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WAIS-III Working Memory and Processing Speed Indexes in Adults with Attention Deficit/Hyperactivity Disorder

by

Karima Lacène

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

Counselling Psychology and School Psychology

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Dr. Bruce M. Shore

Dated: September 10, 2003

DEDICATION

This thesis is dedicated to my wonderful son Troy.

Abstract

This study examined the WAIS-III Working Memory (WM) and Processing Speed (PS) Indexes in adults with attention deficit/hyperactivity disorder (ADHD), as no studies could be found in the literature investigating WAIS-III profiles with this population. The sample consisted of 48 male and female adults between the ages of 16 and 40 years. All participants were diagnosed with ADHD according to specific criteria. WAIS-III WM and PS Index scores from the sample were compared to the WAIS-III standardization sample WM and PS Index scores (N = 2450). The ADHD sample showed significantly lower WM Index scores when compared to the WAIS-III standardization sample. No significant differences were found between Digits Forward and Digits Backward for the sample. WAIS-III profile analysis comparisons indicated that the ADHD sample showed significantly lower mean WM and PS Index scores compared to their VC and PO Index scores. Moreover, these discrepancies were significant when compared to the standardization sample. Present results are consistent with literature supporting lower scores on the WM and PS Indexes in ADHD populations. Results from the present investigation provide information as to the utility of the WM and PS Indexes in differentiating between ADHD adults and non-ADHD adults. Theoretical implications of results for the ADHD sample are discussed within Baddeley's model of working memory, Jensen's model of intelligence and Barkley's theory of frontal lobe disinhibition in ADHD.

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To my mother, who has been, and continues to be a great source of strength and inspiration for me.

Table of Contents

Index of Tables

Chapter One

Introduction

This chapter begins with a review of various theories of intelligence and the measurement of intelligence in adulthood. A description of Attention Deficit Hyperactivity Disorder (ADHD) in adults is provided, followed by the purpose of the study, and research questions.

During the last one hundred years the concept of human intelligence has remained central to the field of psychology (Sattler, 2002). Spearman (1927) developed a model in which intelligence consists of a general (g) factor and a set of specific (s) factors. Others contend that a single 'g' factor does not provide a comprehensive explanation of intelligence. For example, Cattell (1971) and Horn (1968) theorized that intelligence can be divided into two types: crystallized and fluid. Crystallized intelligence involves learning things a given culture considers important, which vary from one culture to another. Fluid intelligence involves thinking and reasoning abilities that are independent of any given culture. Thurstone (1938) proposed a model in which intelligence consists of seven factors: verbal comprehension, word fluency, number, space, associative reasoning, perceptual speech, and general reasoning. Newer theories of intelligence regard intelligence as multidimensional (Gardner, 1983, 1999; Sternberg, 1988). Wechsler (1991) viewed intelligence as a construct with many dimensions. He described it as a global construct that is made up of a combination of specific abilities. These different theoretical accounts have, in turn, spawned different intelligence tests.

From Theory To Practice

The first intelligence test, published in 1905 by Alfred Binet and Theodore Simon at the request of the French government, consisted of a variety of tasks measuring memory of words and numbers, knowledge of basic facts and vocabulary. In 1915, Lewis Terman, a psychologist at Stanford University, translated Simon, and Binet's test into English and adapted it for use with American school children.

Wechsler (1958), a leading researcher in the area of intelligence, created his own series of intelligence tests that measure people's intelligence at three different age ranges (Sattler, 2002). The development of Wechsler's tests was not based on theory but instead on practical and clinical perspectives (Kaufman & Lichtenberger, 1999). The Wechsler Bellevue Intelligence Scale for Adults was created in 1939, then several years later, revised and renamed Wechsler Adult Intelligence Scale (Wechsler, 1955). In 1981, the instrument was again revised (Wechsler Adult Intelligence Scale-Revised) to include gender free language and there were substantial changes to the Comprehension, Similarities and Information scales (Wechsler, 1981). The WAIS-R evolved into the WAIS-III in 1997. Similar to its predecessor, the WAIS-III consists of three separate IQ scores: a Full Scale IQ (FSIQ), a Verbal Scale IQ (VIQ), and a Performance Scale IQ (PIQ). It has excellent reliability and good validity. The revision of the WAIS-R changed the factor structure of the WAIS-III. Wechsler's (1997) factor analysis indicated a four-factor model consisting of the Verbal Comprehension (VC), Perceptual Organization (PO), Working Memory (WM), and Processing Speed (PS) factors. Like the IQ's the indexes have a mean of 100, and a standard deviation of 15.

A large body of research literature has examined the cognitive, and neuropsychological functioning in children diagnosed with attention deficit/hyperactivity disorder (ADHD). These studies have shown that ADHD children obtained significantly lower scores compared to non-ADHD children on neuropsychological tasks measuring sustained attention (Doyle, Biederman, Seidman, Weber & Faraone, 2000; Seidel & Joschko, 1990), working memory and planning ability (Seidman, Biederman, Monuteaux, Doyle & Faraone, 2001; Shue & Douglas, 1992), and the ability to inhibit a motor response (Iaboni, Douglas & Baker, 1995; Oosterlaan, Logan & Sergeant, 1998).

Several investigations have detected lower WISC-III Freedom From Distractibility and Processing Speed Factor scores among groups of children with attention deficit hyperactivity disorder in comparison with control children (Anastopoulos, Spisto, & Maher, 1994; Lufi, Cohen, & Parish-Plass, 1990; Reinecke, Beebe & Stein, 1999; Saklofske, Schwean, Yackulic & Quinn, 1994; Wechsler, 1991).

A recent study examined the construct validity, and diagnostic utility of the WISC-III FFD factor in a sample of 40 children identified as having ADHD on the basis of parent and teacher reporting (Anastopoulos et al., 1994). The results suggested that for the group as a whole, the FFD factor index score was significantly lower than either the Verbal Comprehension (VC) or Perceptual Organization (PO) factor index scores. Reinecke et al. (1999) examined the WISC-III FD factor in a group of 200 children with ADHD. Results indicated the ADHD children's mean score on the FD factor was significantly lower than the other three factor scores.

Saklofske et al. (1994) administered the WISC-III to a group of children with ADHD (N=45). Results indicated that the PS factor was the lowest factor score for these children, followed by the FD factor. A research study by Wechsler (1991) involved the administration of the WISC-III to 69 children with ADHD. Results indicated that the children with ADHD had lower than normal PS index scores (mean=92.0, standard deviation=14.8).

