—do not appear to be impaired in children with ADHD (Barkley, DuPaul et al., 1990; Benezra & Douglas, 1988; Douglas, 1983; French, Zentall, & Bennett, 2001). Instead, these children demonstrate difficulties in the concurrent storage and processing, which rely more heavily on the central executive (Karatekin, 2004).

There has been a limited amount of research completed on the nonverbal working memory impairments associated with ADHD (Barkley, 1998), and the majority of this research has focussed on memory span tasks or measures of short-term memory. In spatial location tasks similar to the Knox Cube Imitation Test, children were required to imitate a sequence presented in a visual array. ADHD children were found to perform at the same level as non-ADHD children (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Weyandt & Willis, 1994). Other spatial recall tasks have also showed no deficits associated with ADHD (Karatekin, 2004; Shue & Douglas, 1992).

Nonverbal short-term memory has also been assessed in ADHD children using pattern replication tasks. These studies have demonstrated conflicting results, with some researchers finding deficits in the ability to reproduce designs from memory (Douglas & Benezra, 1990; Grodzinsky & Diamond, 1992), while others found no difference between ADHD and normal groups (McGee, Williams, Moffitt, & Anderson, 1989; Moffitt & Silva, 1988; Reader, Harris, Schuerholz, & Denckla, 1994).

Neither verbal working memory nor nonverbal working memory abilities appear to be impaired in simple memory span or short-term memory tasks (Barkley, DuPaul et al., 1990; Barkley et al., 2001; Karatekin & Asarnow, 1998; Mariani & Barkley, 1997; Mealer, Morgan, & Luscomb, 1996; Reader et al., 1994). This indicates that rehearsal and simple recall are likely not impaired in children with ADHD (Benezra, & Douglas, 1988; Karatekin, 2004). Rather, deficits in working memory become evident in more complex tasks which require the simultaneous storage and processing of information, and rely on both the subsidiary systems and the central executive (Barnett et al., 2001; Roodenrys et al., 2001; Karatekin & Asarnow, 1998). These results have lead some researchers to conclude that working memory deficits found in ADHD are associated with impaired central executive functioning, but not in the performance of either the visuospatial sketchpad or the phonological loop (Karatekin, 2004; Roodenrys et al., 2001). No previous research was found which directly compares verbal and nonverbal working memory in children with ADHD.

Measurement of Working Memory in Intelligence Tests. Although there are many intelligence tests available, the Wechsler Intelligence Scale for Children, Third Edition (WISC-III; Wechsler, 1991) and the Stanford Binet Intelligence Scale, Fourth Edition (SB-IV; Thorndike et al., 1987) are employed most frequently to assess the general cognitive abilities of children (Saklofske et al., 1994). The WISC-III, with which the majority of the ADHD research has been complied, includes measures of both working and short-term memory in the Freedom From Distractibility index (FFD); including mental arithmetic, and both forward and backward digit span.

Mental arithmetic is considered a good measure of working memory, as it requires concurrent storage (to correctly store the relevant numbers and operations) and processing (to correctly manipulate the information). However, mental arithmetic tasks also have a significant limitation as they depend on mathematical knowledge and skill (Barkley, 1998). Similarly, digit span tasks are also "associated with other numerical tasks such as the ability to identify and manipulate digits and numbers" and therefore somewhat dependent upon mathematical knowledge and skill (Carroll, 1993, p. 257). Additional limitations of this measure may be attributed to the different processes required in forward and backward digit span tasks. The fact that the WISC-III does not differentiate between forward and backward recall seriously reduces its validity as a measure of working memory (Reynolds, 1997). Coding is considered a measure of attention or ability to concentrate (Kaufman, 1994); however, it is not considered an indicator of either short-term memory or working memory (Schwean & Saklofske, 1998).

In light of the previous discussion, it is not surprising that there is considerable variation in the results of WISC studies with ADHD children (summarized in Table 2.5). Measured separately, scores in mental arithmetic and backward digit span are found to be significantly lower in ADHD children, while forward digit span and Coding reveal no such deficits (Barkley, 1998). However, when each subtest is compiled within the FFD index, specific deficiencies associated with ADHD are blurred. As such, the FFD is not considered a reliable measure of ADHD (Cohen, Becker, & Campbell, 1990; Schwean &

Saklofske, 1998). Still, some researchers have found it to be useful in differentiating diagnosed children from a non-diagnosed control group (Assesmany, McIntosh, Phelps, & Rizza, 2001; Lufi, Cohen, & Parish-Plass, 1990; Mayes & Calhoun, 2002; Snow & Sapp, 2000).

Table 2.5

Working Memory Scores for Children Diagnosed with ADHD

	N	IQ Measure	Working Memory M	Working Memory SD	IQ Score M	IQ Score SD
Anastopolous et al. (1994)	40	WISC-III	96.0	13.9	102.4	13.3
Mayes et al. (1998)	13	WISC-III	103.3	—	105.9	—
Naglieri et al. (2003)	25	WISC-III	98.5	16.1	102.3	13.9
Prifitera et al. (1983)	65	WISC-III	94.6	—	101.0	—
Reinecke et al. (1999)	200	WISC-III	97.6	14.2	—	—
Saklofske et al. (1994)	45	WISC-III	93.0	13.0	97.96	12.6
Saklofske et al. (1996)	21	WISC-III	93.43	15.6	98.14	14.7
Schwean et al. (1993)	45	WISC-III	93.0	—	98.0	—
Seidman et al. (1997)	36	WISC-R	99.9	13.2	106.0	13.1
Snow (2000)	35	WISC-III	92.7	—	97.8	—
Saklofske et al. (1994)	45	SB-IV	97.84	13.8	102.0	11.3
Roid (2003c)	94	SBV	90.2	13.7	92.2	16.1

Much less research has been compiled on the Stanford-Binet tests. In one study comparing the WISC-III to the SB-IV, the authors concluded that the WISC-III is a more sensitive measure of ADHD in children (Saklofske, Schwean, Yackulic, Quinn, 1994). This may be due to the SB-IV's focus on short-term memory, including digit span and a pattern replication tasks (Thorndike et al., 1987).

Measures of memory shifted in focus from short-term memory on the SB-IV to working memory on the SBV (Roid, 2003c). The only information concerning the abilities of ADHD children on this IQ measure was collected during the production of the test. During the standardization procedures, the cognitive abilities of 104 children with ADHD were assessed (24 = ADHD-I, 60 = ADHD-C, 20 = ADHD-H; Roid, 2003c). The Working Memory (WM) factor was found to be more than one half a standard deviation below what was expected. Additionally, WM was significantly lower than three of the other factor scores—Fluid Reasoning (FR), Quantitative Reasoning (QR), and Visual-Spatial Processing (VS)—but not lower than Knowledge factor (KN; Roid, 2003c). The author concluded that these results add to the validity of the WM factor as a measure of working memory.

Differential Abilities of ADHD-I and ADHD-C Groups. Much of this research has assessed the working memory abilities of all ADHD children, without differentiating between the inattentive, hyperactive/impulsive, and combined subtypes. Additionally, very few studies have compared the working memory abilities of ADHD-C and ADHD-I groups, and have led to contradictory findings. For example, several studies found no differences between the two subtypes (Ackerman, Anhalt, Dykman, & Holcomb, 1986; Carlson et al., 1986), while others found subtle differences in the type of memory deficits

(Gansler, Fucetola, Krengel, Stetson, Zimering, & Makary, 1998). These studies had similar methodological problems, including small sample sizes and differing diagnostic criteria; therefore the results of these studies should be interpreted with caution (Carlson et al., 1986). Currently, little can be said about the differences in working memory between the ADHD subtypes.

Issues in the Measurement of Working Memory

Appropriateness of Measures. As mentioned previously, measures of memory span are not valid indicators of working memory function. Testing memory span alone (or other simple indicators of visuospatial sketchpad and phonological loop functioning) results in a great variability in research findings (Barkley, DuPaul et al., 1990; Reader et al., 1994). This is an important issue as digit span is one common measure of working memory and is used to test working memory in several commonly used IQ tests such as the WISC-III and the SB-IV.

Similarly, several of the working memory tasks used in research and assessment depend on academic knowledge or skill, especially mathematical ability (Baddeley, 1986; Reinecke, Beebe, & Stein, 1999; Stevens et al., 2002). This may significantly confound estimates of working memory abilities in children with ADHD as many of these children also have comorbid learning disabilities (Marshall et al., 1997; Shaywitz & Shaywitz, 1991) and demonstrate significant deficits in math abilities and scholastic achievement (Carlson et al., 1986).

Sampling Issues. The measurement of working memory in children with ADHD shares several of the methodological weaknesses found in other ADHD research, most significantly, the failure to control for comorbid diagnoses (Mayes et al., 1998) and referral bias (Barkley, 1998). Much of the ADHD research has failed to separate comorbid diagnoses from pure ADHD diagnoses (Barkley, 1998; Mayes et al., 1998). The effects of comorbidity on the working memory and FFD index scores of ADHD children are relatively unexplored and unknown (Reinecke et al., 1999). If comorbidity is not controlled in research studies, patterns of working memory function may be erroneously contributed to the effects of ADHD (Barkley, 1998; Mayes et al., 1998).

Referral bias has also limited the generalizability of much of this research. For example, outcomes on nonverbal working memory measures appear to be highly dependent on the type of sample, as many clinical samples demonstrated nonverbal memory deficits while nonreferred samples did not differ from undiagnosed children (Barkley, 1998). Studies utilizing clinic samples may underestimate the actual working memory abilities of children with ADHD; however, outcomes of these studies likely reflect the difficulties that are regularly encountered in assessment or treatment settings.

An additional weakness in several studies is the lack of a relevant control or comparison group. Without a group to compare to, it is difficult to accurately observe the interaction between ADHD and working memory. Several studies have used a hypothetical mean of 100; however, it is possible that non-ADHD children seen in a clinic setting will achieve a somewhat lower score due to behavioural, emotional, or educational issues other than ADHD. Without a control group, research cannot adequately assess whether the observed deficits are contributable to ADHD or any other behavioural or emotional problem encountered in a clinic setting.

Validity. A final issue in the measurement of working memory is related to the test's consequential validity, or the intended or unintended consequences of test interpretation and use (Messick, 1995). This issue is especially pertinent in ADHD, as many educators and practitioners have "routinely assumed that when a child has a low FFD factor score, ADHD may be present [while] the absence of a low FFD factor score has often been interpreted as evidence against an ADHD diagnosis" (Anastopolous et al., 1994, p. 368). Intelligence tests are second only to continual performance measures in the diagnosis of ADHD (Naglieri et al., 2003). Many authors have stressed the inappropriateness of utilizing working memory indexes as evidence for or against an ADHD diagnosis (Krane & Tannock, 2001; Schwean & Saklofske, 1998). Instead, testing should be used for understanding the deficits associated with ADHD, describing the current functioning of children with ADHD, and developing effective learning strategies (Barkley, 1998; Schwean & Saklofske, 1998).

Stanford-Binet Intelligence Scales

The recently published Stanford Binet Intelligence Scales-Fifth Edition (SBV; Roid, 2003a) may provide a useful tool in the measurement of working memory (Roid, 2003b). Individual measures reflect the function of both the phonological loop and the visuospatial sketchpad functioning. More importantly to ADHD, they also theoretically assess the central executive. Additionally, these measures are relatively independent of academic knowledge or skill, and are not correlated with mathematical ability. This section will focus on first, the theoretical foundations of the test, and second, how the theoretical constructs, especially working memory, are assessed in the SBV.

Cattell-Horn-Carroll Theory of Cognitive Abilities

The underlying theoretical model of the SB5 is founded on the Cattell-Horn-Carroll (CHC) theory of cognitive abilities. The CHC theory provides a structure with which to classify intellectual abilities, and describe their relation to one another (Carroll, 1997). The CHC theory represents the synthesis of Carroll's (1993) three-stratum theory, and Cattell-Horn's *Gf-Gc* theory (Horn & Noll, 1997). This model or structure of intellectual abilities was first proposed by McGrew (1997) and was slightly revised by McGrew and Flanagan (1998) and Flanagan, McGrew, and Ortiz (2000) as further research was compiled (Flanagan & Ortiz, 2001).

In his seminal work, Carroll (1993) proposed a hierarchical structure of human intelligence, which organized intellectual abilities according to their degree of generality into three strata: narrow cognitive abilities (stratum I); broad cognitive abilities (stratum II); and general cognitive abilities (stratum III; see Figure 2.2).

The most specific of these strata are narrow cognitive abilities, which "represent greater specialization of abilities, often in quite specific ways that reflect the effects of experience, learning, or the adoption of particular strategies of performance" (Carroll, 1993, p. 634). There are approximately 70 narrow abilities, which are interrelated in varying degrees. The strength of their correlations reflects their grouping within the second stratum factors, or broad intellectual abilities.

There are ten broad cognitive abilities, including; Fluid Intelligence, Crystallized Intelligence, Quantitative Reasoning, Visual Processing, Short-Term Memory[2], Auditory Processing, Long-Term Retrieval, Processing Speed, Reading and Writing Ability, and

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[2] This term appears to encompass measures of both short-term memory and working memory, and is not limited to measures of memory span or short term memory.

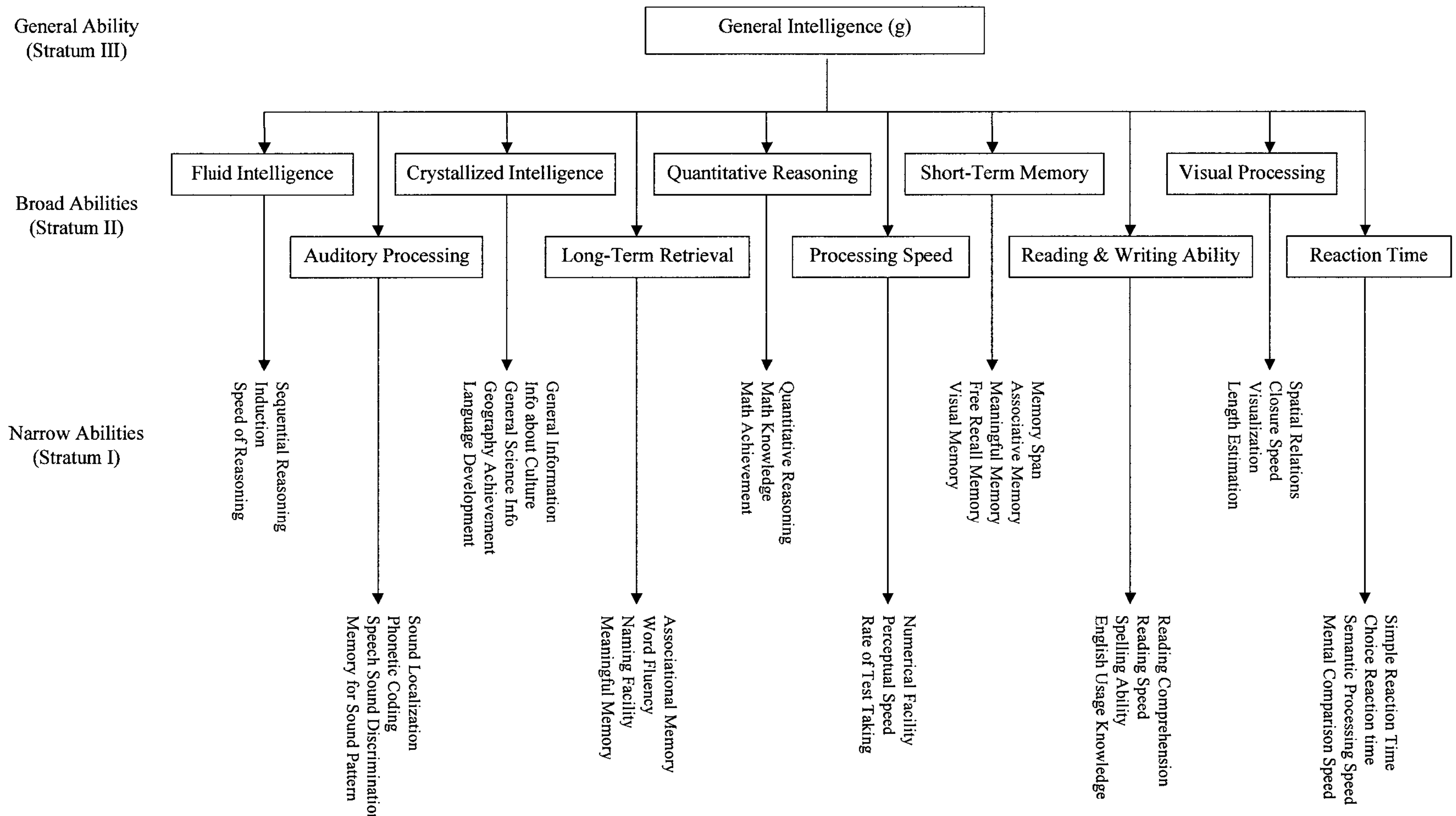
Decision/Reaction Time or Speed. These cognitive abilities are considered "basic constitutional and longstanding characteristics of individuals that can govern or influence a great variety of behaviors in a given domain" (Carroll, 1993, p. 634). These 10 groups are "regarded as representing true cognitive abilities in the sense of being relatively fixed long-term attributes of individuals, respecting the kinds of cognitive tasks they can perform or cannot perform" (Carroll, 1993, p. 137).

Both narrow and broad cognitive abilities are subsumed by the highest stratum, a single overarching general ability, or general intelligence (*g*; see Figure 2.2). This general intelligence is "involved in complex higher-order cognitive processes" (Flanagan & Ortiz, 2001, p. 6), and is similar conceptually to Spearman's *g* (McGrew, 1997).

The SB5 assesses five of the ten broad (Stratum II) cognitive abilities proposed by the CHC model (Roid, 2003b). The SB5 factors of Fluid Reasoning (FR), Quantitative Reasoning (QR), Knowledge (KN), Working Memory (WM), and Visual-Spatial Processing (VS) correspond to the CHC factors Fluid Intelligence, Quantitative Knowledge, Crystallized Knowledge, Short-Term Memory, and Visual Processing, respectively.

Figure 2.2

The C-H-C Model of Human Cognitive Abilities



These five factors were chosen during the development of the SB5 in part due to their relatively strong correlations with *g*, especially FR, KN, and QR which are viewed as "key elements of higher order thinking and general reasoning ability" (Roid, 2003, p. 9). The five factors also include strong predictors of school achievement (Crystallized Intelligence, Short-Term Memory, Quantitative Reasoning; Evans, Floyd, McGrew, & Leforgee, 2002). The remaining CHC constructs were not included in the SB5 due to complexities of test administration (Roid, 2003). The factors included in the SB5 can be measured individually to assess relative strengths and weaknesses in five broad cognitive abilities, but are also utilized in combination as an estimation of *g* (Full Scale IQ).

Assessing the Theoretical Constructs

Only the stratum I abilities are directly assessed in intelligence tests. Scores on these narrow abilities provide estimates of the stratum II abilities to the extent that they are correlated with these factors. Stratum I abilities were chosen to represent the corresponding Stratum II abilities based on high factor loadings, and theoretical suitability or representativeness of the narrow abilities (Roid, 2003c).

Fluid Reasoning (FR) is the ability to solve verbal and nonverbal problems using deductive or inductive reasoning. Emphasizing novel problem solving, FR is measured using matrix tasks and verbal analogies. Knowledge (KN) is a person's accumulated store of general information acquired at home, school, or life. KN tasks test vocabulary, procedural knowledge, and knowledge of situations presented in pictorial form. Quantitative Reasoning (QR) is the ability to solve numerical problems of an applied nature, and is measured using both verbal and nonverbal applied mathematical problems.

Visual-Spatial Processing (VS) is described as the ability to see the patterns, relationships, or spatial orientations between objects in a visual display. It is tested through verbal direction tasks and the replication of patterns. Working Memory is conceptualized as the ability to remember and manipulate visual and auditory stimuli from memory.

Assessing Working Memory

Working memory is assessed in the SBV with both verbal (Last Word) and nonverbal (Block Span) tasks (Roid, 2003a). Last Word is an adaptation of Daneman and Carpenter's (1980) working memory span task (Roid, 2003c). It requires the examinee to provide simple "yes" or "no" answers to a series of brief (and relatively simple) questions, and then recall the last word of each question (Roid, 2003c). It is similar to Daneman and Carpenter's (1980) task in that it involves both the processing of information (to correctly answer the questions) as well as the storage of information (to correctly recall the last word in each question). In other words, it assesses both the phonological loop and central executive. It improves on the Daneman and Carpenter task by removing the dependence of the client's reading ability, and limiting the confounding influence that reading comprehension may play.

The Block Span task is an adaptation of the Knox Cube Imitation Test (Roid, 2003c), and may be considered a nonverbal version of the letter-number sequencing task. In this task, eight blocks are arranged into two rows coded with yellow and red stripes. First, the examiner touches a series of blocks at the rate of one tap per second. Then the examinee is required to tap the blocks in the yellow row first in the same order, and then in the red row in the same order (Roid, 2003a). In this way the examinee is required to sort the blocks into two categories, successfully sequencing the blocks within the category (yellow or red). Block Span is a measure of working memory span as it involves both processing (sorting the blocks into categories) and storage (recalling the proper sequence), testing both the visuospatial sketchpad and the central executive.

Both the last word and block span tasks are measures of working memory span, and based on Baddeley's Working Memory Model (Roid, 2003c). As such, they are considered indicators of working memory abilities, assessing the subsidiary systems as well as central executive functioning (Baddeley, 1986). This focus on working memory shifted away from short-term memory assessment found in previous editions of the Stanford-Binet (Roid, 2003c). This shift was due to emerging research which emphasized the role of working memory in various academic abilities including reading comprehension (Daneman & Carpenter, 1980), mathematical problem solving (Logie et al., 1994), and the acquisition of vocabulary (Gathercole & Baddeley, 1993). Additionally, working memory is considered an important element in reasoning ability (Kyllonen & Christal, 1990).

Summary and Implications

Based on Barkley's (1997b) Behavioural Disinhibition Theory, children with ADHD should demonstrate deficits in working memory ability. The nature of these deficits is clarified when working memory is framed within the Working Memory model (Baddeley, 1986). Specifically, working memory deficits are most evident in tasks which require simultaneous storage and processing, while simple storage and rehearsal tasks remain relatively unimpaired (Karatekin, 2004; Roodenrys et al., 2001). Therefore when testing children with ADHD, measures of working memory, as opposed to short-term memory, should be most sensitive to working memory deficiencies. Additionally, to increase validity, measures of working memory should not rely on academic knowledge or skills.

While the WM factor of the SBV has been conceptually adapted from Baddeley's model (Roid, 2003c), to date no study of the WM factor has been completed. Testing the WM factor with ADHD children may provide important results. First, it will add convergent validity to the SBV construct of working memory. Evidence of distinctive score profiles for special groups provides a type of criterion-related evidence of validity (Roid, 2003c). For example, children with ADHD are hypothesized to have deficits in their working memory abilities. If these impairments are apparent through lower WM scores compared to other factors, this will provide support to the claim that the WM factor is assessing a component of working memory abilities. Considering some of the weaknesses inherent to other intelligence tests, the SBV may prove a useful tool in ADHD assessment and research.

Second, this study will add to the growing body of literature on the working memory deficits associated with ADHD. Both verbal and nonverbal working memory abilities will be assessed using working memory span tasks. This research will build upon previous research by controlling for comorbid diagnoses, assessing ADHD subtypes separately, using consistent diagnostic criteria (i.e., DSM-IV), and including a control group for statistical comparisons.

Additionally, this study may add validity to the use of Baddeley's model of working memory in ADHD research. While Baddeley's model of working memory may provide important contributions to ADHD research, few studies are based on this model (e.g., Roodenrys et al., 2001) and only one study has assessed this model directly (Karatekin, 2004). As the WM factor is based on Baddeley's model (Roid, 2003c), this study may add to the evidence supporting the use of the Working Memory model in ADHD research.

Hypotheses

The purpose of this research study is to assess the working memory abilities of children with ADHD utilizing the SBV. It is hoped that this research will add to the literature concerning the working memory abilities of children with ADHD, add support to the validity of the SBV WM factor, and explore the validity of using the SBV to measure the working memory abilities of children with ADHD. The following hypotheses have been generated based on the previous literature.

Hypothesis 1

The mean WM factor score for the ADHD-C group will not differ from the mean WM score for the ADHD-I group.

Hypothesis 2

The mean WM score for the entire ADHD group (ADHD-I and ADHD-C combined) will be significantly lower than the WM factor score for the comparison group

Hypothesis 3

The WM factor score for the ADHD group will be significantly lower than the FR, QR and VS factor scores. No differences will exist between WM and KN. The WM factor score for the control group will not be significantly different from any of the factor scores (FR, KN, QR, and VS).

Hypothesis 4

The nonverbal WM score will be significantly lower than the verbal WM score in the ADHD group. There will be no significant difference between verbal and nonverbal WM scores in the control group.

Methodology

Overview

The researcher conducted a retrospective causal-comparative study, comparing the archival data of 46 participants with ADHD to 59 participants in the control group. These individuals were administered the SBV as part of a comprehensive psychoeducational assessment at the Education Clinic at the University of Alberta. The mean WM scores of various groups were analyzed and compared using multiple t-test comparisons.

Participants

Participant Selection

The participants were selected from a sample of 202 individuals referred to a university-based psychological counselling and assessment clinic for a variety of behavioural, emotional, cognitive, and/or academic concerns. This original sample consisted of 115 males and 87 females, and ranged in age from 4 years 9 months to 55 years 11 months (M = 12:11, SD = 7.7). Each of these individuals was assessed with a variety of measures, including: the SBV; a developmental history; semi-structured interviews with the children, parents, and teachers; and child, parent, and teacher forms of the BASC.

Individuals were selected for the current study if they were between the ages of 5 years 0 months to 17 years 11 months. This age range was chosen to match the data collected for children with ADHD during the SBV norming process. Additionally, children were only selected if they were attending school at the time of testing. This selection procedure resulted in a sample of 172 individuals (101 males and 71 females), ranging in age from 5 years 0 months to 17 years 11 months (M = 11:3, SD = 3.3).

Diagnostic procedures. The participants were then divided into four groups: ADHD-Predominantly Inattentive Type (ADHD-I); ADHD-Combined Type (ADHD-C); ADHD-Predominantly Hyperactive-Impulsive Type (ADHD-H); and a control group with no ADHD diagnosis. These groups were established using the diagnostic criteria in the DSM-IV (American Psychiatric Association, 1994). The children who qualified for a diagnosis met the established criteria, demonstrated a "persistent pattern of inattention and/or hyperactivity-impulsivity" (APA, 1994, p. 85) at both home and school, and demonstrated significant impairment in developmentally appropriate social or academic functioning (see the Appendix for complete diagnostic criteria). The diagnostic procedures will be discussed in more detail in the procedures section.

Exclusionary Criteria. To focus on the deficits associated with ADHD, a relatively pure sample of ADHD children was desired. Participants were excluded from the sample if: 1) there was evidence of other neurological, developmental, or psychological disorders known to influence attention or cognitive functioning; 2) they were using methylphenidate (Ritalin), dextroamphetamine (Dexedrine), or other central nervous system stimulants at the time of testing; and 3) they are currently learning English as their second language.

Based on parental interviews, child observations, and medical histories, children were assessed for severe psychological or neurological disabilities that may affect intellectual functioning, including Epilepsy, head injury, FAS, and Aspergers. These disorders have been found to affect intellectual functioning, as well as working memory abilities (Baddeley, 1986; Grippo, Pelosi, Mehta, & Blumhardt, 1996; Korkman, Kettunen, & Autti-Raemoe, 2003; Proctor, Wilson, Sanchez, & Wesley, 2000; Roid, 2003c). In total, 52 participants were excluded from the study due to comorbid diagnoses, with 11 participants excluded from the ADHD-I group (32%), 22 participants excluded from the ADHD-C group (44%), and 19 participants excluded from the control group (23%; see Table 3.1).

Similarly, stimulant medications are believed to influence an individual's attention and concentration, (Nieoullon, 2002) as well as working memory (Livingston, Mears, Marshall, Gray, & Haak, 1996; Mehta, Goodyer, & Sahakian, 2004;) by producing an increase in the arousal of the central nervous system. In total, 23 children were excluded from the study as they were using psychostimulants at the time of testing (see Table 3.1). Children learning English as a second language have been found to have impaired performance on several factors of the SBV (Roid, 2003c). They were, therefore, excluded from the study as well. Five children were not included in the sample due to this criteria.

In total, 90 participants met the DSM-IV criteria for ADHD, with 50 included in the ADHD-C group, 34 included in the ADHD-I group, and 6 included in the ADHD-H group. Of these, 40 participants (27 males, 13 females) were excluded from the study. Eighty-two participants were included in the original control group. Of these, 23 individuals (16 males, 7 females) were not included in this study. [3]

[3] The sum of the 3 exclusionary criteria (80) does not equal the total number of individuals excluded from the study (69) as some participants were excluded for more than one reason.

Table 3.1

Frequency and Percentages of Exclusionary Criteria for ADHD and Control Groups

	ADHD-C (n = 50)		ADHD-I (n = 34)		ADHD-H (n = 6)		Control Group (n = 82)	
	f	%	*f*	%	*f*	%	*f*	%
Comorbid Diagnoses								
Reading Disorder	5	10.0	3	8.8	0	0	4	4.9
Mathematics Disorder	5	10.0	4	11.8	0	0	3	3.7
Disorder of Written Expression	6	12.0	2	5.9	0	0	3	3.7
LD (undifferentiated)	0	0	0	0	0	0	2	2.4
Epilepsy	1	2.0	0	0	0	0	0	0
Traumatic Brain Injury	1	2.0	0	0	0	0	0	0
Autism	1	2.0	0	0	0	0	0	0
Fetal Alcohol Syndrome	1	2.0	0	0	0	0	0	0
Mild Mental Retardation	1	2.0	2	5.9	0	0	6	7.3
Cerebral Palsy	0	0	0	0	0	0	1	1.2
Severe Speech/Language Delay	1	2.0	0	0	0	0	0	0
Medication	19	38.0	2	5.9	2	33.3	0	0
English Language Learner	0	0	0	0	0	0	5	6.1

Demographic Information

This sampling process resulted in the selection of 109 children, with 23 participants in the ADHD-C group, 23 participants in the ADHD-I group, 4 participants in the ADHD-H group, and 59 participants in the control group. Due to the low occurrence of a predominantly Hyperactive/Impulsive subtype, the ADHD-H group was excluded from the final analyses. The final sample, which was used in the data analysis, consisted of 105 children. Of these, 50 were female (47.6%) and 55 were male (52.4%). The mean age of the entire sample was 10 years 8 months (SD = 3.3), ranging from 5 years 1 month, to 17 years 11 months. The age, grade, and gender composition of each group is presented in Tables 3.2 and 3.3.

Table 3.2

Average Age and Grade Levels of the ADHD-C, ADHD-I and Control Groups

	ADHD-I		ADHD-C		Control	
	M	SD	M	SD	M	SD
Age	10.92	3.6	10.85	3.2	10.47	3.2
Grade	4.91	3.3	5.04	3.2	4.73	3.0

Gender Representation. The male to female ratio in the current sample of ADHD children (1.3 : 1) is not similar to the proportion found in the population at large (3.6 : 1; APA, 1994; Barkely, 1998). An even higher ratio of males diagnosed with ADHD is generally found in clinical samples (9 : 1; Cantwell, 1996), which is substantially different than the present study. Especially unusual is the male to female ratio in the ADHD-I group (see Table 3.2), with more females in the sample than males.

Table 3.3

Gender Distribution in the ADHD-I, ADHD-C, and Control Groups

	ADHD-I		ADHD-C		Control	
	f	%	*f*	%	*f*	%
Male	11	47.8	15	65.2	29	49.2
Female	12	52.2	8	34.8	30	50.8

One possible reason for this difference may be the selection procedure used in this study. Children are referred to the clinic for a number of educational or behavioural reasons, many being referred for intellectual difficulties demonstrated in the classroom. The majority of girls were referred to the clinic for educational difficulties, and upon further assessment they were found to meet the requirements for ADHD. Had this study assessed only the children who were referred to the clinic for ADHD, the male to female ratio may have matched the other studies. This explanation is partially supported when looking at the referral questions for each individual. In total, 12 of the 26 males included in the ADHD group (46%) were referred to the clinic to be assessed for ADHD, while only 6 of the 20 females (30%) were referred to the clinic for an ADHD assessment.

Another contributing factor may be due to the process of excluding participants from the study. Significantly more males (27) were excluded from the ADHD groups compared to females (13). The greatest difference was in the use of medication with only 5 females excluded for using stimulant medication compared to 18 males. The differential rates of exclusion appear to have influenced the gender distributions.

An alternative explanation for the apparent over-representation of females may be the nature of the Education Clinic. The clinic is a teaching centre, which takes referrals from the community. As it is a training centre, it offers significantly reduced assessment fees and may attract individuals from a lower SES than are seen in other types of clinics. As mentioned previously, in a meta-analytic review of the gender differences in children with ADHD, females with ADHD trended towards lower family SES compared to males with ADHD (Gaub & Carlson, 1997). A higher ratio of children from a lower SES may influence the ratio of males and females seen in the clinic with ADHD.

The performance of males and females diagnosed with ADHD was compared to determine if any differences were present between the genders (see Table 3.4). A two-tailed test with a corrected alpha level set at $\alpha = .01$ was performed. No significant differences were evident on any of the IQ scores or factor scores. As the performance did not differ between genders, it is likely that the high prevalence of females did not influence the group means. Therefore, this study is likely a valid representation of clinic-referred children.

Table 3.4

Mean Factor Scores, IQ Scores, and Test Results Comparing the Males and Females Diagnosed with ADHD

	Males		Females			
	M	SD	M	SD	*t*	*p*
Factor Scores						
WM	89.08	12.2	91.20	12.9	-.57	.571
FR	98.46	13.4	94.35	13.4	1.03	.309
KN	92.46	14.3	92.85	15.1	-.09	.930
QR	94.92	11.9	92.85	9.6	.64	.529
VS	94.75	11.3	94.75	9.0	1.75	.086
IQ Scores						
FSIQ	93.92	12.7	91.55	11.1	.63	.511
NVIQ	94.88	13.0	92.90	11.5	.54	.593
VIQ	93.69	13.2	91.65	11.2	.55	.588

Subtype Representation. In the current sample, there is equal representation of the ADHD-I (n = 23) and ADHD-C (n = 23) groups. However, in the general population, ADHD-I is approximately 1.5 times more common than ADHD-C (Carlson, Shin, & Booth, 1999). This discrepancy in prevalence rates is especially highlighted in the original sample of 172 individuals, which was comprised of 50 ADHD-C and 34 ADHD-I children.

The difference in prevalence rates of ADHD-C and ADHD-I may be due to referral bias. The more severe behavioural problems associated with ADHD-C (Barkley, DuPaul et al., 1990) may have resulted in a more frequent referral of children with ADHD-C. The hypothesis that more severe behavioural problems are associated with ADHD-C is supported in the observation that 38% of the original ADHD-C group were medicated with psychostimulant drugs while less than 6% of the ADHD-I group was medicated. Still, the prevalence of ADHD-I and ADHD-C in the current sample is more reflective of a clinic-referred population in which ADHD-C is more prevalent with a 2:1 ratio (Carlson et al., 1999; Faraone, Biederman, Weber, & Russell, 1998). The present sample may not be a valid representation of the general ADHD population.