To date, there have been few studies that have investigated the relationship between adults with Attention Deficit Hyperactivity Disorder, working memory and processing speed functioning. Evidence from the few controlled studies available suggests that adults with ADHD may have similar profiles on intelligence measures (Biederman, Faraone, Spencer, Wilens & Norman, 1993; Jenkins, Cohen, Malloy, Salloway & Johnson, 1998; Klee, Garfinkel & Beauchesne, 1986; Murphy, Barkley & Bush, 2001; Riordan, Flashman, Saykin, Frutiger & Carroll, 1999; Wechsler, 1997). It has been suggested that some IQ subtests tap into functions impaired in ADHD individuals, such as concentration, sequencing, memory, and speed of information processing (Biederman et al., 1993; Murphy et al., 2001). Statistical comparison of an individual's performance on those subtests relevant to ADHD versus a baseline factor of subtests considered to be independent of ADHD can provide an index of impairment of ADHD symptoms. Although this is not enough to make a diagnosis, it may be useful as one element of the total diagnostic picture. While a number of neuropsychological assessment techniques have been shown to be useful in the assessment of various aspects of attention, the literature contains little information on the use of the WAIS-III in this regard.

The present research study focused on examining the WAIS-III Working Memory (WM) and Processing Speed (PS) Index scores in adults diagnosed with Attention Deficit/Hyperactivity Disorder (ADHD).

ADHD In Adulthood

Within the last decade there has been a change in the premise that Attention Deficit Hyperactivity Disorder (ADHD) is primarily a childhood disorder that ends in adolescence (Barkley, 2002; Barkley, Fischer, Smallish & Fletcher, 2002; Jaffe, 1995; Weiss, Hechtman & Weiss, 1999). The Diagnostic and Statistical Manual of Mental Disorders - Fourth Edition (DSM-IV) (APA, 1994) recognizes that ADHD continues into adulthood but requires that some hyperactive-impulsive or inattentive symptoms that cause impairment must have been present before age 7 years before an accurate diagnosis could be made. The essential feature of ADHD is a persistent pattern of inattention and hyperactivity-impulsivity that occurs with more frequency and severity than is usually observed in individuals at a similar level of development.

Along with significant impairments in attention, concentration, hyperactivity and impulsivity, individuals with ADHD are at a greater risk for low academic achievement, retention in grade, school suspensions and expulsions, poor peer and family relations, anxiety and depression, aggression, conduct problems, and delinquency (Barkley, 2002; Biederman et al., 1993; Fischer, Barkley, Smallish & Fletcher, 2002). Empirical findings suggest that as children with ADHD grow older, they are at an increased risk for early substance experimentation and abuse, driving accidents, and speeding violations, as well as difficulties in adult social relationships, marriage and employment (Barkley, Murphy, DuPaul & Bush, 2002; Murphy, Barkley & Bush, 2002).

Although the notion that ADHD in adults has been accepted as a valid entity, the empirical research on diagnosing adults with ADHD is extremely limited, as the majority of research continues to focus on children with this disorder (Barkley, 2002; Barkley & Grodzinsky, 1994).

Purpose of the Study

The purpose of the present study is to examine whether the WAIS-III Working Memory Index score (comprised of the Arithmetic, Digit Span, and Letter-Number Sequencing), and the Processing Speed Index score (comprised of the Digit Symbol-Coding, and Symbol Search) distinguishes between adults diagnosed with Attention Deficit Hyperactivity Disorder and the WAIS-III standardization sample. In addition, the present research will attempt to clarify whether individuals with ADHD have lower Working Memory and Processing Speed Index scores in comparison to their Verbal Comprehension and Perceptual Organization Index scores, as no studies could be found in the literature that have addressed this question.

Statement of the Research Problem

The purpose of this research will be to examine the utility of the Working Memory (WM) Index and Processing Speed (PS) Index in distinguishing between adults with ADHD and the WAIS-III standardization sample. Specifically, the questions to be answered in this study are:

1. Does the mean WAIS-III Working Memory Index score differ significantly from the mean Verbal Comprehension Index score for the ADHD sample?
2. Does the mean WAIS-III Working Memory Index score differ significantly from the mean Perceptual Organization Index score for the ADHD sample?

3. Does the mean WAIS-III Working Memory Index score differ significantly from the mean Processing Speed Index score for the ADHD sample?

4. Does the mean WAIS-III Processing Speed Index score differ significantly from the mean Verbal Comprehension Index score for the ADHD sample?

5. Does the mean WAIS-III Processing Speed Index score differ significantly from the mean Perceptual Organization Index score for the ADHD sample?

6. Does the mean WAIS-III Working Memory Index score for the ADHD sample differ significantly from the mean Working Memory Index score of the WAIS-III standardization sample?

7. Does the mean WAIS-III Processing Speed Index score for the ADHD sample differ significantly from the mean Processing Speed Index score of the WAIS-III standardization sample?

8. What percentage of the ADHD sample shows significant WMI<VCI, and WMI<POI factor differences?

9. What percentage of the ADHD sample shows significant PSI<VCI, and PSI<POI factor differences?

10. How do those percentages from the ADHD sample showing significant WMI<VCI and WMI<POI compare with the estimated base rates or the frequency of such differences occurring in the standardization sample?

11. How do those percentages from the ADHD sample showing significant PSI<VCI, and PSI<POI factor differences, compare with the estimated base rates or the frequency of such differences occurring in the standardization sample?

12. Does the mean difference between the Digits Forward and Digits Backward components of the WAIS-III Digit Span subtest from the ADHD sample differ significantly from those scores of the standardization sample?

13. How do the percentages of differences between Digits Forward and Digits Backward from the ADHD sample compare with the frequency of such differences occurring in the standardization sample?

It is hoped that this study will assist with improving the diagnostic process and will provide more information as to the usefulness of the WM Index and PS Index in distinguishing between ADHD adults and non ADHD adults. Findings from this study may help to increase our understanding of the cognitive capacities of ADHD adults.

Definition of Terms

WAIS-III.

The Wechsler Adult Intelligence Scale-Third Edition (WAIS-III) was published in 1997 and designed for adults aged 16 to 89 years. The WAIS-III has three IQ scores: a FSIQ, a VIQ, and a PIQ score. The FSIQ score is the overall summary score that estimates an individual's general level of intellectual functioning. It is the aggregate score of the VIQ and PIQ scores and is usually considered to be the score that is most representative of 'g' or global intellectual functioning. Motivation, interests, cultural opportunities, natural endowment, neurological integrity, attention span, and the ability to process verbal and visual information may affect the Full Scale IQ. The VIQ score of the WAIS-III is thought to be a measure of acquired knowledge, verbal reasoning, and attention to verbal materials. The PIQ score is described as a measure of fluid reasoning, spatial processing, attentiveness to visual detail, and visual-motor integration. With the exception of some content changes to the scales at the item level, the VIQ and PIQ scores are relatively unchanged from the VIQ and PIQ scores in the WAIS-R, the previous version of the test. One difference is that the PIQ score is less speed-dependent with the introduction of Matrix Reasoning. The WAIS-III contains 14 subtests, with seven subtests in the Verbal Scale and seven subtests in the Performance Scale. The Verbal scale consists of the following subtests: Vocabulary, Similarities, Information, Comprehension, Arithmetic, Digit Span, and Letter-Number Sequencing. The Performance scale consists of the following subtests: Block Design, Matrix Reasoning, Picture Completion, Object Assembly, Picture Arrangement, Digit Symbol-Coding, and Symbol Search. It should be noted that Object Assembly is a supplementary subtest. The standardization sample consisted of 2,450 adults in the United States and included an equal number of males and females in each age group. It has excellent reliability and good validity. Wechsler (1997) suggests that a four-factor model best fits the WAIS-III: the Verbal Comprehension (VC) factor, the Perceptual Organization (PO) factor, the Working Memory (WM) factor, and the Processing Speed (PS) factor.