Educational Information. All children were attending school between kindergarten and grade 12 at the time of testing. The average grade level for the entire sample was 5.25 (SD = 3.29); the average grade level of each group is presented in Table 3.2. Previous studies have suggested children with ADHD experience greater difficulties in school and require more in-class assistance compared to children without ADHD (Campbell & Baker, 1991). In this study as well, children with ADHD appeared to experience more difficulties in school (see Table 3.5). Eleven percent of the children with

ADHD were held back a grade compared to 5% of the control group. Similarly, 30% of the ADHD children required in-class support or modified curriculum compared to 24% of the control group. These numbers reflect the reports that children with ADHD require more individualized help in school.

Achievement scores were also compared between the ADHD and control groups. Both groups demonstrated difficulties in math, reading, and spelling as measured by standardized achievement tests (see Table 3.6). However, there were no significant differences between the groups on any of the three achievement tests.

Table 3.6

Achievement Scores for the ADHD and Control Groups

	ADHD		Control			
	M	SD	M	SD	*t*	*p*
Math	81.04	27.0	87.27	27.2	1.17	.245
Reading	87.24	25.5	93.86	23.1	1.39	.166
Spelling	77.54	35.6	86.19	34.8	1.25	.214

Table 3.5

Special Programs, Resources, and Grade Retention for the ADHD and Control Groups

	ADHD-C (n = 50)		ADHD-I (n = 34)		ADHD-H (n = 6)		Control Group (n = 82)	
	f	%	*f*	%	*f*	%	*f*	%
Retained Grade	3	6.0%	4	11.8%	0	0	6	7.3%
Modified Curriculum	5	10.0%	6	17.6%	0	0	13	15.9%
IOP	1	2.0%	0	0	0	0	1	1.2%
IPP	8	16.0%	4	11.8%	1	16.7%	6	7.3%
Resourse Room	1	2.0%	0	0	0	0	3	3.7%
Teacher's Aide	1	2.0%	1	2.9%	0	0	1	1.2%
Early Literacy Intervention	1	2.0%	2	5.9%	0	0	1	1.2%

In sum, the demographic characteristics of the current study generally reflect those found in other studies with clinic-referred children, with the exception of the higher representation of females in the current sample. As the samples are similar, this research is likely to be comparable to other studies which have utilized clinical samples. A notable difference, however, is that the current study controlled for the use of psychostimulant medication and several comorbid diagnoses, which were present in other studies. In contrast, the current sample appears to differ from the general ADHD population (in relation to gender ratio, subtype prevalence, and comorbidity). Therefore, the findings of this study may not generalize to the ADHD population as a whole.

Measures

Stanford-Binet Intelligence Scales, Fifth Edition

The SBV (Roid, 2003b) is an individually administered test of general intelligence and cognitive abilities for individuals ages 2 through 85. As mentioned previously, the SBV assesses five factors: FR, KN, QR, VS, and WM. These factors are assessed through nonverbal subtests (measuring non-language based abilities, including the ability to "reason, solve problems, visualize, and recall information presented in pictorial, figural and symbolic form") and verbal subtests (measuring language-based abilities, including the ability to "reason, solve problems, visualize, and recall important information presented in words and sentences (printed and spoken)"; Roid, 2003b, p. 5). The verbal scale (VIQ) and nonverbal scale (NVIQ) are combined to produce a Full Scale IQ (FSIQ), which is the "general ability to reason, solve problems, and adapt to the cognitive demands of the environment" (Roid, 2003b, p.5).

The IQ and factor scores have a mean of 100 and a standard deviation of 15. Scores between 90 and 110 are considered to lie within the average range. The individual subtests (verbal and nonverbal) have a mean of 10 and a standard deviation of 3, with average scores between 9 and 11 (Roid, 2003b).

Standardization Sample. The SBV was standardized on a sample of 4,800 individuals between the ages of 2 to 85. This standardization sample was representative of the United States (according to the 2001 U.S. Census) on five variables: age, gender, ethnicity, geographic region, and socioeconomic level (Roid, 2003c). Thirty age groups were tested, with smaller intervals used to measure the ages where cognitive abilities change rapidly. The gender ratio was equal at 50 %, with the exception of the elderly, where a higher percentage of females were tested. The ethnic categories consisted of Anglo-American, African American, American Indian, Asian, Hispanic, and Pacific Islander. The four geographic regions of the United States (Northeast, Midwest, South, and West) were all sampled to represent the 2001 census. SES for individuals under 18 was measured using years of education completed by the parents or guardians (Roid, 2003c).

M*easures of Reliability*. The reliability, or degree of measurement error, of the SBV was assessed in terms of internal consistency, test-retest stability, and interrater agreement (Roid, 2003c). Internal consistency is the extent to which the test items assess the same characteristic or skill (Gay & Airasian, 2003). The internal consistency of the SBV was calculated using the split-half method with the Spearman-Brown analysis (Roid, 2003c). The split-half reliability was excellent for the FSIQ (ranging from .97 to .98), VIQ and NVIQ (ranging from .95 to .96), and five Factor Indexes (greater than .90).

Specific scores for the WM factor ranged from (M = .91). Split-half reliability for the ten (verbal and nonverbal) subtests was very good ranging from .84 to .89.

Test stability, or test-retest reliability is the stability of test scores or agreement of the measuring instrument over time (Gay & Airasian, 2003). Measures of test stability were obtained by retesting 96 individuals ages 2- 5, 87 individuals ages 6-20, 81 individuals ages 21-59, and 92 individuals ages 60 and over. Scores tended to increase slightly across administrations due to practice effects and familiarity with testing procedures, however, they remained quite stable over time ranging from .79 to .95 (Test-retest reliability scores are listed in Table 3.7 below).

Table 3.7

Stability Coefficients of IQ Scores and Factor Index Scores Across Age Groups

	Correlations			
	Ages 2-5	Ages 6-20	Ages 21-59	Ages 60-85
n	96	87	81	92
IQ Scores				
Full Scale IQ	.95	.93	.93	.95
Nonverbal IQ	.92	.90	.89	.93
Verbal IQ	.94	.93	.95	.95
Factor Index Scores				
Fluid Reasoning	.82	.85	.84	.83
Knowledge	.92	.92	.94	.95
Quantitative Reasoning	.88	.92	.89	.93
Visual-Spatial Processing	.82	.86	.87	.89
Working Memory	.90	.88	.79	.87

Interscorer agreement, or interrater reliability, is the extent to which two or more individuals (or scorers) agree on the scoring of a test, and addresses the consistency of test implementation (Gay & Airasian, 2003). Interrater reliability for the SBV ranged from .74 to .97 with a high median interrater correlation of .90 (Roid, 2003c).

Measures of Vailidity. The validity of the SBV was supported through content-related evidence, criterion-related evidence, and construct-related evidence (Roid, 2003c). Content-related validity is "based on the extent to which a measurement reflects the specific intended domain of content" (Carmines & Zeller, 1991, p.20). The content validity for the SBV was established through empirical item analysis, the professional judgement of researchers and experts in assessment, and consultation with experts in the CHC theory of intellectual abilities.

Criterion-related validity was established by comparing the SBV with other measures of intelligence which have been demonstrated to be valid (concurrent validity) and by assessing the extent to which the SBV predicts academic achievement (predictive validity). Measures of concurrent and predictive validity for the SBV are presented in Tables 3.8 and 3.9, respectively.

Table 3.8

Correlations Between the SBV IQ Scores and Wechsler Intelligence Measures

	WPPSI-R			WISC-III			WAIS-III		
	PIQ	VIQ	FSIQ	PIQ	VIQ	FSIQ	PIQ	VIQ	FSIQ
IQ Scores									
FSIQ	.75	.79	.83	.71	.82	.84	.77	.78	.82
NVIQ	.72	.66	.75	.66	.72	.77	.76	.72	.77
VIQ	.66	.82	.80	.70	.85	.85	.75	.81	.82
Index Scores									
FR	.45	.45	.49	.62	.62	.69	.72	.70	.74
KN	.55	.76	.72	.50	.72	.69	.77	.78	.81
QR	.66	.70	.74	.66	.79	.80	.71	.74	.77
VS	.70	.58	.69	.42	.60	.58	.71	.71	.75
WM	.49	.59	.59	.46	.42	.49	.69	.70	.73

Concurrent validity was assessed by comparing the SBV to other highly used intelligence tests including: previous editions of the Stanford-Binet Intelligence Scale (the SB-IV and Form L-M), the Woodcock-Johnson III Tests of Cognitive Abilities (WJ-III), the Wechsler Adult Intelligence Scale–Third Edition (WAIS-III), the WISC-III, and the Wechsler Preschool and Primary Scale of Intelligence–Revised (WPPSI-R). Concurrent validity of the FSIQ and the other intelligence measures ranged from .78 to .90.

Table 3.9

Correlations Between the SBV IQ and Factor Index Scores and Measures of Achievement

	FSIQ	NVIQ	VIQ
WJ-III Tests of Achievement			
Reading Comprehension	.84	.79	.82
Broad Math	.76	.70	.75
Math Reasoning	.80	.75	.78
Written Expression	.70	.67	.65
Academic Application	.84	.79	.82
WIAT-II			
Math	.79	.72	.79
Oral Language	.77	.70	.78
Reading	.67	.52	.75
Writing	.53	.42	.58
Total	.80	.70	.83

Predictive validity was assessed by correlating the SBV with highly used measures of academic achievement including: the Woodcock-Johnson-III Tests of Achievement (WJ-III) and the Wechsler Individual Achievement Test–Second Edition (WIAT-II). Predictive validity ranged from .65 to .84 for the WJ-III, and from .42 to .80 for the WIAT-II.

Table 3.10

IQ and Factor Index Scores for Children with Various Psychological Disorders and Special Needs

	Mental Retardation	ADHD	ESL	Autism	Learning Disability		
					Reading	Math	Writing
n	119	94	65	83	212	49	44
IQ Scores							
FSIQ	56.5	92.2	91.4	70.4	84.1	85.6	94.9
NVIQ	58.7	93.1	95.3	73.3	85.6	86.0	94.1
VIQ	58.1	92.3	88.6	70.2	84.3	86.7	96.2
Index Scores							
FR	62.0	93.4	92.6	76.0	86.8	88.5	94.9
KN	62.4	92.7	89.3	75.5	85.0	88.4	96.9
QR	64.2	95.9	96.2	75.7	87.1	84.5	97.5
VS	62.3	95.1	93.8	75.0	88.1	90.4	97.0
WM	62.9	90.2	92.0	71.6	85.6	87.6	92.4

Construct validity, the evidence that test scores accurately reflect their intended construct (Gall, Gall, & Borg, 2003), was supported through the intercorrelations of test results with various special groups (Roid, 2003c; see Table 3.10). Theoretically, test scores should vary depending on the special characteristics of the population being tested. As found in the standardization sample, scores on the various SBV factors varied as predicted by the deficits associated with the disorder (Roid, 2003c). Particularly relevant to this study, 104 children with diagnoses of ADHD were tested and scored significantly lower on the WM and KN factor scores.

Behavior Assessment System for Children

The BASC TRS and PRS forms were developed as multidimensional indicators of the behaviour of children (Reynolds & Kamphaus, 1992). The BASC evaluates 11 to 14 dimensions of a child's behaviour depending on the child's age and form used (PRS or TRS). The scales consist of 126 to 148 items utilizing a 4-point Likert scale format (never, sometimes, often, and almost always). Scores are measured as T-scores with an average of 50 and standard deviation of 10. Scores are considered clinically significant (suggesting a high level of maladjustment) if they are two standard deviations above the mean (>70). The 95% confidence interval (the range within which the true score is likely to lie) is calculated by adding or subtracting 2 standard errors of measurement to the observed T-score. For example, the 95% confidence interval for a T-score of 70 would equal 65-75.

Reliability. The internal consistency of the BASC TRS scales are high, with average correlations ranging from .82 to .90 for the three age levels. The internal consistency of the Hyperactivity and Attention Problems subscales ranges from .87 to .93. In the PRS scales internal consistency is somewhat lower, but still good, with average correlations in the upper .70's for the three age levels.

Test-retest reliability for the PRS is high with average values between .82 and .91 for the three age levels. Specifically measuring the Hyperactivity and Attention Problems subscales, test stability scores range from .84 to .92. Test-retest reliability for the TRS is good, with average correlations ranging from .70 to .88. Test stability measures for the Hyperactivity and Attention Problem scales range from .77 to .92, with the lowest scores occurring in the adolescent group. These scores suggest that both parents and teachers are consistent over time in how they interpret the test items (Reynolds & Kamphaus, 1992).

The inter-rater reliability for the TRS is good with average correlations ranging from .60 to .91 for the various scales. Inter-scorer agreement is lowest in the preschool range (Hyperactivity = .54; Attention Problems = .63) but increases in the child level (Hyperactivity = .75; Attention Problems = .69). In the PRS, inter-rater reliability is moderate, with average correlations ranging from .46 to .67 for the three age levels. Inter-scorer agreement for the Hyperactivity and Attention Problem scales ranges from .56 to .73. Generally, these correlations indicate that different individuals generally interpret the BASC items similarly (Reynolds & Kamphaus, 1992).

Validity. The validity of the BASC was assessed through the correlation with other behavioural measures (Reynolds & Kamphaus, 1992). The BASC has been correlated with the Achenbach (1991) Teacher Report Form, the Revised Behaviour Problem Checklist (Quay & Peterson, 1983), the Conner's Rating Scales (Conners, 1989), and the Behaviour Rating Profile (Brown & Hammill, 1983). These measures are moderately correlated with the corresponding measures on the BASC, supporting the validity of this scale (Reynolds & Kamphaus, 1992).

Assessing ADHD. Specifically regarding its ability to diagnose ADHD, the BASC is considered a valid and reliable assessment tool (Manning & Miller, 2001; Ostrander et al., 1998). Both the PRS and TRS forms are considered superior to other rating scales in their ability to distinguish ADHD children from non-ADHD children (Vaughn et al., 1997; Ostrander et al., 1998). However, the results of the BASC should be used with caution as a sole diagnostic tool for ADHD, and are best utilized as part of a multidimensional assessment (Manning & Miller, 2001).

Procedures

This study is based on a causal-comparative design, in which archival data was collected and analyzed from the files of individuals assessed at the Education Clinic at the University of Alberta. Since May of 2003, approximately 200 children have been assessed in the Education Clinic with the SBV as part of a larger psychoeducational assessment. The tests were administered and scored according to standardized procedures (see Roid, 2003a) by Master's level students enrolled in Educational Psychology at the University of Alberta, under the supervision of a chartered psychologist. Protocols were followed in the administration of each assessment (i.e., the BASC, SIDAC-R, etc.) as per the respective manuals. The assessments were conducted between May 2003 and April 2004 and generally required four to six hours to complete, with the SBV requiring between 45 to 75 minutes to administer (Roid, 2003c).

As required by standard procedure at the Education Clinic, prior to assessment all clients are required to consent to the assessment, and parents are asked to complete a standard consent form. Included in this form is the consent to participate in research. Participants were only considered for participation in the study if they consented to participate in research and signed the consent form. The researcher has no contact with any of the participants, and the clinicians' assessments are completely independent from the research study. The clinicians explain to the clients during the informed consent procedures that participation in the research is completely voluntary and independent from the assessment procedure.

Diagnosis

The file of each individual between the ages of 5 years, 0 months and 17 years, 11 months was reviewed to determine if the participant met the DSM-IV criteria for a diagnosis of ADHD. Specifically, these criteria include: a persistent pattern of inattention and/or hyperactivity and impulsivity, which is considered developmentally inappropriate for the child's age or developmental level; evidence of clinically significant impairment in social, academic, or occupational functioning; impairment from these symptoms in two or more settings; symptoms persisting for at least 6 months, with the presence of these symptoms before the age of seven; and ruling out a differential diagnosis (APA, 1994; see Appendix). The evaluation of ADHD symptomatology was based on: parent and teacher forms of the BASC; semi-structured interviews with the children, parents, and/or teachers (e.g., the SIDAC-R); medical, academic, and developmental histories; and clinical observation. Neither IQ scores nor factor scores were utilized in any way during the diagnostic procedure.

First, the persistent pattern of inattention and/or hyperactivity/impulsivity was assessed in several ways. Elevated T-scores (above 65) of the Hyperactivity and Attention Problems scales of the TRS and PRS were considered indicators of the presence of inattention and hyperactivity/impulsivity. This value was chosen to reflect the clinically significant range while accounting for measurement error by using the lower limit of the confidence interval. Additionally, the SIDAC-R was utilized to determine the presence or absence of these conditions by directly questioning whether or not the symptoms occur. Finally, the children were directly observed during the assessment to determine the presence or absence of these symptoms in an assessment situation.

Second, parent and teacher reports were used to determine if these symptoms resulted in clinically significant impairment in functioning. Personal and academic histories were reviewed, as well as interviews with the parents. As indicated by these reports, children included in the various ADHD groups demonstrated impairment in social, academic, or occupational functioning.

Third, it was determined whether these symptoms occurred in two or more settings. This was accomplished by comparing the various reports (BASC, SIDAC-R, and clinical observation) from teachers, parents, and clinicians. To be included in the ADHD group, observations of clinically significant symptoms were required by at least two of these raters, indicating the presence of these symptoms is not situation-specific.

Fourth, the duration of these symptoms was evaluated. Medical and developmental histories were reviewed to determine if the symptoms were present before the age of seven. Additionally, reports from teachers and parents were used to determine if the symptoms have persisted for at least 6 months. Fifth, differential diagnoses were ruled out through medical and developmental histories. Again, all children included in the ADHD groups met these requirements.

Placement into these categories was determined considering the child's current level of functioning and not according to previous diagnoses. As indicated by the medical histories, 54 children were referred to the clinic with a previous ADHD diagnosis. Of these, only one child did not currently meet the diagnostic criteria, and was not included in the ADHD group.

On the basis of these criteria, children were assigned to the ADHD-I, ADHD-C, and ADHD-H groups. Children in these groups met the diagnostic criteria specified in the DSM-IV (see Appendix). Participants without an ADHD diagnosis were assigned to the control group. Individuals were subsequently excluded from the study based on the exclusion criteria discussed earlier.

Data collection

Once assessments and assessment reports were completed, the resulting data was collected by the researcher. All information was gathered from the participant's files, and the participants were not contacted at any time by the researcher. The collected data included IQ, factor, and subtest scores, BASC scores, demographic information (i.e., age and gender), school information (i.e., current grade, special programs, grade retention) and medical information (i.e., current medication, current diagnoses). Information concerning family SES and ethnicity was unavailable for the majority of participants, and was therefore not collected. The information was collected by the author and entered into a computer database. The data was then reviewed by a Ph.D. student in school psychology, and the placement into the various ADHD groupings was confirmed.

Data Analysis

Once the data was collected, it was entered into the Statistical Program for the Social Sciences (SPSS 11.5). The data was checked for errors by randomly selecting 10% of the original sample and comparing the SPSS data with the original files. In total, 15 errors were detected (and corrected) out of a total 31,916 data entry points.

Multiple t-test comparisons were employed to test the various hypotheses. A two-tailed significance level of $\alpha = .05$ was used in the analyses. However, because several independent tests were performed simultaneously, the alpha level was corrected using the Bonferroni Correction. This technique lowers the alpha value to account for the number of comparisons being performed, and reduces the chance of making a Type-I error (Shaffer, 1995). Because the between group comparisons of WM (hypotheses 1 and 2) are planned, the alpha level does not require to be changed (Evans, 1998). However, because it is part of a multiple comparison procedure, the alpha level was corrected to be consistent between the multiple comparisons.

Prior to hypothesis testing, the data were analyzed to ensure they met the assumptions of normality and equal variances. The assumption of approximately normal distributions was assessed by visually evaluating the distributions and measuring skewness and kurtosis. The assumption of equal variances was tested by Levene's Test for Equality of Variances (see Ramsey & Schafer, 1997). All data met these assumptions.

Comparisons between the ADHD-I and ADHD-C groups were made using a t-test for independent samples, with the significance level set at $\alpha = .01$. Comparisons between the ADHD-T and control groups were also made using a t-test for independent samples. The significance level for these comparisons was set at $\alpha = .01$. Comparisons between the WM scores and other factor scores were made using a paired sample t-test, with a significance level set at $\alpha = .0125$. Within group comparisons of verbal and nonverbal WM scores were made using a paired sample t-test with a corrected significance level set at $\alpha = .01$.

Limitations and Delimitations

Limitations

A relatively high proportion of the sample (40%) was excluded from the study. While excluding the various comorbid diagnoses from the ADHD and control groups may have resulted in a more clear understanding of the deficits associated with ADHD, it may have also limited the clinical validity. The comorbid conditions that were excluded from the study are often associated with ADHD (Shaywitz & Shaywitz, 1991) and a child referred to a mental health clinic may likely exhibit one or more of these diagnoses. Excluding these groups from this study may limit the generalizability of this research to ADHD children with comorbid diagnoses. This is particularly significant as comorbidity with ADHD is considered the rule rather than the exception in clinical samples (Cantwell & Baker, 1991; Eiraldi, Power, & Nezu, 1997; Shaywitz, & Shaywitz, 1991).

The age range selected in this study (5 years, 0 months to 17 years, 11 months) was quite large. Systematic differences may exist between younger and older children in relation to the history of treatment and educational remediation, as well as the severity and neurobiology of the disorder (Barkley, 1998; Karaketin, 2004). Similarly, normal developmental and neurological changes in working memory also occur during this age range (Baddeley, 1986). These factors may limit both the validity and reliability of the study. As previously discussed, this age range was selected to match the data collected for ADHD children during the SBV norming process, and the small sample size restricted the groups from being divided by age.

The retrospective method utilized to diagnose ADHD is an additional limitation of this study. Great effort was taken to ensure accurate diagnoses based on well-researched methods. Nevertheless, the utilization of the BASC as a behavioural measure of ADHD has some degree of error (Manning & Miller, 2001; Vaughn et al., 1997). Clinical interviews are considered the most valid tool in assessment (Barkley, 1998), and a direct assessment of ADHD from a chartered psychologist or medical doctor may have proven a more valid method of diagnosis. Time restraints and practical considerations precluded this method of assessment. It is assumed that the ADHD groups formed in this study are similar to those used in other research.

Delimitations

While there are many cognitive abilities measured by the SBV that could be the focus of study, this research solely investigated working memory. Theoretically, compared to other cognitive abilities, this construct should be most significantly impaired in children with ADHD (Barkley, 1997b). Additionally, of the five factors tested in the SBV, WM was reportedly the most impaired in ADHD children (Roid, 2003c). This assessment of working memory will not elucidate specific aspects of central executive deficits, or clarify how or why these deficits occur. This study will only find whether or not these deficits occur in ADHD, as indicated by the SBV.

This study is also delimited by the decision to use data from the Education Clinic at the University of Alberta. These children were referred to the clinic for a variety of academic, behavioural, and emotional concerns, and as such, may not be considered a random sample. The results of this study are intended to apply only to clinic-referred children, and do not reflect the full range of abilities of children with ADHD. While this sample may not accurately represent the ADHD population as a whole, or even a typical child with the disorder, this sample may be more indicative of cases seen in treatment and assessment (Carlson, Shin, & Booth, 1999). As such, this study may provide important information concerning the assessment and research of clinic-referred children.

Results

This chapter presents the results of the data analyses, organized by hypothesis. A two-tailed significance level of $\alpha = .05$ was used for all of the analyses. In the multiple t-test comparisons, this significance level was corrected with the Bonferroni technique. This accounts for the number of comparisons being performed, and reduces the chance of making a Type I error.

Hypothesis 1

H_o: There will be no significant differences between the ADHD-I and ADHD-C groups on the mean WM factor score.

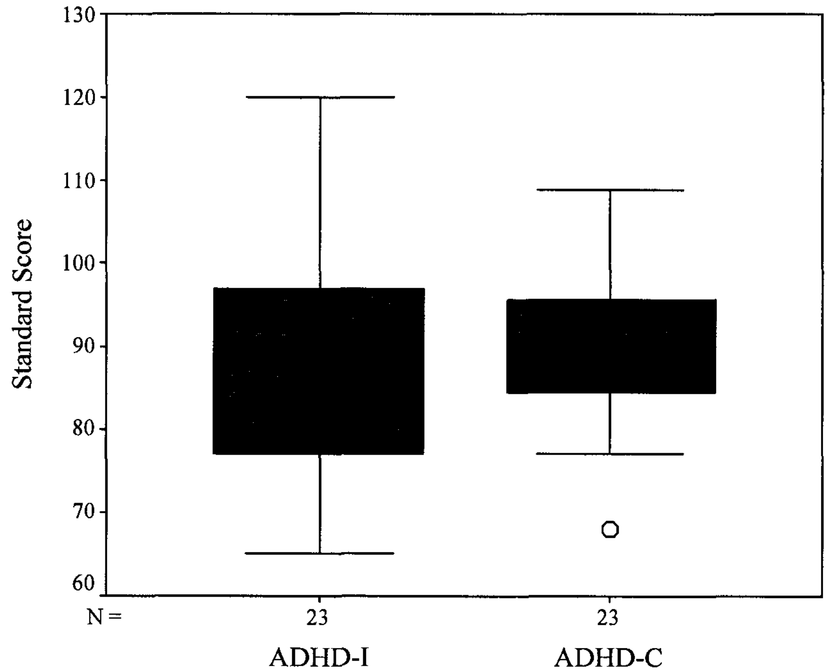
To test this hypothesis, the data were first analyzed to determine the suitability of the intended statistical procedures. The Levene Test for homogeneity of variance was performed to determine if the variances were sufficiently equivalent to allow comparison between the groups. The results did not indicate any significant differences in the variance of the ADHD-I and ADHD-C scores. The data were also analyzed for skewness. As indicated in Figure 4.1, the distribution of each group is relatively normal. These results suggest that the data meet the assumptions of normality and suggest that an analysis with the t-test procedure is warranted.

To compare the WM factor scores for the ADHD-C and ADHD-I groups, an independent-samples t-test analysis was performed with a corrected significance value of $\alpha = .01$. The WM factor scores for the ADHD-C group ($M = 91.3$, $SD = 10.2$) did not differ significantly from the WM scores for the ADHD-I group ($M = 88.70$, $SD = 14.5$;

$t_{(44)} = -.48, p = ns$). Therefore, we fail to reject the null hypothesis. This indicates that the ADHD-I and ADHD-C groups do not perform differently on the WM factor of the SBV.

Figure 4.1

Boxplot for the ADHD-I and ADHD-C Groups



The ADHD-I and ADHD-C groups were further compared to determine if the mean scores of the other four factors were also significantly different (see Table 4.1). Again, the data were analyzed with a corrected significance value of $\alpha = .01$. The ADHD-I group did not significantly differ from the ADHD-C group on any of the factor scores or IQ scores. Similarly, the patterns of performance on the various subtests were consistent between the two groups (see Figure 4.2). This suggests that the pattern of performance of these two groups on the SBV did not vary significantly, and does not indicate any subtype differences in performance on the SBV.

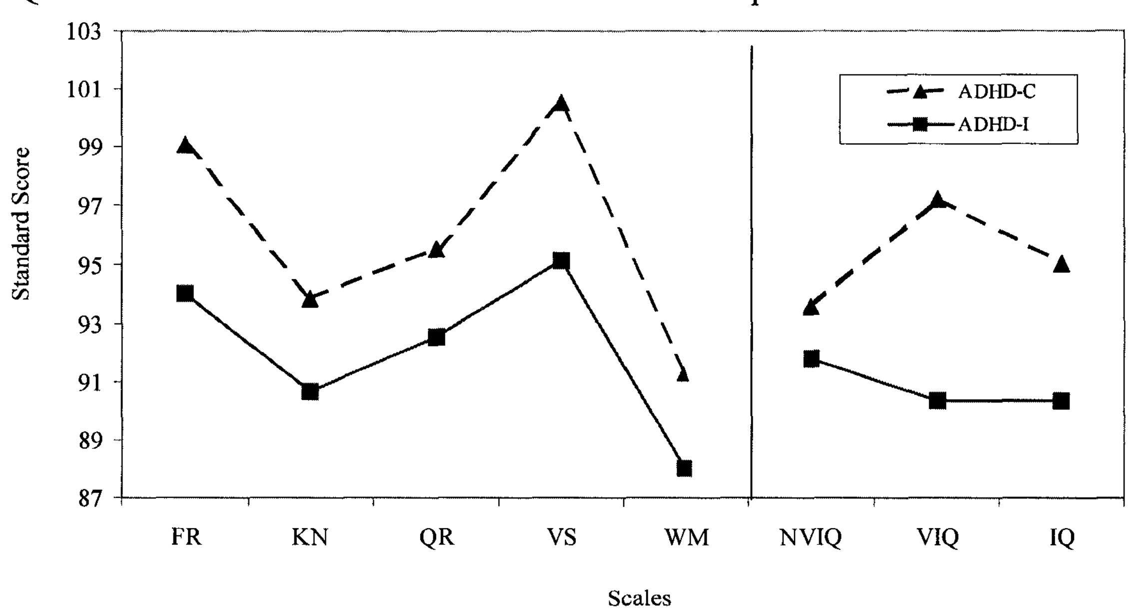
Table 4.1

Mean Factor and IQ Scores and Test Results Comparing the ADHD-I and ADHD-C Groups

	ADHD-I		ADHD-C			
	M	SD	M	SD	*t*	*p*
Factor Scores						
WM	88.70	14.5	91.30	10.2	-.71	.483
FR	94.26	14.3	99.09	12.4	-1.23	.227
KN	91.43	16.5	93.83	12.5	-.55	.582
QR	92.52	10.4	95.52	11.4	-.93	.356
VS	95.09	9.0	100.52	11.6	-1.78	.082
IQ Scores						
FSIQ	90.74	12.5	95.04	11.3	-1.23	.226
NVIQ	90.78	12.8	97.26	11.1	-1.83	.680
VIQ	92.04	12.7	93.57	12.2	-.42	.074

Figure 4.2

IQ and Factor Scores for the ADHD-C and ADHD-I Groups



Taken together, these results indicate that when comparing the ADHD-I and ADHD-C groups on the SBV, there appears to be no significant differences in factor score profiles. Because these groups do not appear to differ, they will be collapsed into a single ADHD group (ADHD-T) for the remainder of the analyses. This is done because the analysis of subtype differences in ADHD was not a primary objective of this study. Furthermore, creating a single ADHD group will increase the power of the statistical analyses.

Hypothesis 2

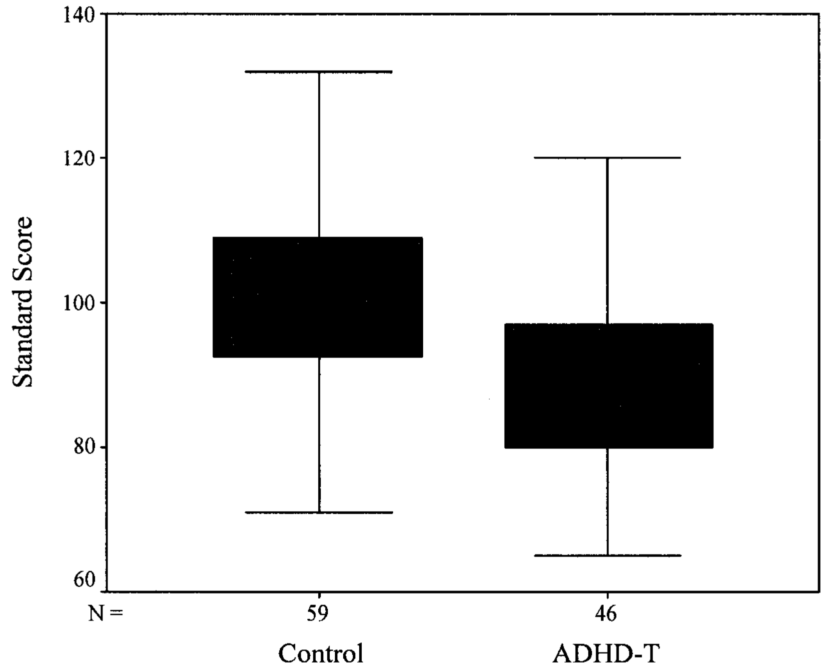
H_o: There will be no significant differences between the ADHD-T and control groups on WM factor scores.

Again, the data were analyzed to determine the appropriateness of the intended statistical procedures. The Levene Test for homogeneity of variances did not indicate any significant differences in the variance of the ADHD-T and control group scores. An analysis of skewness also indicated relatively normal distributions in both groups (see Figure 4.3). These results suggest that the data meet the assumptions of normality and suggest that an analysis with the t-test procedure is warranted.

An independent-samples t-test analysis was performed with the alpha level set at $\alpha = .01$. The WM factor scores for the ADHD-T group (M = 90.00, SD = 12.4) were significantly lower than the WM scores for the control group (M = 100.20, SD = 12.6; $t_{(103)} = 4.15$, $p < .01$). Therefore, we reject the null hypothesis. These results indicate that the ADHD-T group, as a whole, performed significantly different than the control group on the WM factor of the SBV.

Figure 4.3

Boxplot for the ADHD-T and Control Groups



The factors of both the ADHD-T and control group were further compared to ensure that the ADHD-T group was not simply lower on all measures, and that the observed deficits were confined to the WM factor. Multiple t-test comparisons were performed with a corrected alpha level set at $\alpha = .01$. The ADHD-T group did not differ significantly from the control group on any of the other factors (i.e., FR, KN, QR, and VS; see Table 4.2).

IQ scores were also compared between the ADHD and comparison groups. Multiple t-test comparisons were performed with a corrected alpha level set at $\alpha = .02$. A significant difference did emerge between these groups on both the FSIQ and VIQ scores. There were no differences between the groups on the NVIQ score (see Table 4.2).

Table 4.2

Mean Factor and IQ Scores and Test Results Comparing the ADHD-T and Control Groups

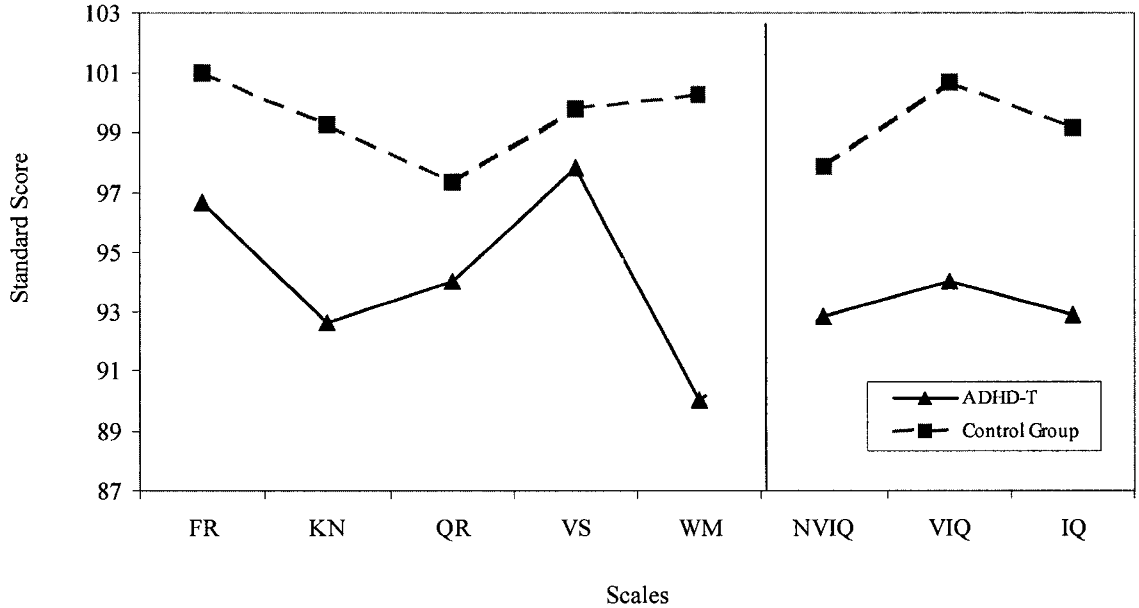
	ADHD-T		Control			
	M	SD	M	SD	*t*	*p*
Factor Scores						
WM	90.00	12.4	100.20	12.6	4.15	.000**
FR	96.67	13.4	101.02	12.7	1.69	.094
KN	92.63	14.5	99.10	14.5	2.27	.025
QR	94.02	10.9	97.42	11.6	1.53	.130
VS	97.80	10.6	99.88	12.2	.91	.363
IQ Scores						
FSIQ	92.89	12.0	99.14	11.0	2.78	.006*
VIQ	94.02	12.3	100.66	11.8	2.81	.006*
NVIQ	92.80	12.3	97.86	11.9	2.13	.035

* Significant at $p < .02$
** Significant at $p < .01$

This finding supports the suggestion that performance on the WM factor is impaired in ADHD children, in comparison to a non-ADHD clinical control group. Additionally, these results indicate that deficits in the ADHD-T group are only evident in the WM factor, and not in the other factors (see Figure 4.4). In contrast to the standardization sample (Roid, 2003c), significant differences were not found when comparing the KN factor in the two groups. Overall IQ scores and verbal IQ scores also appeared to be impaired in the ADHD-T group compared to the control group, but no differences were found in measures of nonverbal IQ.