Verbal Comprehension Index (VCI)

This index consists of the Vocabulary, Similarities and Information subtest. It is considered to be a measure of verbal acquired knowledge and verbal reasoning.

Vocabulary subtest (V): A WAIS-III subtest measuring word knowledge, verbal fluency and long-term memory. The examinee is required to orally define a series of orally and visually presented words.

Similarities subtest (S): A WAIS-III subtest measuring the ability to see verbal relationships, and to use concept formation with categories. The examinee is orally presented with a series of pairs of words for which the examinee explains the similarity of the common objects or concepts they represent.

Information subtest (I): A WAIS-III subtest measuring general factual knowledge reflecting education and background experience. It involves a series of orally presented questions that tap the examinee's knowledge of common events, objects, places and people.

Perceptual Organization Index (POI)

This index consists of the Picture Completion, Block Design, and Matrix Reasoning subtests. It is considered to be a measure of nonverbal, fluid reasoning, attentiveness to visual detail and visual-motor integration. Quick responding is less important on this scale.

Picture Completion (PC): A WAIS-III subtest measuring alertness to visual details in everyday objects. This subtest is described as a set of colour pictures of common objects and settings each of which is missing an important part that the examinee must identify.

Block Design (BD): A WAIS-III subtest measuring spatial visualization, nonverbal reasoning ability and working from the whole to the parts. This subtest is described as a set of modeled or printed two-dimensional geometric patterns that the examinee replicates using two-colour cubes.

Matrix Reasoning (MR): A new WAIS-III subtest measuring visual information processing and abstract reasoning skills. This subtest is described as a series of incomplete patterns that the examinee completes by pointing to or saying the number of the correct response from five possible choices.

Working Memory Index (WMI)

The Working Memory Index is a new WAIS-III factor consisting of the arithmetic, digit span and letter-number sequencing subtests. It includes a range of tasks that require the examinee to attend to information, to hold briefly and process that information in memory, and then to formulate a response.

Arithmetic subtest (AR): A WAIS-III subtest that measures numerical computation and reasoning. It also measures auditory attention and concentration, and short-term memory. This subtest is described as a series of arithmetic problems that the examinee solves mentally and responds to orally.

Digit Span subtest (DS): A WAIS-III subtest that measures short-term memory for auditory material. It also measures attention and concentration. This subtest is described as a series of orally presented number sequences that the examinee repeats verbatim for Digits Forward and in reverse for Digits Backward.

Letter-Number Sequencing subtest (LNS): A new WAIS-III supplementary subtest measuring auditory working memory. This subtest requires the examinee to order sequentially a series of numbers and letters orally presented in a specified random order. The examinee must first remember the numbers and letters and then reorganize the numbers into ascending order and the letters into alphabetical order.

Processing Speed Index (PSI)

The Processing Speed Index is a WAIS-III factor that is described as a measure of the individual's ability to process visual information quickly.

Digit Symbol-Coding subtest (CD): A WAIS-III subtest that measures visual-motor accuracy and speed under time pressure. It also measures short-term memory for visual details and discriminations, and attention to visual material. This subtest is described as a series of numbers, each of which is paired with its own corresponding hieroglyphic-like symbol. Using a key, the examinee writes the symbol corresponding to its number.

Symbol Search subtest (SS): A WAIS-III supplementary subtest that measures visual-perceptual scanning and visual discrimination ability. This subtest is described as a series of paired groups, each pair consisting of a target group and a search group. The examinee indicates by marking the appropriate box whether either target symbol appears in the search group.

Attention Deficit Hyperactivity Disorder (ADHD)

The present study uses the DSM-IV definition of ADHD as part of the diagnostic process. ADHD is defined as a persistent pattern of inattention and/or hyperactivity-impulsivity that occurs with more frequency and severity than is usually observed in individuals at a similar level of development (APA, 1994). For example, the average 4-year old can typically sit with an adult looking through picture books. In contrast, young children with ADHD move excessively and are difficult to contain. The DSM-IV presents three different types of ADHD: 1) a combined type (at least six symptoms of inattention and six or more symptoms of hyperactivity-impulsivity), 2) a predominantly inattentive type (six or more symptoms of inattention), and 3) a predominantly hyperactive-impulsive type (six or more symptoms of hyperactivity-impulsivity). The DSM-IV suggests that the person's symptoms must be maladaptive and inconsistent with his or her developmental level. Symptoms must have persisted for at least 6 months and must be present prior to age 7. The adult must show impaired functioning in at least two settings (e.g., home, school, work).

For the purposes of this investigation ADHD was operationalized in the following manner: (a) The participants were diagnosed with ADHD according to clinical interviews, DSM-IV diagnostic criteria including age of onset, behavioural indices, work-related problems, job-changes, and past school history, (b) A T-Score above 70 on the Total Score scale of the Attention-Deficit Scales for Adults (ADSA), (c) Achievement test results within one standard deviation below the mean, (d) Conditions that can produce ADHD-like symptoms were ruled out (e.g. Depression, anxiety disorders, personality disorders, substance abuse, and schizophrenia), in the clinical interview and with the administration of the Personality Assessment Inventory (e) Each subject had a WAIS-III Full Scale IQ (FSIQ) score greater than 90, had normal hearing and vision, and was not taking any medication. (Please note that a detailed discussion of the specific research criteria for diagnosing ADHD is provided in Chapter Three).

Summary

In the preceding pages, the reader was introduced to the research questions, and was provided with relevant study definitions. The next chapter begins with a review of the WAIS-III as a measure of intelligence in adulthood.

Chapter Two

Literature Review

The WAIS-III as a Measure of Intelligence

Current researchers in the area of intelligence testing, indicate the WAIS-III is a good measure of global intellectual functioning or 'g' (Kaufman & Lichtenberger, 1999; Sattler, 2002; Wechsler, 1997). Sattler (2002) suggests that approximately 50 percent of the variance of the FSIQ is attributed to 'g'. Although the WAIS-III FSIQ can be affected by motivation, environmental factors, processing abilities and genetics, it is still considered to be the score that is the most representative of global intellectual functioning (Sattler, 2002).