Figure 4.4

IQ and Factor Scores for the ADHD-T and Control Groups



Hypothesis 3

H_o 3.1: The WM factor score for the ADHD-T group will not differ significantly from the FR, QR, and VS factor scores.

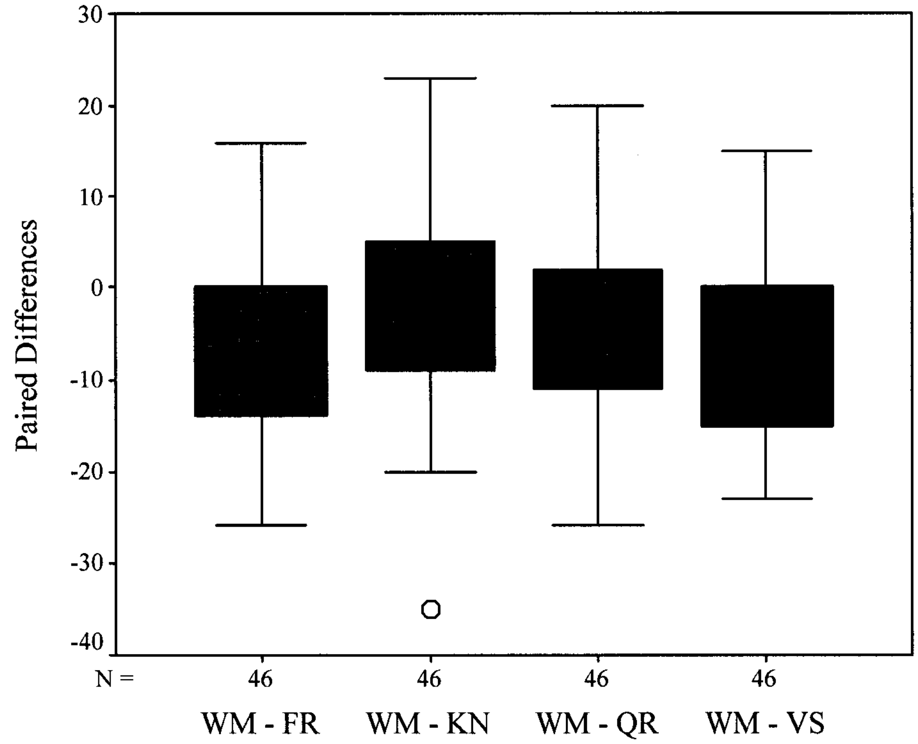
H_o 3.2: The WM factor score for the ADHD-T group will not differ significantly from the KN factor score.

Each of the five factors were first assessed to determine if they met the assumptions of normality. All factors had equal variances, and the paired differences between the factors were normally distributed with the exception of WM and VS, which had a slight positive skew (.84; see Figure 4.5). However, the t-test is relatively robust to the assumption of normalcy. In other words, the test is considered valid even when this assumption is not met (Ramsey & Schafer, 1997), and the t-test procedure is warranted.

Multiple t-test procedures were utilized with a corrected alpha level set at $\alpha = .0125$. The mean factor scores are presented in Table 4.2, and the mean differences between the WM factor and other factors are presented in Table 4.3.

Figure 4.5

Boxplot of the Paired Differences Between WM and the Other Factor Scores



In the ADHD-T group, the differences between the WM factor and the FR, QR, and VS factor scores were statistically significant (see Table 4.3 for t-scores and p-values) No such differences were evident in the analysis of the control group, which found no significant differences between the WM factor and the FR, QR, and VS factors (see Table 4.3). Therefore we reject the null hypothesis 3.1; the WM factor score for the ADHD-T group differed significantly from the FR, QR, and VS factor scores.

However, the WM factor was not significantly different from the KN factor in either the ADHD-T or control group (see Table 4.3). Therefore, we fail to reject the null hypothesis 3.2; the WM factor does not significantly differ from the KN factor.

Table 4.3

Mean Differences Between the WM and Other Factor Scores for the ADHD and Control Group

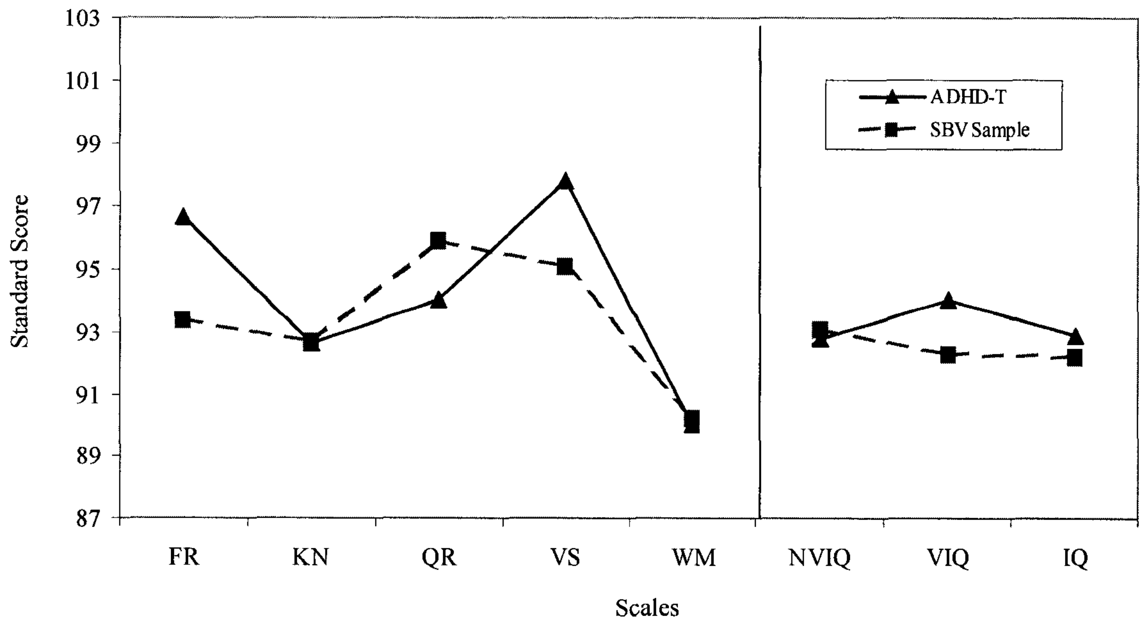
	Paired Differences				
	M	SD	*df*	*t*	*p*
ADHD-T					
WM - FR	6.67	10.3	45	4.41	.000*
WM - KN	2.63	10.8	45	1.65	.107
WM - QR	4.02	10.0	45	2.73	.009*
WM - VS	7.80	9.8	45	5.38	.000*
Control					
WM - FR	.81	12.0	58	.52	.606
WM - KN	-1.10	15.0	58	-.56	.575
WM - QR	-2.78	11.2	58	-1.91	.061
WM - VS	-.32	13.9	58	-.18	.860

* Significant at $p < .0125$

The WM factor was significantly lower than the FR, QR, and VS factors, but did not significantly differ from the KN factor (see Figure 4.4). These findings were similar to Roid's (2003c), which found WM to be significantly lower than all factors with the exception of KN. Figure 4.6 compares the current sample with Roid's (2003c) sample, and indicates a similar pattern of subtest scores. The clinical control group in the present study added to the significance of the finding, and suggests that WM is not the lowest factor for all children referred to psychoeducational assessment services.

Figure 4.6

Comparison of SBV Profiles for the ADHD-T Group and the ADHD Group Included in the SBV Standardization Sample



In addition to answering the null hypothesis, the data were also analyzed to determine the number of individual cases in the ADHD-T and control groups which had significant differences between the WM and the other factor scores (see Table 4.4). Significance was determined according to the magnitude of the split between WM and the other factors, and was calculated with the SBV computer scoring program (Roid, 2003b). Compared to the control group, more individuals in the ADHD-T group had significantly lower WM scores related to the other factor scores, with the exception of KN. There also appeared to be more children in the control group with WM scores significantly higher than the other factors.

Table 4.4

Frequency of Significant Differences Between Factor Scores for the ADHD-T and Control Groups

	ADHD-T (n = 46)		Control (n = 59)	
Significant Differences	*f*	%	*f*	%
WM > FR	2	4.3	7	11.9
WM > KN	5	10.9	14	23.7
WM > QR	2	4.3	11	18.6
WM > VS	2	4.3	11	18.6
FR > WM	14	30.4	13	22.0
KN > WM	5	10.9	10	16.9
QR > WM	7	15.2	2	3.4
VS > WM	15	32.6	10	16.9

Finally, the data were analyzed to determine how many individuals in each group had WM as the lowest factor score. First the WM scores were ranked in comparison to the other factor scores from highest to lowest (see Table 4.5). Over 40% of the ADHD-T group had WM as their lowest score, and only 3% had WM as their highest score. The ranking of the WM score was more evenly distributed in the control group, with 18.6% of the children having WM as their lowest score and 27.1% having WM as their highest score. A chi-square analysis was administered to determine if the distribution among the 5 ranks was equal, assuming each rank (one through five) would represent 20% of the participants in each group. Significant differences were found in the ADHD-T group ($\chi^2_{(4)} = 16.61, p < .05$) but not in the control group ($\chi^2_{(4)} = 3.97, p = ns$).

Table 4.5

Frequency of WM Score in Ordinal Ranks for the ADHD-T and Control Groups

	ADHD-T (n = 45)		Control (n = 60)	
	f	%	*f*	%
Highest Score	3	6.5	16	27.1
Second Highest	7	15.2	11	18.6
Third Highest	6	13.0	14	23.7
Second Lowest	11	23.9	7	11.9
Lowest Score	19	41.3	11	18.6

This analysis indicates that significantly more children in the ADHD-T group had WM as their lowest score in comparison to the other factors. It is important to note that nearly 60% of the ADHD-T group did not have WM as their lowest score.

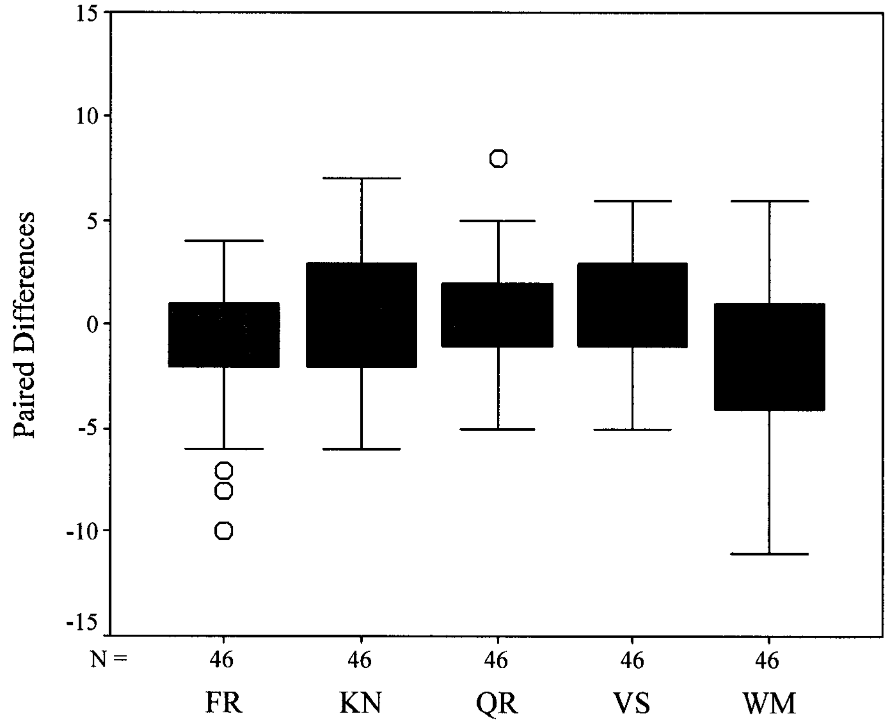
Hypothesis 4

H_o: There will be no significant differences between the verbal WM score and the nonverbal WM score in the ADHD-T group.

Again, the data were analyzed to determine the appropriateness of the intended statistical procedures. The Levene Test for homogeneity of variances did not indicate any significant differences in the variance of either the verbal WM or nonverbal WM scores in the ADHD-T or control group. The paired differences between the nonverbal and verbal subtests were normally distributed with the exception of FR, which had a slight negative skew (-.90; see Figure 4.7). However, due to the robustness of the t-test procedure, the t-test procedure is warranted.

Figure 4.7

Boxplot for the Paired Differences (Nonverbal – Verbal) Between Factor scores in the ADHD-T Group



A paired-samples t-test analysis was performed to compare the verbal and nonverbal WM factor scores for the ADHD-T group. The nonverbal WM factor scores (M = 7.46, SD = 2.8) were significantly lower than the verbal WM scores for the ADHD-T group (M = 9.07, SD = 3.1; $t_{(45)} = -2.75$, $p < .01$). The control group did not differ in their performance of verbal (M = 10.22, SD = 2.8) and nonverbal (M = 9.81, SD = 2.7) WM subtests ($t_{(58)} = -.94$, p = *ns*). Similarly, the differences between verbal and nonverbal scores for the other factors were not significant (see Table 4.6). Therefore, we reject the null hypothesis; there was a significant difference between the verbal WM score and the nonverbal WM score in the ADHD-T group.

These results indicate that the ADHD-T group as a whole performed significantly lower on the nonverbal WM task compared to the verbal WM task. The control group did not demonstrate differential abilities between verbal and nonverbal working memory tasks. Verbal-nonverbal differences were not evident in the other factor scores.

Table 4.6

Verbal and Nonverbal WM Scores for the ADHD-T and Control Groups

	Paired Differences			
Nonverbal-Verbal	M	SD	*t*	*p*
FR	- 1.28	3.28	- 2.65	.011
KN	.52	2.90	1.22	.229
QR	.54	2.60	1.42	.163
VS	.74	2.63	1.91	.063
WM	- 1.61	3.96	- 2.75	.008*

* Significant at $p < .01$

Discussion

The two-fold objective of this study was to: 1) assess the working memory abilities of children with ADHD; and 2) add to the validity of the WM factor of the SBV as a measure of working memory abilities. Relating to these objectives, this chapter will summarize the results of the present study, compare these results to previous studies, present possible conclusions, and provide recommendations for future research.

Working Memory Deficits in ADHD

Summary of Research Findings

The results of this study confirmed the hypothesis that children with ADHD have deficits in working memory. First, children with ADHD scored significantly lower in measures of working memory compared to children without ADHD. Children with ADHD diagnoses did not perform more poorly than non-diagnosed children on any other measures indicated by the SBV.

Second, within the ADHD group, the mean WM score was significantly lower than all other factors with the exception of KN. The WM factor did not differ from the other factors in children without ADHD. As well, there were disproportionately more ADHD children with WM as their lowest factor score; this factor was the lowest score for 41% of the these children and the highest factor score for only 6%. Ordinal rankings of the factors within the control group were more evenly distributed. Within the WM factor, nonverbal WM scores were significantly lower than verbal WM scores.

Working memory deficits were further analyzed by comparing differences between ADHD subtypes. This study found that the ADHD-I and ADHD-C groups do not perform differently on the WM factor, or any of the other factors on the SBV. Similarly, nearly identical factor score patterns were found between these two groups, indicating no differential abilities in their performance on the SBV.

Comparing the current findings to previous research

This study attempted to build on previous research by utilizing a measure of working memory span that is not correlated with mathematical abilities, controlling for comorbid diagnoses, assessing ADHD subtypes separately, using consistent diagnostic criteria (i.e., DSM-IV), and including a control group for statistical comparisons. Unfortunately, the current study also suffered limitations in regards to the diagnostic procedure used, as direct clinical interviews were unavailable. Additionally, the sample utilized a broad age range wherein many developmental changes in working memory occur. Nevertheless, despite these limitations the current research provides support for several previous research findings.

Working Memory Deficits in ADHD. This study supports the findings of other studies that suggest working memory is impaired in ADHD children. Previous researchers have found deficits in working memory span performance while short-term memory performance appears unaffected (Barkley, 1998; Karatekin, 2004; Mariani & Barkley, 1997; Roodenrys et al., 2001). Comparable to these other measures of working memory span, the WM factor of the SBV was also found to be impaired in ADHD children tested in the current study. This study also supported Roid's (2003c) findings that the WM factor scores on the SBV are lower in ADHD children as similar subtest patterns were found in both studies.

It is unlikely that the differences in WM scores were due to differences in test-taking styles, or inattention and impulsivity in the testing environment. An impulsive test-taking style would expectedly impair the performance in all of the subtests; however, there were no significant differences found between the other subtest scores. Similarly, differences between groups is likely not due to academic abilities as no significant between-group differences found were found in the measures of academic achievement.