The Verbal IQ score of the WAIS-III measures verbal reasoning and attention, as well as acquired knowledge. The Performance IQ score of the WAIS-III provides information regarding spatial processing, attention to visual detail, fluid reasoning, and eye-hand coordination (Sattler, 2002).

The measurement of 'g' is accomplished by reporting the loadings on the unrotated first factor in principal components analysis. In other words the 'g' loadings represent the intercorrelations among the WAIS-III subtests. Kaufman and Lichtenberger (1999) suggest that factor loadings of .70 or higher are deemed 'good', 'g' loadings of .50 to .69 are considered 'fair', and loadings of .50 or below are considered 'poor'. According to Kaufman and Lichtenberger, the Verbal Scale of the WAIS-III shows very strong loadings on 'g'. Moreover, of the Performance subtests, Block Design and Matrix Reasoning also tend to hold relatively strong 'g' loadings.

Digit Span, Digit Symbol-Coding, Object Assembly and Picture Completion are among the weakest measures of 'g' on the WAIS-III (Sattler & Ryan, 1998). However, they are still considered fair 'g' loadings.

Although the 'g' loadings illustrate how the subtests are grouped mathematically, Kaufman & Lichtenberger (1999) remind us that they do not represent a comprehensive theory of human intellect. Since the WAIS-III is not based on an explicit theory of intelligence, we must refer to current research to provide a conceptual framework for and to help us organize our thoughts regarding intelligence.

Theoretical Framework of Intelligence

Contemporary research in the areas of cognitive psychology and neuroscience frequently employ the information-processing framework to describe human intelligence (Sattler, 2002). It has been suggested that this framework can be applied to the WAIS-III because it focuses on the mental processing and representation of information in the brain (Lezak, 1995, 2002). Moreover, it may help to explain the cognitive difficulties that are occurring in adults with ADHD. First, a review of the information-processing framework will be provided. Then, within this framework, an overview of a three-stage memory model that is deemed to be a suitable framework for conceptualizing and understanding memory difficulties in adults will be provided. This is followed by a review of the literature on the speed of processing and intelligence.

Information-Processing Framework

The information-processing approach categorizes mental processes by the different operations performed during various tasks. Human cognition is conceived of as occurring in a series of discrete stages with information received being operated on at one stage and then passed on as input to the next stage for further processing (Sattler, 2002). Lezak (1995, 2002) suggests that there are four major classes of cognitive functions. These include input, storage, processing (e.g., sorting, combining, relating data in various ways), and output.

The input stage can be likened to receptive functions that involve the ability to select, acquire, classify, and integrate information. Information storage and retrieval refer to memory and learning processes. The processing stage involves the mental organization and reorganization of information. In other words this is the 'thinking' stage. The fourth stage, output, involves information that is communicated or acted upon.

In summary, the information-processing framework provides a way to organize neuro-scientific data regarding cognitive capacities. One of the most important components to cognitive functioning is the capacity for memory and learning. Next, within the information-processing framework, a review of Lezak's (1995, 2002) model of memory stages will be provided.

A Model of Memory Stages

Lezak (1995, 2002) developed a three-stage model that provides a framework for understanding memory. This comprehensive model is based on current neuropsychological, cognitive, memory and psychometric research literature. Lezak describes memory as having three stages with various subtstages. These three primary stages of memory include the following: (a) registration, (b) short-term storage, and (c) long-term storage.

Stage One: Registration Memory.

Registration, or sensory memory, holds incoming information for about 1 to 2 seconds in sensory store. It is a selecting and recording process whereby perceptions enter the memory system. The term iconic memory refers to visual sensory memory and it can last up to 200 milliseconds. Echoic memory is the auditory equivalent and can last up to 2000 milliseconds. The information being registered is either processed as short-term memory or it quickly decays.

Stage Two: Short-Term Memory.

Short-term memory involves three different substages. Immediate memory, the first stage of short-term memory (STM) storage, temporarily holds information taken from the registration process. Immediate memory can hold about seven bits of information at a time. The typical duration is from about 30 seconds up to several minutes (Lezak, 1995, 2002).

The second stage of short-term memory is the working memory system (Baddeley, 1999, 2002) defined as a person's information processing capacity. It is capable of manipulating information and transferring it to the more permanent long-term store. The working memory system comprises a central executive and two subsystems. The first system consists of the phonological loop that processes verbal material. The second subsystem consists of the visuospatial sketchpad where visual and spatial information is processed. This stage of short-term memory is particularly relevant when discussing the cognitive functioning of adults with ADHD. Consequently, Baddeley's model will be later reviewed in more detail.

The third stage of short-term memory is primary memory. This component of short-term storage is highly attention dependent and the information dissipates rapidly with distraction.

Stage Three-Long-Term Memory.

The final stage of the three-stage memory system is long-term memory. Long-term memory (LTM) or secondary memory refers to more durable encoding and storage systems (Lezak, 1995, 2002). With rehearsal and repetition, a memory trace may be maintained for hours. Two types of long-term memory include episodic memory, the capacity to recollect experience, and semantic memory or stored knowledge of the world.

To summarize, Lezak's (1995, 2002) comprehensive model of the three main stages of memory includes sensory, short-term and long-term memory. Since the issues discussed in this dissertation are mainly related to the working memory substage of the short-term memory system, this substage will be examined in more detail. The next section provides the reader with an overview of working memory.

Baddeley's Model of Working Memory.

Working memory can be defined as a person's information-processing capacity. This notion originated in 1974 when Baddeley and Hitch described a model system, working memory, that was developed to account for a variety of data concerning human short-term memory. This model advances beyond the traditional view of short-term memory as a store because it emphasizes mental processes as well. The model was based on the notion that short-term memory could be active, and thus contribute to the processing of information to be remembered.

The working memory model describes a system of interacting subsystems, one specialized for verbal information and one for nonverbal information, with a central executive. The two subsystems are the phonological loop where verbal material is stored and processed and the visuospatial sketchpad where visual and spatial material is stored and processed (Baddeley, 1999, 2002). Baddeley and Hitch hypothesized that these two "slave systems", the phonological loop and visuospatial sketchpad, enabled the central executive to offload some of its own capacity for performing more complex information processing tasks. An analogy can be drawn with a senior manager who, if he or she is to prevent becoming overloaded, must delegate certain aspects of the job to subordinates leaving him or herself free to give full attention to novel problems and situations.

The Phonological Loop System.