Still, some caution in the interpretation of these results is necessary. One significant limitation of the WM factor appears to be that it does not provide a clear measure of both working memory and short-term memory processes. Successful completion of the verbal and nonverbal WM tasks requires the concurrent storage, processing, and recall of information. Difficulties in any one of these areas may disrupt the working memory process and result in a lower WM score. These lower factor scores, in turn, may not provide sufficient information to specifically analyze the individual components or discriminate the source of the memory deficit.

For example, it is suggested that children with ADHD and Reading Disorders have distinct memory impairments; children with ADHD demonstrate deficits in the processing of information, while children with Reading Disabilities exhibit difficulties in serial recall and verbal memory (Rashid, Morris, & Morris, 2001; Roodenrys et al., 2001; Willcutt et al., 2001). WM scores for children with Reading Disorders or ADHD may be indistinguishable even though they have distinct memory deficits.

The current study, therefore, cannot state conclusively that the low WM scores found in the present study are due to deficient working memory or short-term memory systems. However, previous researchers have found the memory deficits associated with

ADHD are generally evident in measures of the central executive, and not in measures of the subsidiary systems (Benezra & Douglas, 1988; Karatekin, 2004; Karatekin & Asarnow, 1998; Mariani & Barkley, 1997; Roodenrys et al., 2001). Based on these conclusions, it is assumed that the memory deficits apparent in the current study are due to working memory, and not short-term memory impairments.

Verbal and Nonverbal Differences. In general, previous research has found neither the phonological loop nor the visuospatial sketchpad to be impaired in ADHD children (Karatekin, 2004; McInnes et al., 2003; Roodenrys et al., 2001). These tests involved measures of short-term memory, and did not assess the central executive (Karatekin, 2004). In tests of working memory (as opposed to short-term memory) both verbal and nonverbal deficits are manifest in ADHD children (Barnett et al., 2001; Karatekin, 2004; Roodenrys et al., 2001); however, no previous research was found which directly compares verbal and nonverbal working memory.

Because there is no evidence of differential impairment between the phonological loop and visuospatial sketchpad (Karatekin, 2004), it was assumed that there would be no differences when these subsidiary systems were measured in conjunction with the central executive. However, scores on the nonverbal WM factor were significantly lower than scores on the verbal WM factor. No verbal-nonverbal discrepancies were evident in the other factors, and the control group did not demonstrate a similar nonverbal difficulties in relation to verbal performance.

It has been suggested that compared to the phonological loop, the visuospatial sketchpad depends more strongly on the central executive (Baddeley, Cocchini, Sala, Logie, & Spinnler, 1999; Vandierendonck, Kemps, Fastame, & Szmalec, 2004). If both verbal and nonverbal abilities are held constant (as suggested by previous research), measures of nonverbal working memory may be more impaired than verbal working memory as a higher load is placed on the central executive. This hypothesis could be explored in future research by directly comparing performance of individual subsidiary systems, as well as performance of these subsidiary systems in conjunction with the central executive.

Differential Abilities in ADHD-I and ADHD-C. Few studies have directly assessed the differences in cognitive functioning or working memory between ADHD subtypes. Some researchers have suggested that children with ADHD-C demonstrate a greater impairment in intellectual or cognitive functioning (Carlson et al., 1986; Hinshaw, 1992), while others failed to find differences between ADHD subtypes (Morgan et al., 1996). Similarly, between-group differences in working memory have been found in some studies (Gansler et al., 1998) but not in others (Ackerman et al., 1986). The current study found no between-group differences in working memory or other cognitive abilities as measured by the SBV.

One possible explanation for these divergent findings is the type of sample (i.e., clinical or nonreferred) utilized in the various research studies. Children with ADHD-C are frequently referred to mental health services due to pervasive behavioural problems and impairment in multiple domains (Barkley, DuPaul et al., 1990; Faraone et al., 1998), whereas only those ADHD-I children who demonstrate significant impairment will be referred to these services (Carlson et al., 1999). As such, children with ADHD-I who are seen in clinics may demonstrate substantially greater difficulties compared to their non-referred counterparts (Carlson et al., 1999). Because of this selection bias, cognitive differences may not be evident in clinic-referred children, while they may be more apparent in the general ADHD population.

As would be expected under this hypothesis, Carlson et al. (1986) utilized a non-referred sample, while Morgan et al. (1996) utilized a clinical sample. Furthermore, the similarities found between ADHD-I and ADHD-C groups in the current research also fit with this hypothesis as a clinical sample was used. Therefore, due to referral bias, the current finding of no significant subtype differences in SBV performance may only apply to clinic-referred children. These findings cannot be generalized to non-clinical ADHD populations.

Support of Barkley's Model of ADHD

This study provides support for one component of Barkley's (1997b) model of ADHD; namely, children with ADHD experience deficits in the executive function of working memory. Based on the conclusions of previous studies, the memory deficits associated with ADHD are evident in tests of working memory and not in tests of short-term memory (Benezra & Douglas, 1988; Karatekin, 2004; Karatekin & Asarnow, 1998; Roodenrys et al., 2001). It is therefore assumed that the memory deficits found in the current study are due to working memory impairments, and not short-term memory deficits. This study also supports the proposition that these executive function deficits are unique to ADHD (Barkley, 1997b; Berlin et al., 2003; Clark et al., 2002; Weyandt & Willis, 1994). Although no specific disorders were directly compared, working memory deficits were not evident in the clinical control group. As the control group was referred for various emotional, behavioural, and educational challenges, this study suggests that working memory deficits are not present in individuals who experience general difficulties in these areas.

While this study does support Barkley's (1997b) model of ADHD, it does not rule out alternative models such as Denney and Rapport's (2000) Working-Memory Model of ADHD. This model defines working memory as a set of processes that "construct, maintain, and manipulate cognitive representations of incoming stimuli" (Denney & Rapport, 2000, p. 297). They posit that working memory processes play a pivotal role in the organization of behaviour and attention to the environment. Deficits in working memory lead to disruptions in the ability to process incoming stimuli, and result in disorganized behaviour, inattention, and impulsivity.

The central distinction between these two models of ADHD is the role working memory plays in behavioural inhibition and inattention. Barkley (1997b) places working memory as a secondary impairment resulting from disinhibition, whereas Denney and Rapport (2000) identify working memory processes as a primary deficit, with other symptoms (such as disinhibition) described as secondary manifestations. Low working memory scores would be predicted in each model, and insufficient information is available from the current study to clarify the nature of these working memory deficits.

This study has generated several questions which merit investigation in future research. First, an in-depth study of working memory deficits in ADHD is required. To better understand the underlying memory deficits associated with ADHD, numerous working memory and short-term memory tasks may be employed. The objective of this research would be to elucidate the working memory processes in ADHD, and clarify what measures best reflect these processes. An additional line of research may address the validity of Barkley's (1997b) model. Here, working memory deficits can be studied in their relation to behavioural disinhibition, other executive functions, and ADHD symptomatology. To reveal the role working memory plays in ADHD, treatment studies may prove useful (Denney & Rapport, 2000). For example, a study may investigate the effect of working memory training on disinhibition and the severity of ADHD symptoms in comparison with the effect of behavioural training (focusing on behavioural inhibition) on working memory and ADHD symptoms. If working memory plays a central role in ADHD, then working memory training may prove more effective; if behavioural disinhibition plays a central role, then behavioural training may prove a more effective treatment modality.

The Use of Baddeley's Model in ADHD Research

Barkley's (1997b) model has not been well researched, in part, because the concepts are neither well defined nor operationalized (Tannock, 1998). In relation to Barkley's concept of working memory, Baddeley's (1986) Working Memory Model may provide an important framework in which to structure the research. The current study provides preliminary support for this synthesis of theories, as tasks in the WM factor are theoretically based upon Baddeley's model (Roid, 2003c). Within this framework, it is assumed working memory deficits are due to central executive impairments. As discussed previously, the lower nonverbal WM scores may be due in part to deficits in the central executive, providing possible credence to this theory.

Again, the WM factor does not allow for a detailed analysis of the separate subsidiary system and central executive processes. Tests of this nature, which combine processing and storage tasks to predict other cognitive skills, fall under the general rubric of the *psychometric approach* to working memory research. This methodology allows for research of practical significance, such as investigations into the role working memory plays in reading comprehension, reasoning, or other cognitive tasks (Baddeley, 1992). Therefore, the WM factor may be a useful instrument in the study of the cognitive and academic impairments associated with ADHD. This factor, however, may not be an appropriate tool to analyze the specific nature of working memory deficits in ADHD.

A complementary group of tests are designated as a *dual-task approach* (Baddeley, 1992). This approach measures the ability to divide attention between memory tasks (Gathercole, 1999), and analyzes the separate components of the working memory system. These tests may be an important next step in future ADHD research as they may clarify the deficits associated with the subsidiary systems and the central executive (Karatekin, 2004). Research examining working memory deficits in ADHD may be best accomplished by utilizing the psychometric and dual-task approaches conjointly. In this way, the nature of working memory deficits may be elucidated, while also clarifying their influence on other educational or cognitive abilities.

Validity of the SBV

Evidence for the validity of a test develops over a period of years as research is accumulated (Roid, 2003c). This process of accumulating evidence for the validity of the WM factor began during the test development and standardization procedures. Both verbal and nonverbal WM tasks were adapted from previous instruments, and modified to better assess working memory (as opposed to short-term memory) and limit the role that reading skills may play in task completion (Roid, 2003c). Similarly, support was also provided based on comparisons of the WM factor with other measures and special groups. No other research has addressed the validity of the WM factor of the SBV, and test validity remains unconfirmed outside of test development.

Validity of the WM Factor

The results of this study provide initial support for the validity of the WM factor of the SBV as a measure of working memory. The ADHD group, as a whole, demonstrated impairment in the WM factor, evidenced by lower WM scores compared to both the control group, and three of the four other factor scores. Because ADHD children are hypothesized to have impaired working memory, these results are interpreted as criterion-related evidence of validity (see Roid, 2003c). These results build upon the results of the standardization process, which also found ADHD children to have lower WM scores (Roid, 2003c).

Again, these results should be interpreted with caution as the WM factor does not provide a clear measure of both working memory and short-term memory processes. While low WM scores may reflect true working memory impairments, they may also reflect deficient short-term memory processes. To add to the validity of the WM factor as a measure of working memory, this test could be compared to previously validated working memory span and short-term memory span tasks. An important direction in this research may be to better understand how individuals deficits in recall and storage perform in this factor when compared to individuals with working memory deficits (or impaired central executive). To address this research question, ADHD and reading disabled children may be useful comparison groups, as they may possess distinct memory deficits.

Assessing Children with ADHD

Test Use. A test, by itself, is neither valid nor invalid; rather, it is the use and interpretation of the test that is demonstrated to be valid or invalid (Roid, 2003c; Turner, DeMers, Fox, & Reed, 2001). The valid use of the SBV with ADHD children is an important research question as many of the children seen in assessments may present with ADHD symptoms (Cantwell, 1996). The current research supports the opinion that the WM scale of the SBV is an appropriate instrument to assess working memory in children with ADHD. Similar factor profiles for ADHD children were found in both the current research and the standardization sample, suggesting the SBV is sensitive to the deficits associated with ADHD.

Compared to other measures of cognitive ability, the SBV may provide a powerful tool when assessing children with ADHD. The WM tasks do not rely heavily upon academic abilities, such as word recognition, reading comprehension, and mathematical skill. Considering the academic challenges many ADHD children face, the SBV may be a more appropriate tool than other measures that correlate more highly with mathematical or numerical ability. When testing children with ADHD or LDs, the SBV may provide a more valid measure of abilities.

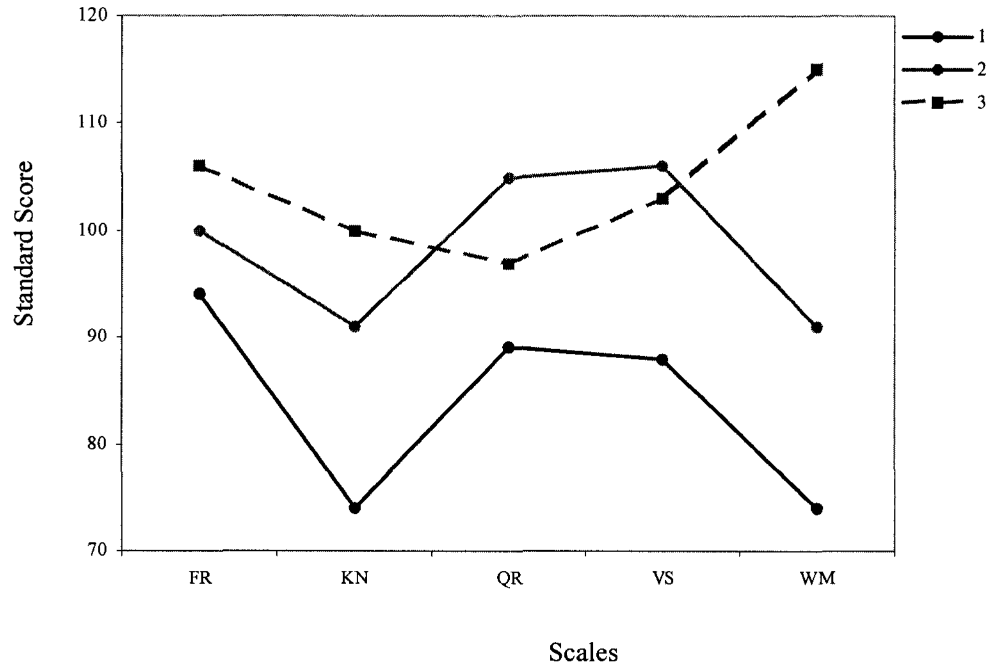
This is an important area for future research, and an important consideration when planning the assessments of children with suspected disabilities. Additional research may address this issue by comparing WM scores of children with Mathematics Disorder, ADHD, combined Mathematics Disorder and ADHD, and no diagnosis. Additionally, correlational studies may be of some use in examining this question; for example, comparing the correlations of the WM and FFD indexes with mathematical achievement in non-diagnosed and learning disabled populations.

Many children with ADHD will likely require multiple assessments throughout their academic careers (Cantwell, 1996; Weiss & Hechtman, 1993). Because different measures may be required during this process, it is important to know how these children will compare on the various tests (Saklofske et al., 1994). Future research is required to determine how ADHD children compare on the various assessment instruments, and determine the concurrent validity of these measures with ADHD children.

Test Interpretation. The interpretation of the SBV raises additional questions of validity. Although as a group, children diagnosed with ADHD scored significantly lower in measures of WM, the SBV patterns may not have diagnostic or clinical utility in determining whether an individual child has ADHD. As indicated by the present findings, a child with a low WM score may not have ADHD; conversely, an average WM score cannot be interpreted as the absence of ADHD. While there were disproportionately more ADHD children with WM as their lowest factor score, the patterns of children with ADHD were very similar to children with other disorders (see Figure 5.1).

Figure 5.1

Factor Profiles of Three Children Tested with the SBV



The factor profiles presented in Figure 5.1 represent three children tested in the current study. Child 1 was diagnosed with ADHD, and has an individual profile very similar to that of the ADHD group as a whole. However, using this profile to diagnose ADHD would lead to spurious diagnoses. For example, Child 2 also presented with a similar profile, although this child was from the control group, and not diagnosed. Conversely, Child 3 was diagnosed with ADHD, yet presented with a WM score in the above average range, which was substantially higher than the other factors. Otherwise stated, the utilization of factor scores in ADHD diagnoses would lead to excessive Type I and Type II errors.

Additionally, because deficits in recall, storage, and processing may be difficult to distinguish using the WM factor, the SBV may not be a useful instrument for differential diagnosis, even if memory deficits are evident. For example, even though memory impairments are manifest in both ADHD and reading disabilities (Reid, Hresko, & Swanson, 1996; Roodenrys et al., 2001), various factor profiles may not differentiate between these groups. Still, a direct comparison of these groups may be useful in better understanding the various deficits associated with each disorder.

In sum, the use of the WM factor alone to diagnose ADHD is not warranted from the current research. This study echoes the recommendations of others, that an evaluation for ADHD should include a medical examination, behavioural rating scale, and interviews with the parent, teacher, and child (Barkley, 1998). Along with other diagnostic indicators or measures of behavioural functioning, the SBV may be a valid tool, supplying significant and meaningful information to the diagnostic or assessment procedure.

Issues in Treatment and Education

An increased understanding of the WM deficits associated with ADHD may have important implications for school psychologists and counsellors. The working memory capacity of individuals with ADHD plays a central role in their cognitive, academic, and behavioural functioning (Baddeley, Papagno, & Vallar, 1988; Barkley, 1998; Klingberg, Forssberg, & Westerberg, 2002). Including working memory training in the treatment and education of these children may therefore help ameliorate the impairments associated with ADHD on each of these levels by addressing the underlying features of ADHD.

Klingberg and colleagues (2002) have suggested that working memory training has improved both behavioural and academic functioning in children. This is a significant finding as many of the other treatment methods do not generalize to other areas; for example, behavioural interventions reduce certain behaviours, but typically do not improve academic functioning (Purtie, Hattie, & Carroll, 2002). Other forms of memory training, such as rehearsal training, have not proved as successful (Klingberg, 2002). This may be predicted as rehearsal training would increase the capacity of the subsidiary systems, but have little effect on the central executive. Future research addressing working memory training may prove fruitful in developing improved treatment and educational strategies.

The use of theoretically sound assessment instruments is becoming increasingly important in psychoeducational assessment (Daniel, 1997; Zeidner, 2001). This issue is especially significant in ADHD, as a significant number of these children are being seen in psychological services. This study does provide initial support for the use of the SBV with ADHD children. It is hoped that this research will contribute to the current body assessment research, and help assessors effectively meet the needs of these children.

References

Achenbach, T. M. (1991). *Teacher's Report Form.* Burlington: University of Vermont, Department of Psychiatry.

Achenbach, T. M., & Edelbrock, C. (1983). *Manual for the Child Behavior Checklist and Revised Child Behavior Profile.* Burlington: University of Vermont, Department of Psychiatry.

Ackerman, P. T., Anhalt, J. M., Dykman, R. A., & Holcomb, P. J. (1986). Effortful processing deficits in children with reading and/or attention disorders. *Brain & Cognition, 5,* 22-40.

American Psychiatric Association. (1980). *Diagnostic and statistical manual of mental disorders* (3rd ed.). Washington, DC: American Psychiatric Association.

American Psychiatric Association. (1987). *Diagnostic and statistical manual of mental disorders* (3rd ed. - Revised). Washington, DC: American Psychiatric Association.

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

Anastopolous, A. D., Spisto, M. A., & Maher, M. C. (1994). The WISC-III Freedom from Distractibility factor: Its utility in identifying children with attention deficit hyperactivity disorder. *Psychological Assessment, 6,* 368-371.

Arnold, L. E. (1996). Sex differences in ADHD: Conference summary. *Journal of Abnormal Child Psychology, 24,* 555-569.

Assesmany, A., McIntosh, D. E., Phelps, L., & Rizza, M. G. (2001). Discriminant validity of the WISC-III with children classified as ADHD. *Journal of Psychoeducational Assessment, 19,* 137-147.

August, G. J., & Garfinkel, B. D. (1990). Comorbidity of ADHD and Reading Disability Among Clinic-Referred Children. *Journal of Abnormal Child Psychology, 18,* 29-45.

August, G. J., & Holmes, C. S. (1984). Behavior and academic achievement in hyperactive subgroups and learning-disabled boys. *American Journal of Diseases of Childhood, 138,* 1025-1029.

Baddeley, A. D. (1986). *Working memory.* Oxford, England: Clarendon Press.

Baddeley, A. (1992). Working memory. *Science, 255,* 556-559.

Baddeley, A. (1996a). Exploring the central executive. *Quarterly Journal of Experimental Psychology, 49A,* 5-28.

Baddeley, A. (1996b). The fractionation of working memory. *Proceedings of the National Academy of Sciences, 93,* 13468-13472.

Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Science, 4,* 417-423.

Baddeley, A. D., Cocchini, G., Sala, S. D., Logie, R. H., & Spinnler, H. (1999). Working memory and vigilance: Evidence from normal aging and Alzheimer's disease. *Brain & Cognition, 41,* 87-108.

Baddeley, A. D. & Hitch, G. (1974). Working memory. In G.A. Bower (Ed.), *The psychology of learning and motivation* (Vol. 8, pp. 47–90). San Diego, CA: Academic Press.

Baddeley, A. D., Logie, R. H., & Ellis, N. C. (1988). Characteristics of developmental dyslexia. *Cognition, 29,* 197-228.

Baddeley, A. D., Papagno, C., & Vallar, G. (1988). When long-term learning depends on short-term storage. *Journal of Memory & Language, 27,* 586-595.

Barkley, R. A. (1989). Hyperactive girls and boys: Stimulant drug effects on mother-child interactions. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 30,* 379-390.

Barkley, R. A. (1997a). *Attention-deficit hyperactivity disorder and the nature of self-control.* New York: Guilford Press.

Barkley, R. A. (1997b). Behavioral inhibition, sustained attention, and executive functions: Constructing a unifying theory of ADHD. *Psychological Bulletin, 121,* 65-94.

Barkley, R. A. (1998). *Attention-deficit/hyperactivity disorder: A handbook for diagnosis and treatment* (2nd ed.). New York: Guilford Press.

Barkley, R. A., DuPaul, G. J., & McMurray, M. B. (1990). A comprehensive evaluation of attention deficit disorder with and without hyperactivity. *Journal of Consulting and Clinical Psychology, 58,* 775-789.

Barkley, R. A., Edwards, G., Laneri, M., Fletcher, K., & Metevia, L. (2001). Executive functioning, temporal discounting, and sense of time in adolescents with Attention Deficit Hyperactivity Disorder (ADHD) and Oppositional Defiant Disorder (ODD). *Journal of Abnormal Child Psychology, 29,* 541-556.

Barkley, R. A., Fischer, M., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: An 8-year prospective follow-up study. *Journal of the American Academy of Child and Adolescent Psychiatry, 29,* 546-557.

Barkley, R., & Gordon, M. (2002). Research on comorbidity, adaptive functioning, and cognitive impairments in adults with ADHD: Implications for a clinical practice. In S. Goldstein, & A.T. Ellison, (Eds.), *Clinicians' guide to adult ADHD: Assessment and intervention* (pp. 43-69). San Diego, CA, US: Academic Press.

Barkley, R. A., Grodzinsky, G., & DuPaul, G. J. (1992). Frontal lobe functions in attention deficit disorder with and without hyperactivity: A review and research report. *Journal of Abnormal Child Psychology, 2,* 163-188.

Barnett, R., Maruff, P., Vance, A., Luk, E.S.L., Costin, J., Wood, C., et al. (2001). Abnormal executive function in attention deficit and hyperactivity disorder: The effect of stimulant medication and age on spatial working memory. *Psychological Medicine, 31,* 1107-1115.

Baumgaertel, A., Wolraich, M., & Dietrich, M. (1995). Comparison of Diagnostic Criteria for Attention Deficit Disorders in a German Elementary School Sample. *Journal of the American Academy of Child and Adolescent Psychiatry, 34,* 629-638.

Bayliss, D. M. & Roodenrys, S. (2000). Executive processing and attention deficit hyperactivity disorder: An application of the supervisory attentional system. *Developmental Neuropsychology, 17,* 161-181.

Benezra, E., & Douglas, V. I. (1988). Short-term serial recall in ADDH, normal, and reading-disabled boys. *Journal of Abnormal Child Psychology, 16,* 511-525.

Berlin, L., Bohlin, G., Nyberg, L., & Janols, L. (2004). How well do measures of inhibition and other executive functions discriminate between children with ADHD and controls? *Child Neuropsychology, 10,* 1-13.

Berlin, L., Bohlin, G., & Rydell, A. (2003). Relations between inhibition, executive functioning, and ADHD symptoms: A longitudinal study from age 5 to 8 1/2 years. *Child Neuropsychology, 9,* 255-266.

Biederman, J., Faraone, S., & Milberger, S. (1996). Predictors of persistence and remission of ADHD into adolescence: Results from a four year prospective follow-up study. *Journal of the American Academy of Child and Adolescent Psychiatry, 35,* 343-351.

Biederman, J., Keenan, K., & Faraone, S. V. (1990). Parent-based diagnosis of attention deficit disorder predicts a diagnosis based on teacher report. *Journal of the American Academy of Child & Adolescent Psychiatry, 29,* 698-701.

Binet, A., & Simon, T. (1905). Méthodes nouvelles pour le diagnostic du niveau intellectuel des anormaux. [New methods for diagnosing the intellectual level of abnormals.] *Annèe Psychologique, 11,* 191-336.

Bohline, D. S. (1985). Intellectual and effective characteristics of attention deficit disordered children. *Journal of Learning Disabilities, 18,* 604-608.

Bowers, T. G., Risser, M. G., Suchanec, J. F., & Tinker, D. E. (1992). A developmental index using the Wechsler Intelligence Scale for Children: Implications for the diagnosis and nature of ADHD. *Journal of Learning Disabilities, 25,* 179-185.

Brand, N., Geenen, R., Oudenhoven, M., Lindeborn, B., van der Ree, A., Cohen-Kettenis, P., et al. (2002). functioning in children with Tourette's syndrome with and without comorbid ADHD. *Journal of Pediatric Psychology, 27,* 203-208.

Brown, L. L., & Hammill, D. D. (1983). *Behaviour Rating Profile*. Austin, TX: Pro-Ed.

Cantwell, D. P. (1996). Attention deficit disorder: A review of the past 10 years. *Journal of the American Academy of Child and Adolescent Psychiatry, 35,* 978-987.

Cantwell, D. P., & Baker, L. (1991). Association between attention deficit-hyperactivity disorder and learning disorders. *Journal of Learning Disabilities, 24,* 88-95.

Cantwell, D. P., & Baker, L. (1992). Attention deficit disorder with and without hyperactivity: A review and comparison of matched groups. *Journal of the American Academy of Child & Adolescent Psychiatry, 31,* 432-438.

Carlson, C. L., Lahey, B. B., Frame, C. L., & Walker, J. (1987). Sociometric status of clinic-referred children with attention deficit disorders with and without hyperactivity. *Journal of Abnormal Child Psychology, 15,* 537-547.

Carlson, C. L., Lahey, B. B., & Neeper, R. (1986). Direct assessment of the cognitive correlates of Attention Deficit Disorders with and without hyperactivity. *Journal of Psychopathology and Behavioral Assessment, 8,* 69-86.

Carlson, C. L., Shin, M., & Booth, J. (1999). The case for DSM-IV subtypes in ADHD. *Mental Retardation & Developmental Disabilities Research Reviews, 5,* 199-206.

Caron, C., & Rutter, M. (1991). Comorbidity in child psychopathology: Concepts, issues, and research strategies. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 32,* 1063-1080.

Carroll, J. B. (1993) *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge UK: Cambridge University Press.

Carroll, J. B. (1997). The three-stratum theory of cognitive abilities. In D.P. Flanagan, J.L. Genshaft, & P.L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 122–130). New York: Guilford Press.

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.

Clark, C., Prior, M., & Kinsella, G. (2002). The relationship between executive function abilities, adaptive behaviour, and academic achievement in children with externalising behaviour problems. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 43,* 785-796.

Cohen, M., Becker, M. G., & Campbell, R. (1990). Relationships among four methods of assessment of children with Attention Deficit-Hyperactivity Disorder. *Journal of School Psychology, 28,* 189-202.

Conners C. K. (1989). *Conners' Rating Scales.* North Tonawanda, NY: Multi-Health Systems Inc.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Verbal Learning & Verbal Behaviour, 19,* 450-466.

Daniel, M. H. (1997). Intelligence testing: Status and trends. *American Psychologist, 52,* 1038-1045.

Denney, C. B., & Rapport, M. D. (2000). Cognitive pharmacology of stimulant drugs in AD/HD. In M.V. Solanto, A.F.T. Arnsten, & F.X. Castellanos (Eds.), *Stimulant drugs and ADHD: Basic and clinical neuroscience* (pp. 283-302). New York: Oxford University Press.

Douglas, V. I. (1988). Cognitive deficits in children with attention deficit disorder with hyperactivity. In L.M. Bloomingdale & J.A. Sergeant (Eds.), *Attention deficit disorder: Criteria, cognition, intervention* (pp. 65-82). Oxford: Pergamon Press.

Douglas, V. I., & Benezra, E. (1990). Supraspan verbal memory in attention deficit disorder with hyperactivity, normal, and reading disabled boys. *Journal of Abnormal Child Psychology, 11,* 313-326.

Eiraldi, R. B., Power, T. J., & Nezu, C. M. (1997). Patterns of Comorbidity Associated With Subtypes of Attention-Deficit/Hyperactivity Disorder Among 6- to 12-Year-Old Children. *Journal of the American Academy of Child & Adolescent Psychiatry, 36,* 503-514.

Elliot, S. N., Busse, R. T., & Gresham, F. M. (1993). Behavior rating scales: Issues of use and development. *School Psychology Review, 22,* 313-321.

Evans, A. N. (1998). *Using basic statistics in the social sciences* (3rd Ed.). Scarborough, Ontario: Prentice-Hall Canada Inc.

Evans, J. J., Floyd, R. G., McGrew, K. S., & Leforgee, M. H. (2002). The relations between measures of Cattell-Horn-Carroll (CHC) cognitive abilities and reading achievement during childhood and adolescence. *School Psychology Review, 31,* 246-262.

Faraone, S. V., Biederman, J., Weber, W., & Russell, R. L. (1998). Psychiatric, neuropsychological, and psychosocial features of DSM-IV subtypes of attention-deficit/hyperactivity disorder: Results from a clinically referred sample. *Journal of the American Academy of Child & Adolescent Psychiatry, 37,* 185-193.

Firestone, P., & Martin, J. E. (1979). An analysis of the hyperactive syndrome: A comparison of hyperactive, behaviour problem, asthmatic, and normal children. *Journal of Abnormal Child Psychology, 7,* 261-273.

Fischer, M., Barkley, R. A., Edelbrock, C. S., & Smallish, L. (1990). The adolescent outcome of hyperactive children diagnosed by research criteria: Academic, attentional, and neuropsychological status. *Journal of Consulting & Clinical Psychology, 58,* 580-588.

Flanagan, D. P., McGrew, K. S., & Ortiz, S. O. (2000). *The Wechsler intelligence scales and CHC theory: A contemporary approach to interpretation.* Boston: Allyn & Bacon.

Flanagan, D. P., & Ortiz, S. O. (2001). *Essentials of cross-battery assessment.* New York: John Wiley & Sons.

French, B. F., Zentall, S. S., & Bennett, D. (2001). Short-term memory of children with and without characteristics of attention deficit hyperactivity disorder. *Learning & Individual Differences, 13,* 205-225.

Fuster, J. M. 1989. *The prefrontal cortex: Anatomy, physiology, and neuropsychology of the frontal lobe.* New York: Raven Press.

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational research: an introduction* (7th Ed.). Boston: Allyn Bacon.

Gansler, D. A., Fucetola, R., Krengel, M., Stetson, S., Zimering, R., & Makary, C. (1998). Are there cognitive subtypes in adult attention deficit/hyperactivity disorder? *Journal of Nervous & Mental Disease, 186,* 776-781.

Gathercole, S. E. (1999). Cognitive approaches to the development of short-term memory. *Trends in Cognitive Sciences, 3,* 410-419.

Gathercole, S. E. & Baddeley, A. D. (1993). Phonological working memory: A critical building block for reading development and vocabulary acquisition. *European Journal of Psychology in Education, 8,* 259-272.

Gaub, M., & Carlson, C. L. (1997). Gender differences in ADHD: A meta-analysis and critical review. *Journal of the American Academy of Child & Adolescent Psychiatry, 36,* 1036-1045.

Gay, L. R., & Airasian, P. (2003). *Educational research: Competencies for analysis and applications* (7^{th} Ed.). Upper Saddle River, NJ: Merrill Prentice Hall.

Gold, J. M., Carpenter, C., Randolph, C., Goldberg, T. E., & Weinberger, D. R. (1997). Auditory working memory and Wisconsin Card Sorting Test performance in schizophrenia. *Archives of General Psychiatry, 54,* 159-165.

Goodyear, P., & Hynd, G. W. (1992). Attention-deficit disorder with (ADD/H) and without (ADD/WO) hyperactivity: Behavioral and neuropsychological differentiation. *Journal of Clinical Child Psychology, 21,* 273-305.

Grippo, A., Pelosi, L., Mehta, V., & Blumhardt, L. D. (1996). Working memory in temporal lobe epilepsy: An event-related potential study. *Electroencephalography & Clinical Neurophysiology, 99,* 200-213.

Grodzinsky, G. M., & Diamond, R. (1992). Frontal lobe functioning in boys with attention-deficit hyperactivity disorder. *Developmental Neuropsychology, 8,* 427-445.

Hinshaw, S. P. (1992). Externalizing behavior problems and academic underachievement in childhood and adolescence: Causal relationships and underlying mechanisms. *Psychological Bulletin, 111,* 127-155.

Hinshaw, S. P. (1994). *Attention deficits and hyperactivity in children.* Thousand Oaks, CA: Sage Publications.

Hinshaw, S. P. (2002). Preadolescent girls with attention-deficit/hyperactivity disorder: Background characteristics, comorbidity, cognitive and social functioning, and parenting practices. *Journal of Consulting & Clinical Psychology, 70,* 1086-1098.

Horn, J. L., & Noll, J. (1997). Human cognitive capabilities: Gf-Gc Theory. In D.P. Flanagan, J.L. Genshaft, & P.L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 53–91). New York: Guilford.

Kaplan, B. J., Crawford, S. G., Dewey, D. M., & Fisher, G. C. (2000). The IQs of children with ADHD are normally distributed. *Journal of Learning Disabilities, 33,* 425-432.

Karatekin, C. (2004). A test of the integrity of the components of Baddeley's model of working memory in attention-deficit/hyperactivity disorder (ADHD). *Journal of Child Psychology & Psychiatry, 45,* 912-926.

Karatekin, C., & Asarnow, R.F. (1998). Working memory in childhood-onset schizophrenia and attention-deficit/hyperactivity disorder (ADHD). *Psychiatry Research, 80,* 165-176.

Kaufman, A. S. (1994). *Intelligent testing with the WISC-III.* New York: John Wiley & Sons.

Kimberg, D. Y., & Farah, M. J. (1993). A unified account of cognitive impairments following frontal lobe damage: The role of working memory in complex, organized behaviour. *Journal of Experimental Psychology: General, 122,* 411-428.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of working memory in children with ADHD. *Journal of Clinical & Experimental Neuropsychology, 24,* 781-791.

Klorman, R., Hazel-Fernandez, L. A., Shaywitz, S. E., Fletcher, J. M., Marchione, K. E., Holahan, J. M., et al. (1999). Executive functioning deficits in attention-deficit/hyperactivity disorder are independent of oppositional defiant or reading disorder. *Journal of the American Academy of Child & Adolescent Psychiatry, 38,* 1148-1155.

Knox, H. A. (1913). The differentiation between moronism and ignorance. *New York Medical Journal, 98,* 564–566.

Korkman, M., Kettunen, S., & Autti-Raemoe, I. (2003). Neurocognitive impairment in early adolescence following prenatal alcohol exposure of varying duration. *Child Neuropsychology, 9,* 117-128.

Korkman, M., & Pesonen, A. (1994). A comparison of neuropsychological test profiles of children with addtention deficit hyperactivity disorder and/or learning disorder. *Journal of Learning Disabilities, 27,* 383-392.