The phonological loop component of Baddeley's model is conceptualized as responsible for storing and processing verbal information. It involves some process of rehearsal, usually via subvocal speech, to maintain the memory trace. However, the phonological loop can only hold speech-based information for about 2 seconds unless it is revived through subvocal rehearsal. The phonological loop consists of a store and a rehearsal process, with the store being affected by the acoustic similarity effect and the rehearsal factor being affected by word length and phonological interferences (Baddeley, 1999, 2002). The acoustic similarity effect occurs when an individual listens to sequences of items that have similar speech sounds (e.g., F or S and B or G). Baddeley (1966) determined that similar speech sounds are hard to remember in the appropriate order. For example mad can cap man map is harder to remember than pen day cow dog red.

A source of information about the articulatory loop came from studies on the word length on memory span (Baddeley, Thomson, & Buchanan, 1975). The results suggested that the span of working memory is related to the length of the words or digits to be memorized. It was assumed that the reason long words were harder to remember was because the subjects said the words to themselves under their breath. Since it takes more time to say longer words, the memory trace of earlier words will fade away more quickly.

Working memory processes are greatly influenced by phonological interferences. For example, if you interfere with rehearsal by having a person repeat the word 'the', retention of the target materials will be suppressed. When they are suppressing articulation, subjects appear to be unable to transfer visually presented material to the phonological short-term store (Baddeley, 1999, 2002).

Baddeley (1999, 2002) argued that the phonological loop evolved for the important task of language acquisition. He suggests that adults who have a disruption to this system are likely to have difficulty learning new languages. As well, children who have problems with phonological coding may encounter problems in reading and spelling.

The Visuospatial Sketchpad.

The visuospatial sketchpad is assumed to be a system for maintaining and manipulating visual images. The notion of the visuospatial sketchpad has its origins in the research of Roger Shepard of Stanford University in California. One of his early experiments involved pictures of shapes that if they were made out of paper, could be folded to create a solid, with the shaded area being the base. The subjects were required to imagine folding the shapes and to decide whether the arrows will meet head on. The results suggested that the time it took for subjects to arrive at their solution was directly related to the number of folds that would have been needed had they really done the folding (Shepard & Metzler, 1971).

In another study, Baddeley, Grant, Wight and Thomson (1973) found that subjects had great difficulty tracking a light spot while visualizing letters. Subjects had to try to keep a pointer in contact with the spot of light that moved along a circular path. Their success was measured by how much of the time they were on target. Baddeley concluded that an immediate memory task relying heavily on imagery was disrupted by tracking because of the demands on the visuospatial sketchpad. Moreover, subjects did not have difficulty tracking a light spot while completing an immediate memory task that relied heavily on verbal coding.

The Central Executive.

The central executive has been suggested to house the control of attention and action, to regulate information flow through the working memory system, and to operate the retrieval of information from long-term memory (Baddeley 1999, 2002). It has been harder to investigate the central executive because it is considerably more complex than the two slave systems. One approach to understanding the central executive has been to define working memory in terms of the need to combine memory and processing. One way of measuring its capacity is through a working memory span task, which correlates with comprehension capacity. Research findings from a study on working memory and comprehension indicated that children with a low working memory span tend to have low listening and reading comprehension skills (Oakhill, Yuill, & Parking, 1988). In the study children were read a story containing what appeared to be an inconsistent response by an adult to a child but where the inconsistency was explained later in the text. Low working memory span children were likely to miss the link between the two pieces of information in the passage. The researchers interpreted the results in terms of a central executive deficit rather than a specific language problem.

The model has evolved over the last 25 years, and it has increasing importance for understanding normal memory, memory loss, and other cognitive operations. Working memory involvement has been implicated in everyday tasks including mental arithmetic and logical reasoning (Baddeley, 2002). Working memory has often been assessed in neuropsychological research with the following tasks: retention and oral repetition of digit spans (especially in reverse order); mental arithmetic; holding sequences of information that must be held in memory; and holding sequences of information in memory to properly execute a task (Becker, 1994).

Neurological Evidence

Some evidence in support of the specific organization of working memory comes from the use of neuroimaging techniques such as the Positron Emission Tomography (PET) scan and functional Magnetic Resonance Imaging (fMRI). Several researchers have found that ventral regions in the frontal lobes of the brain act as more passive storage-rehearsal units, whereas dorsal frontal regions involve the manipulation and monitoring of information (D'Esposito & Postle, 2002; D'Esposito, Postle, Ballard, & Lease, 1999; Owen, 1997). In addition, other studies have concluded that verbal storage is located in the left ventral region and visuospatial storage is located in the right ventral region (Smith & Jonides, 1997; 1999).

Working Memory and Speed of Processing

Working memory (WM) is believed to have a limited capacity and information is usually lost from working memory if it is not rehearsed or if there is interference (Baddeley, 1999, 2002). In order to compensate, information must either be held in working memory or stored in long-term memory. Information storage, however, requires time and capacity, so the amount of information that can be simultaneously stored and processed is compromised. Working memory capacity is related to speed of processing (see Lehrl & Fischer, 1988), because the faster the information flows, the greater the capacity of working memory. Fast processing is particularly advantageous on tasks requiring complex information or information that reduces the capacity of working memory (e.g., Larson & Saccuzzo, 1989; Larson, Merritt & Williams, 1988).

Speed of Processing and Intelligence

Jensen's Model of Intelligence

The notion that there is a relationship between speed of cognitive processing and intelligence has been around since the beginning of the twentieth century (Eysenck, 1987). Jensen (1982 a, b, 1993, 1997, 1998) developed a model of intelligence that hypothesizes that processing speed is directly related to intelligence. According to this model, the brain is an information processing system with a limited capacity. As such, the faster information is processed, the more operations can be done within a certain amount of time without overloading the system. Moreover, this model suggests that speed is advantageous to the system because it allows processes to be performed on the information before it disintegrates.

Contemporary research is focused on studying the speed of information processing through reaction time experiments (Miller & Vernon, 1992; Vernon, 1998). Researchers hypothesize that speed of information processing, operationalized by reaction time, is one component of intelligence.

Reaction Time.

Reaction time can be measured by using a computerized procedure (Jensen, 1979; 1982 a, b, 1998), in which a computer screen displays 1, 2, 4, 6 or 8 windows, with a small bar at the bottom of the screen. First, the subject touches the bar, watches the screen until a window lights up, and touches the lit window as quickly as possible. Next, the screen goes blank and a new trial begins.

This task measures decision time and movement time. Decision time is the amount of time from the onset of the stimulus (e.g., window lighting up) to initiating a response; it is measured as how long the subject keeps a finger on the bar after one of the windows has lit up. Movement time is the amount of time required for the subject to respond, and it is measured as the length of time it takes to lift a finger from the bar and touch the window. Other measures include: the number of errors, the total amount of time for each trial, as well as the slope of decision time over set size.

The general hypothesis is that as the number of alternatives increases, reaction time will increase. Hick's Law (1952), according to Jensen (1987), states that reaction time increases as a linear function of the logarithm of n. Specifically, reaction time is a linear function of the log (base 2) of the number of choices (the log of number of choices equaling the number of windows—1,2,4,6 or 8). It is hypothesized that less intelligent individuals have longer reaction times than more intelligent individuals as the amount of information (the number of windows) increases.

Overall, the relationship between processing speed and intelligence has been supported in several experiments (see Vernon, 1990), and supported by meta-analyses (e.g., Kranzler & Jensen, 1989). The main findings suggest that 1) reaction time correlates with intelligence (around –0.2 to –0.3), 2) the correlation of reaction time with IQ increases as the number of choices (e.g., windows) increase (e.g., information complexity); and 3) the angle of the Hick Slope (b) correlates negatively with IQ.

One of the most comprehensive studies examining the relationship between reaction time and IQ involved 100 university students, who were given five measures of cognitive processing, as well as the Wechsler Intelligence Scale and Raven Progressive Matrices Scale as IQ measures (Vernon, 1983). The measures of speed included: inspection time; the Sternberg short-term memory scanning task; the Posner long-term memory information retrieval task; an efficiency of short-term memory storing and processing task (a combination of the Sternberg and Posner tasks); and reaction time. When the matrix of correlations between speed of processing tests was factor analyzed, results demonstrated a strong first main factor: speed of processing was the only variable correlating significantly with IQ.

In another study, Rattan, Dean and Fischer (1986) examined the role of response time with a more complex measure, the Halsteid Reitan Neuropsychological Test Battery (HRNB). Response time measures were collected on the Category test—a complex test used as an index of executive functioning (e.g., problem solving and conceptual abilities), visual-spatial skills, concentration, attention and memory. These measures were factor analyzed for a sample of mentally average adults, and results indicated that response time loaded heavily on the first factor and accounted for greater variability (21.2%) than the other neuropsychological variables. Since no other variables significantly loaded on the first factor, the researchers suggested that speed of information processing is an important part of cognition.

In the preceding pages, the reader was provided with a review of two models (e.g. Baddeley's model of working memory and Jensen's model of intelligence) within the information-processing framework. The information-processing framework can be applied to the WAIS-III because it focuses on cognitive processes and how information is represented in the brain. Specifically, Baddeley's (2002) theory of working memory will be applied to the WAIS-III Working Memory factor, and Processing Speed factor. In addition, Jensen's (1982, 1998) model of intelligence will be used in the interpretation of the WAIS-III Processing Speed factor. The next section reviews these factors in more detail.

WAIS-III: WM and PS Indexes

What does the WM Index measure?

The Wechsler Adult Intelligence Scale - Third Edition (WAIS-III) has included a Working Memory Index as part of the four-factor model. This third factor is comprised of Digit Span, Arithmetic, and a new subtest, Letter-Number Sequencing. The Working Memory Index measures number ability, sequential processing, planning ability, short-term memory, and executive processing (Kaufman & Lichtenberger, 1999). Levels of attention, concentration and anxiety also affect this factor (Kaufman & Lichtenberger; Sattler, 2002).

WMI Construct Validity

According to the WAIS-III technical manual (1997) the intercorrelations between Arithmetic, Digit Span, and Letter Number Sequencing of the Working Memory Index range from .52 to .57. The inclusion of the new Letter-Number Sequencing subtest made the factor loading stronger, and provides evidence of convergent validity. Moreover, the addition of this subtest made the four-factor model stronger.

As well, the third factor has a much higher correlation with the Wechsler Memory Scale (WMS-R) index (.66) than do the other factors on the WAIS-III. However, the high correlation coefficient is partly due to the fact that these two indexes share a common subtest (Digit Span). The WAIS-III WMI correlations with other measures range from -.37 (Trails A) to -.65 (Trails B). This finding provides additional evidence of the construct validity of the WMI factor because Trails B requires the use of working memory, and is a much more complex task than Trails A. Moreover, the Working Memory indexes of both the WAIS-III and the WMS-III are highly correlated (r =.82). The correlation between the WMI and the Wisconsin Card Sorting Test is .48. The Wisconsin Card Sorting Test is a measure of executive functioning that assesses problem-solving strategies, cognitive flexibility, the ability to use corrective feedback, and working memory.

The tasks on the Working Memory Index were developed to test a person's working memory ability by either increasing the amount of information to be stored, or by asking the examinee to perform two tasks simultaneously. The WMI factor emphasizes the verbal (phonological loop) component of Baddeley's model of working memory. In other words the Working Memory Factor measures working memory with tasks in which the material is presented auditorily.

Arithmetic.

The Arithmetic subtest consists of 20 mathematical problems presented orally to the examinee. This subtest requires the examinee to follow verbal directions, concentrate on selected parts of questions, hold information in working memory, mentally perform the required operations, and remember partial results until the problem is solved (Newmark, 1996). Although the examinee may need knowledge of addition, subtraction, multiplication, or division operations, the emphasis of the problems is on mental computation, spatial visualization and concentration. Similar to the Vocabulary and Information subtests, Arithmetic involves memory and prior learning. This subtest is influenced by level of education, fluctuations in attention, and anxiety. Kaufman and Lichtenberger (1999) suggest that the Arithmetic subtest is a more complex working memory task because there is an increase in the amount of material that is stored and manipulated, and the individual is required to perform complex arithmetic calculations. Information-processing strategies, as well as mathematical skills, may underlie performance on the Arithmetic subtest. These strategies may include (a) rehearsal (e.g., to remember the information presented in the task) and (b) recognition of an appropriate response (e.g., to continue using a correct strategy or change an incorrect strategy).

A testing-of-limits procedure may help to determine whether the examinee has poor arithmetical knowledge or attention difficulties. For example, if the examinee can solve the math problems with pencil and paper, then the errors may be related to attention, concentration or memory difficulties that interfere with mental computation (Kaufman & Lichtenberger, 1999).

Arithmetic is a good measure of g, as 56% of its variance may be attributed to g. This subtest contributes moderately to the Working Memory Index with an average loading = .50. Subtest specificity is either ample or adequate for all age groups. Arithmetic is a reliable subtest (r_{xx}=.88), with reliability coefficients at or above .77 at all of the 13 age groups (range of .77 to .91). It correlates better with Information (r = .63) and Vocabulary (r =.60) than with any of the other subtests. It has a moderately high correlation with the Full Scale (r=.72) and the Verbal Scale (r=.70) and a moderate correlation with the Performance Scale (r = .63) (Sattler, 2002).

The arithmetic subtest emphasizes the phonological loop component of Baddeley's (2002) theory of working memory because this task requires verbal rehearsal strategies, the storing and manipulation of information, and mental computation.

Digit Span.

The Digit Span subtest consists of two different tasks that vary in complexity. The Digits Forward subtest calls for the immediate repetition of increasing numbers of digits ranging in length from two to nine digits. The Digits Backward subtest requires the examinee to repeat an increasing series of numbers in the reverse order, ranging in length from two to eight digits.