Krane, E., & Tannock, R. (2001). WISC-III third factor indexes learning problems but not attention deficit/hyperactivity disorder. *Journal of Attention Disorders, 5,* 69-78.

Kyllonen, P. C., & Christal, R. E. (1990). Reasoning ability is (little more than) working-memory capacity?!. *Intelligence, 14,* 389-433.

Lahey, B. B., Applegate, B., McBurnell, K., Biederman, J., Greenhill, L., Hynd, G. W., et al. (1994). DSM-IV field trials for attention deficit hyperactivity disorder in children and adolescents. *American Journal of Psychiatry, 151,* 1673-1685.

Lahey, B. B., & Carlson, C. L. (1991). Validity of the diagnostic category of attention deficit disorder without hyperactivity. *Journal of Learning Disabilities, 24,* 110-120.

Lahey, B. B., Schaughency, E. A., Strauss, C. C., & Frame, C. L. (1984). Are attention deficit disorders with and without hyperactivity similar or dissimilar disorders? *Journal of the American Academy of Child Psychiatry, 23,* 302-309.

Lengenfelder, J., Chiaravalloti, N. D., Ricker, J. H., & DeLuca, J. (2003). Deciphering components of impaired working memory in multiple sclerosis. *Cognitive & Behavioral Neurology, 16,* 28-39.

Livingston, R. B., Mears, G., Marshall, R., Gray, R., & Haak, R. A. (1996). Psychostimulant effects on neuropsychological, intellectual, and achievement measures for children and adolescents with attention deficit hyperactivity disorder. *Applied Neuropsychology, 3,* 174-177.

Lockwood, K. A., Marcotte, A. C., & Stern, C. (2001). Differentiation of attention-deficit/hyperactivity disorder subtypes: Application of neuropsychological model of attention. *Journal of Clinical & Experimental Neuropsychology, 23,* 317-330.

Logie, R.H., Gilhooly, K. J., & Wynn, V. (1994). Counting on working memory in arithmetic problem solving. *Memory & Cognition, 22,* 395-410.

Lufi, D., Cohen, A., & Parish-Plass, J. (1990). Identifying Attention Deficit Hyperactive Disorder with the WISC-R and the Stroop Color and Word Test. *Psychology in the Schools, 27,* 28-34.

Mahone, E. M., Miller, T. L., Koth, C. W., Mostofsky, S. H., Goldberg, M. C., & Denckla, M. B. (2003). Differences between WISC-R and WISC-III performance scale among children with ADHD. *Psychology in the Schools, 40,* 331-340.

Manning, S. C., & Miller, D. C. (2001). Identifying ADHD subtypes using the parent and teacher rating scales of the Behavior Assessment Scale for children. *Journal of Attention Disorders, 5,* 41-51.

Marshall, R. M., Hynd, G. W., Handwerk, M. J., & Hall, J. (1997). Academic underachievement in ADHD subtypes. *Journal of Learning Disabilities, 30,* 635-642.

Mariani, M. A., & Barkley, R. A. (1997). Neuropsychological and academic functioning in preschool boys with attention deficit hyperactivity disorder. *Developmental Neuropsychology, 13,* 111-129.

Mayes, S. D., & Calhoun, S. L. (2002). The Gordon Diagnostic System and WISC-III Freedom from Distractibility index: Validity in identifying clinic-referred children with and without ADHD. *Psychological Reports, 91,* 575-587.

Mayes, S. D., Calhoun, S. L., & Crowell, E. W. (1998). WISC-III Freedom from Distractibility as a measure of attention in children with and without attention deficit hyperactivity disorder. *Journal of Attention Disorders, 2,* 217-227.

McGee, R., & Share, D. L. (1988). Attention deficit disorder-hyperactivity and academic failure: Which comes first and what should be treated? *Journal of the American Academy of Child and Adolescent Psychiatry, 27,* 318-325.

McGee, R., Williams, S., Moffitt, T., & Anderson, J. (1989). A comparison of 13-year old boys with attention deficit and/or reading disorder on neuropsychological measures. *Journal of Abnormal Child Psychology, 17,* 37-53.

McGee, R., Williams, S., & Silva, P. A. (1984). Behavioral and developmental characteristics of aggressive, hyperactive and aggressive-hyperactive boys. *Journal of the American Academy of Child Psychiatry, 23,* 270-279.

McGrew, K. S., & Flanagan, D. P. (1998). *The intelligence test desk reference (ITDR): Gf-Gc cross-battery assessment.* Boston: Allyn & Bacon.

McGrew, K.S. (1997). Analysis of the major intelligence batteries according to a proposed comprehensive Gf-Gc framework. In D.P. Flanagan, J.L. Genshaft, & P.L. Harrison (Eds.), *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 131–150). New York: Guilford.

McInnes, A., Humphries, T., Hogg-Johnson, S., & Tannock, R. (2003). Listening comprehension and working memory are impaired in attention-deficit hyperactivity disorder irrespective of language impairment. *Journal of Abnormal Child Psychology, 31,* 427-443.

Mealer, C., Morgan, S., & Luscomb, R. (1996). Cognitive functioning of ADHD and non-ADHD boys on the WISC-III and WRAML: An analysis within a memory model. *Journal of Attention Disorders, 1,* 133-145.

Mehta, M. A., Goodyer, I. M., & Sahakian, B. J. (2004). Methylphenidate improves working memory and set-shifting in AD/HD: relationships to baseline memory capacity. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 45,* 293-305.

Messick, S. (1995). Validity of psychological assessment. *American Psychologist, 50,* 741-749.

Milich, R., Balentine, A. C., & Lynam, D. R. (2001). ADHD combined type and ADHD predominantly inattentive type are distinct and unrelated disorders. *Clinical Psychology: Science & Practice, 8,* 463-488.

Moffitt, T. E., & Silva, P. A. (1988). Self-reported delinquency, neuropsychological deficit, and history of attention deficit disorder. *Journal of Abnormal Child Psychology, 16,* 553-569.

Morgan, A. E., Hynd, G. W., Riccio, C. A., & Hall, J. (1996). Validity of DSM-IV ADHD predominantly inattentive and combined types: Relationship to previous DSM diagnoses/subtype differences. *Journal of the American Academy of Child & Adolescent Psychiatry, 35,* 325-333.

Naglieri, J. A., Goldstein, S., Iseman, J. S., & Schwebach, A. (2003). Performance of children with attention deficit hyperactivity disorder and anxiety/depression on the WISC-III and Cognitive Assessment System (CAS). *Journal of Psychoeducational Assessment, 21,* 32-42.

Nieoullon, A. (2002). Dopamine and the regulation of cognition and attention. *Progress in Neurobiology, 67,* 63-84.

Ostrander, R., Weinfurt, K. P., Yarnold, P. R., & August, G. J. (1998). Diagnosing attention deficit disorders with the Behavioral Assessment System for Children and the Child Behavior Checklist: Test and construct validity analyses using optimal discriminant classification trees. *Journal of Consulting & Clinical Psychology, 66,* 660-672.

Power, T. J., Costigan, T. E., Eiraldi, R. B., & Leff, S. S. (2004). Variations in anxiety and depression as a function of ADHD subtypes defined by DSM-IV: Do subtype differences exist or not? *Journal of Abnormal Child Psychology, 32,* 27-37.

Proctor, A., Wilson, B., Sanchez, C., & Wesley, E. (2000). Executive function and verbal working memory in adolescents with closed head injury (CHI). *Brain Injury, 14,* 633-647.

Purdie, N., Hattie, J., & Carroll, A. (2002). A review of the research on interventions for attention deficit hyperactivity disorder: What works best? *Review of Educational Research, 72,* 61-99.

Quay, H. C., & Peterson, D. R. (1983). *Revised Behavior Problem Checklist.* Coral Gables, FL: University of Miami, Department of Psychiatry.

Ramsey, F. L., & Schafer, D. W. (1997). *The statistical sleuth: A course in methods of data analysis*. Belmont, CA: Wadsworth Publishing Company.

Rapport, M. D., Scanlan, S. W., & Denney, C. B. (1999). Attention-deficit/hyperactivity disorder and scholastic achievement: A model of dual developmental pathways. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 40,* 1169-1183.

Rashid, F. L., Morris, M. K., & Morris, R. (2001). Naming and verbal memory skills in adults with attention deficit hyperactivity disorder and reading disability. *Journal of Clinical Psychology, 57,* 829-838.

Reader, M. J., Harris, E. L., Schuerholz, L. J., & Denckla, M. B. (1994). Attention Deficit Hyperactivity Disorder and executive dysfunction. *Developmental Neuropsychology, 10,* 493-512.

Reid, D. K., Hresko, W. P., & Swanson, H. L. (1996). *Cognitive approaches to learning disabilities*. Austin, TX: Pro-Ed.

Reinecke, M. A., Beebe, D. W., & Stein, M. A. (1999). The third factor of the WISC-III: It's (probably) not freedom from distractibility. *Journal of the American Academy of Child & Adolescent Psychiatry, 38,* 322-327.

Reynolds, C. R. (1997). Forward and backward memory span should not be combined for clinical analysis. *Archives of Clinical Neuropsychology, 12,* 29-40.

Reynolds, C. R., & Kamphaus, R. W. (1992). *Behavior Assessment System for Children.* Circle Pines, MN: American Guidance Service.

Robinson, L. M., Sclar, D. A., Skaer, T. L., & Galin, R. S. (1999). National trends in the prevalence of attention-deficit/hyperactivity disorder and the prescribing of methylphenidate among school-age children: 1990-1995. *Clinical Pediatrics, 38,* 209-217.

Rohde, L. A., Biederman, J., Busnello, E. A., Zimmermann, H., Schmitz, M., Martins, S., et al. (1999). ADHD in a school sample of Brazilian adolescents: A study of prevalence, comorbid conditions, and impairments. *Journal of the American Academy of Child & Adolescent Psychiatry, 38,* 716-722.

Roid, G. H. (2003a). *Stanford-Binet Intelligence* Scales, Fifth Edition. Itasca, IL: Riverside Publishing.

Roid, G. H. (2003b). *Stanford-Binet Intelligence Scales, Fifth Edition, interpretive manual*. Itasca, IL: Riverside Publishing.

Roid, G. H. (2003c). *Stanford-Binet Intelligence Scales, Fifth Edition, technical manual*. Itasca, IL: Riverside Publishing.

Roodenrys, S., Koloski, N., & Grainger, J. (2001). Working memory function in attention deficit hyperactivity disordered and reading disabled children. *British Journal of Developmental Psychology, 19,* 325-337.

Rosenthal, R. H., & Allen, T. W. (1980). Intra-task distractibility in hyperkinetic and nonhyperkinetic children. *Journal of Abnormal Child Psychology, 8,* 175-187.

Routh, D. K. (1978). Hyperactivity. In P.R. Magrab (Ed.), *Psychological management of pediatric problems*. Baltimore: University Park Press.

Saklofske, D. H., & Schwean, V. L., & O'Donnell, L. (1996). WIAT performance of children with ADHD. *Canadian Journal of School Psychology, 12,* 55-59.

Saklofske, D. H., Schwean, V. L., Yackulic, R. A., & Quinn, D. (1994). WISC-III and SB:FE performance of children with attention deficit hyperactivity disorder. *Canadian Journal of School Psychology, 10,* 167-171.

Schachar, R., & Logan, G. D. (1990). Impulsivity and inhibitory control in normal development and childhood psychopathology: Development of regulation and control. *Developmental Psychology, 26,* 710–720.

Schwean, V. L., & Saklofske, D. H. (1998). WISC-III assessment of children with Attention Deficit/Hyperactivity Disorder. In A. Prifitera, & D.H. Saklofske (Eds.). *WISC--III clinical use and interpretation: Scientist-practitioner perspectives* (pp. 92-118). San Diego, CA: Academic Press, Inc.

Seidman, L. J., Biederman, J., Faraone, S. V., & Weber, W. (1997). A pilot study of neuropsychological function in girls with ADHD. *Journal of the American Academy of Child & Adolescent Psychiatry, 36,* 366-373.

Shaffer, J. P. (1995). Multiple hypothesis testing. *Annual Review of Psychology, 46,* 561-584.

Shaywitz, B. A., & Shaywitz, S. E. (1991). Comorbidity: A critical issue in attention deficit disorder. *Journal of Child Neurology, 6, Supplemental,* 13-22.

Shue, K. L., & Douglas, V. I. (1992). Attention deficit hyperactivity disorder and the frontal lobe syndrome. *Brain & Cognition, 20,* 104-124.

Snow, J. B., & Sapp, G. L. (2000). WISC-III subtest patterns of ADHD and normal samples. *Psychological Reports, 87,* 759-765.

Stevens, J., Quittner, A. L., Zuckerman, J. B., & Moore, S. (2002). Behavioral inhibition, self-regulation of motivation, and working memory in children with attention deficit hyperactivity disorder. *Developmental Neuropsychology, 21,* 117-140.

Tannock, R. (1998). Attention deficit hyperactivity disorder: Advances in cognitive, neurobiological, and genetic research. *Journal of Child Psychology & Psychiatry & Allied Disciplines, 39,* 65-99.

Thorndike, R. L., Hagen, E. P., & Sattler, J. M. (1987). *The Stanford-Binet Intelligence Scale: Fourth Edition.* Chicago: The Riverside Publishing Company.

Todd, R. D., Sitdhiraksa, N., Reich, W., Ji, T. H., Joyner, C. A., Heath, A. C., et al. (2002). Discrimination of DSM-IV and latent class attention-deficit/hyperactivity disorder subtypes by educational and cognitive performance in a population-based sample of child and adolescent twins. *Journal of the American Academy of Child & Adolescent Psychiatry, 41,* 820-828.

Turner, S. M., DeMers, S. T., Fox, H. R., & Reed, G. M. (2001). APA's guidelines for test user qualifications. *American Psychologist, 56,* 1099-1113.

Vandierendonck, A., Kemps, E., Fastame, M. C., & Szmalec, A. (2004). Working memory components of the Corsi blocks task. *British Journal of Psychology, 95,* 57-79.

Vaughn, M. L., Riccio, C. A., Hynd, G. W., & Hall, J. (1997). Diagnosing ADHD (predominantly inattentive and combined type subtypes): Discriminant validity of the Behavior Assessment System for Children and the Achenbach Parent and Teacher Rating Scales. *Journal of Clinical Child Psychology, 26,* 349-357.

Vecchi, T., & Richardson, J. T. E. (2001). Measures of visuospatial short-term memory: The Knox Cube Imitation Test and the Corsi Blocks Test compared. *Brain & Cognition, 46,* 291-294.

Wechsler, D. (1991). *Wechsler Intelligence Scale for Children – Third Edition, Technical and Interpretive Manual.* San Antonio, TX: The Psychological Corporation.

Wechsler, D. (2003). *Wechsler Intelligence Scale for Children – Fourth Edition, Technical and Interpretive Manual.* San Antonio, TX: The Psychological Corporation.

Weiss, G., & Hechtman, L. (1993). *Hyperactive children grown up.* New York: Guilford Press.

Weyandt, L. L., & Willis, W. G. (1994). Executive functions in school-aged children: Potential efficacy of tasks in discriminating clinical groups. *Developmental Neuropsychology, 19,* 27-38.

Willcutt, E. G., Pennington, B. F., Boada, R., Ogline, J. S., Tunick, R. A., Chhabildas, N. A., et al. (2001). A comparison of the cognitive deficits in reading disability and attention-deficit/hyperactivity disorder. *Journal of Abnormal Psychology, 110,* 157-172.

Wolraich, M. L., Hannah, J. N., Pinnock, T. Y., Baumgaertel, A., & Brown, J. (1996). Comparison of diagnostic criteria for attention-deficit hyperactivity disorder in a county-wide sample. *Journal of the American Academy of Child & Adolescent Psychiatry, 35,* 319-324.

Zeidner, M. (2001). Invited forward and introduction. In J. J. W. Andrews, D. H. Saklofske, & H. L. Janzen (Eds.), *Handbook of psychoeducational assessment* (pp. 1-10). San Diego, CA: Academic Press.

Appendix

Diagnostic criteria for Attention-Deficit/Hyperactivity Disorder (American Psychiatric Association, 1994, pp. 92-93).

A. Either (1) or (2):

(1) six (or more) of the following symptoms of **inattention** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Inattention

(a) Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities

(b) Often has difficulty sustaining attention in tasks or play activities

(c) Often does not seem to listen when spoken to directly

(d) Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behaviour or failure to understand instructions)

(e) Often has difficulty organizing tasks and activities

(f) Often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)

(g) Often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books, or tools)

(h) Is often easily distracted by extraneous stimuli

(i) Is often forgetful in daily activities

(2) six (or more) of the following symptoms of **hyperactivity-impulsivity** have persisted for at least 6 months to a degree that is maladaptive and inconsistent with developmental level:

Hyperactivity

(a) Often fidgets with hands or feet or squirms in seat

(b) Often leaves seat in classroom or in other situations in which remaining seated is expected

(c) Often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)

(d) Often has difficulty playing or engaging in leisure activities quietly

(e) Is often "on the go" or often acts as if "driven by a motor"

(f) Often talks excessively

Impulsivity

(a) Often blurts out answers before questions have been completed

(b) Often has difficulty awaiting turn

(c) Often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairments were present before age 7 years.

C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home).

D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning.

E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder).

Code based on type:

314.00 Attention-Deficit/Hyperactivity Disorder, Combined Type: if both criteria A1 and A2 are met for the past 6 months

314.00 Attention-Deficit/Hyperactivity Disorder, Predominantly Inattentive Type: if Criterion A1 is met but Criterion A2 is not met for the past 6 months

314.01 Attention-Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type: if Criterion A2 is met but Criterion A1 is not met for the past 6 months

Coding note: For individuals (especially adolescents and adults) who currently have symptoms that no longer meet full criteria, "In Partial Remission" should be specified.