Digit Span assesses an examinee's short-term sequential auditory memory and attention (Sattler, 2002). This subtest requires sequencing skills because an examinee must recall auditory information and repeat the information aloud in proper sequence.

The Digits Span task emphasizes the phonological loop component of Baddeley's (2002) model of working memory. The Digits Forward task emphasizes the storage component of working memory, while the Digits Backward task emphasizes both the storage and processing of information simultaneously. On Digits Backward, the examinee must hold the mental image of the number sequence while mentally manipulating the sequence before restating it. Due to the differences between the two tasks, Sattler (2002) suggests that is it useful to consider Digits Forward and Digits Backward separately.

The Digit Span subtest is a fair measure of g, as 32% of its variance may be attributed to g. This subtest contributes substantially to the Working Memory Index with an average loading = .67. Specificity is ample for all age groups. Digit Span is a reliable subtest (r_{xx} =.90), with reliability coefficients at or above .84 at all of the 13 age groups (range of .84 to .93). It correlates better with Letter-Number Sequencing (r=.57) and Arithmetic (r=.52) than with any of the other subtests. It has a moderate correlation with the Full Scale (r=.52) and the Verbal Scale (r=.51) and a moderately low correlation with the Performance Scale (r = .47) (Sattler, 2002).

The Digit Span subtest is not a pure measure of auditory working memory because other variables such as anxiety or impaired hearing may account for low scores. As such, the examiner should attempt to rule out these confounding variables.

Letter-Number Sequencing.

The Letter-Number Sequencing subtest is a supplementary subtest containing seven items, each consisting of three trials. This subtest was designed as a measure of auditory working memory. It requires the examinee to first remember the numbers and letters, and then reorganize both the numbers from lowest to highest, and the letters in alphabetical order, before repeating them sequentially.

The Letter-Number Sequencing subtest involves attention, short-term auditory memory, and information processing (Sattler, 2002). The WAIS-III-WMS-III Technical Manual (The Psychological Corporation, 1997) indicates that the Letter-Number Sequencing subtest is a measure of working memory, a dynamic short-term memory storage system of limited capacity, used to hold information that is being processed. Letter-Number Sequencing is a more complex working memory task, and like the Arithmetic and Digit Span subtests, it emphasizes the phonological loop component of Baddeley's (2002) model of working memory.

The Letter-Number Sequencing subtest is a fair measure of g, as 42% of its variance may be attributed to g. This subtest contributes substantially to the Working Memory Index (average loading = .61). Specificity is either ample or adequate for five age groups (18-19, 30-34, 45-54, 70-74, 85-89 years); at eight age groups (16-17, 20-24, 25-29, 35-44, 55-64, 65-69, 75-79, 80-84 years), it is adequate. Letter-Number Sequencing is a reliable subtest (r_{xx}=.82), with reliability coefficients at or above .75 at all of the 13 age groups (range of .75 to .88). It correlates better with Digit Span (r=.57) and Arithmetic (r=.55) than with any of the other subtests. It has a moderate correlation with the Full Scale (r=.64), the Verbal Scale (r=.62), and the Performance Scale (r=.57) (Sattler, 2002).

Similar to the Digit Span subtest, low scores on the Letter-Number Sequencing subtest may indicate poor auditory working memory, anxiety, and auditory processing

(Sattler, 2002). Therefore, the examiner should determine whether anxiety or impaired hearing affected the scores.

In summary, the Arithmetic-Digit Span-Letter Number Sequencing triad of the WAIS-III Working Memory Index was developed to test a person's working memory ability by either increasing the amount of information to be stored, or by asking the examinee to perform two tasks simultaneously. The Working Memory Index factor emphasizes the verbal (phonological loop) component of Baddeley's model of working memory.

What does the PS Index measure?

The WAIS-III has included the Processing Speed Factor as part of its four-factor model, and it therefore includes the assumption that speed of cognitive processing is part of our conceptualization of intelligence. The Processing Speed Index is comprised of Digit Symbol-Coding and Symbol Search. The term Processing Speed reflects the ability to process perceptual information quickly in both mental and psychomotor tasks (Sattler, 2002). Since this fourth factor measures an individual's ability to process visual information quickly, it can be conceptualized within Jensen's (1982, 1998) model of intelligence. This model hypothesizes that processing speed is directly related to intelligence, because the faster the information is processed, the more operations can be done within a short period of time without taxing the information processing system. In addition, the Processing Speed Index measures visual working memory abilities, and as such, this factor can be applied to the visuospatial sketchpad component of Baddeley's (2002) model of working memory.

PSI Construct Validity.

According to the WAIS-III technical manual (1997) the correlation between Digit Symbol-Coding and Symbol Search of the Processing Speed Index is .65. The inclusion of the Symbol Search subtest made the factor loading stronger, and provides evidence of convergent validity. The addition of this subtest made the four-factor model stronger. The correlations between the PSI factor and other measures of fine motor speed and fine motor dexterity are discussed next. The PSI factor has a much higher correlation with the Dominant-Hand score of the Finger-Tapping Test (.47) than do the other factors on the WAIS-III. The highest correlation is between the WAIS-III PSI and the Grooved Pegboard dominant-hand (-.63).

Digit Symbol-Coding.

The Digit Symbol-Coding subtest requires the examinee to copy symbols that are paired with numbers. The key consists of nine boxes, with each box containing one of the numbers 1 to 9 and a symbol. Each test box has a number in the upper portion and the lower portion is empty. The examinee is required to draw the symbol that is paired with the number in the key, in the empty space provided.

The Digit Symbol-Coding subtest has two optional procedures: Digit Symbol-Copy and Digit Symbol-Incidental Learning. Digit Symbol-Copy is administered at the end of the WAIS-III, and this task requires the examinee to draw in the blank space below the box, the symbol that appears in the box. Digit Symbol-Incidental Learning requires the examinee to recall the associated number-symbol pairs (i.e. Pairing) and the individual symbols independent of the numbers (i.e. Free Recall). These optional procedures are intended to help determine what skills may be deficient if the examinee performs poorly on the Digit Symbol-Coding subtest.

Digit Symbol-Coding measures visual-motor accuracy and speed under time pressure. It can be conceptualized as an information-processing task involving visual working memory and attention to visual detail (Kaufman & Lichtenberger, 1999). The speed and accuracy with which the examinee performs the tasks are a measure of the examinee's intellectual ability. At each step in this task the examinee must look at the next digit, go to the right location in the table, code the symbol that is paired with that digit, and carry this information in working memory long enough to reproduce the symbol in the proper box. In addition, Digit Symbol-Coding involves attentional skills, visual acuity, visual scanning and tracking, cognitive flexibility, handwriting speed and possibly motivation.

The supplemental Digit Symbol-Copy subtest helps to determine whether perceptual accuracy and speed are affecting a person's score while ruling out the effect of memory. The supplemental Digit Symbol-Incidental Learning procedures provide useful information for determining how well a person has memorized the digit-symbol pairs and the symbols themselves while ruling out the effect of fine motor difficulties (Kaufman & Lichtenberger, 1999).

Digit Symbol-Coding is a fair measure of g, as 35% of the variance may be attributed to g. This subtest contributes substantially to the Processing Speed Index with an average loading = .73. Specificity is ample for all age groups. Digit Symbol-Coding is a reliable subtest (r_{xx} = .84), with reliability coefficients at or above .81 at all of the 13 age groups (range of .81 to .87). It correlates better with Symbol Search (r = .65) than with any of the other subtests. It has a moderate correlation with the Full Scale (r = .53) and the Performance Scale (r = .50) and a moderately low correlation with the Verbal Scale (r = .49).

Digit Symbol-Coding is useful for evaluating attentional difficulties, such as in cases of attention deficit/hyperactivity disorder (ADHD), anxiety, or a traumatic brain injury (Sattler, 2002). Low scores on the Digit Symbol-Coding subtest may also suggest poor motivation, perfectionism, boredom, or impulsivity (Kaufman & Lichtenberger, 1999).

Symbol Search.

The Symbol Search subtest is a supplementary subtest that requires the examinee to look at two symbols and decide whether either one is present in an array of five symbols. The subtest contains 60 items, and the examinee has 120 seconds to complete the task.

Symbol Search can be conceptualized as an information-processing task involving visual discrimination and visuoperceptual scanning. Similar to the Digit Symbol-Coding subtest, the speed and accuracy with which a person performs the task are a measure of the examinee's intellectual ability. Moreover, the task involves attention and concentration, visual working memory, mental speed, planning, and cognitive flexibility (Kaufman & Lichtenberger, 1999). Visual-motor coordination plays a minor role because the only motor movement is that of drawing a slash.

The Symbol Search subtest is a fair measure of g, as 49% of its variance may be attributed to g. This subtest contributes substantially to the Processing Speed Index with an average loading = .70. Specificity is ample or adequate for three age groups (30-34 through 45-54 years); at 10 age groups (16-17 through 25-29, 55-64 through 85-89 years), it is inadequate. Symbol Search is a relatively reliable subtest ($r_{xx} = .77$), with reliability coefficients at or above .74 at all of the 13 age groups (range of .74 to .82). It correlates better with Digit Symbol-Coding (r = .65) than with any of the other subtests. It has a moderate correlation with the Full Scale (r = .77), the Performance Scale (r = .69), and the Verbal Scale (r = .57) (Sattler, 2002).

Kaufman and Lichtenberger (1999) suggest that low scores on the Processing Speed Index may be due to slowed processing speed, difficulties with fine motor coordination, compulsiveness, and weak visual working memory. The examiner can determine whether fine motor coordination is affecting a person's score with the administration of the supplemental Digit Symbol-Copy subtest. Moreover, if an examinee obtains a low score on the Digit Symbol-Incidental learning subtest the examiner may suspect visual working memory difficulties.

The Processing Speed index can be applied to Jensen's model of intelligence because the Digit Symbol-Coding and Symbol Search subtests are highly speed dependent. With respect to speed of processing, Symbol Search taps mental speed, whereas Digit Symbol-Coding measures both mental and psychomotor speed.

Moreover, the Processing Speed index can be interpreted within the visuospatial sketchpad component of Baddeley's model of working memory. The visuospatial sketchpad is a working memory system where visual images are maintained and manipulated. The tasks on the Processing Speed index require the examinee to maintain visual information in working memory before providing a motor response. Kaufman and Lichtenberger (1999) suggest that a weak visual working memory can lower the

Processing Speed Index score, because the Digit Symbol-Coding and Symbol Search subtests depend to a considerable extent on the ability to retain abstract visual stimuli for brief periods of time.

The next section will provide a review of ADHD in adulthood, followed by Barkley's model of ADHD.

Overview of ADHD

For many years, attention deficit hyperactivity disorder (ADHD) has been viewed as consisting of three primary symptoms, these being poor sustained attention, impulsiveness, and hyperactivity (Barkley, 1997b). These symptoms appear relatively early in childhood, typically before the age of seven, and are fairly persistent over development (Barkley, 2002; Barkley, Fischer et al., 2002; Fischer et al., 2002). The cluster of symptoms now known as ADHD, have endured decades of changes. A variety of terms have been employed to describe this and related disorders including: Minimal Brain Dysfunction (MBD), Hyperkinetic Syndrome Childhood, Attention Deficit Disorder (ADD), Residual Attention Deficit Disorder (ADD-RT), and ADDwoH (Attention Deficit Disorder without Hyperactivity) (Barkley, 1998a).

Current Diagnostic Criteria.

More recently, the three major symptoms have been reduced to two, with hyperactivity and impulsivity combined into a single impairment. As a result, three subtypes of the disorder have been proposed in the current clinical view of ADHD offered in the fourth edition of the Diagnostic and Statistical Manual of Mental Disorders (APA, 1994): predominantly inattentive, predominantly hyperactive-impulsive, and combined types. The signs and symptoms of the disorder must be present prior to age 7 years, and create marked impairment in at least two different settings (e.g. academic, occupational, social). Moreover, the symptoms must not be better explained by another mental or physical disorder. The term that will be used throughout this study for attention deficits in adults is ADHD, following the DSM-IV criteria. Please see Table 1 for the DSM-IV criteria for ADHD. A more detailed description of the present study's operational definition for ADHD will be presented in Chapter Three.

Table 1

DSM-IV Diagnostic Criteria For ADHD (APA, 1994)

A. Either (1) or (2):
  (1) six (or more) of the following symptoms of inattention have persisted for at least six 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 or 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 forgetful in daily activities

  (2) six (or more) of the following symptoms of hyperactivity-impulsivity have persisted for at least six 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 acts as if "driven by a motor"
    (f) often talks excessively

  Impulsivity
    (g) often blurts out answers before questions have been completed
    (h) often has difficulty awaiting turn
    (i) often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairment 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 are not better accounted for by another mental disorder (pp. 83-85)

Prevalence and Sex Ratio.

ADHD occurs in approximately 3-7% of school-age children, with boys being over-represented, on average, approximately 4:1 to 9:1, depending on the setting (i.e. general population or clinics) (APA, 1994; Faraone, Biederman, Spencer, Wilens & Seidman, 2000). The disorder continues into adolescence in 50-80% of cases clinically diagnosed in childhood and into adulthood in 30-70% or more of these same cases (Barkley, 1997b). The persistence of ADHD in young adulthood varies according to who is being interviewed and the criteria used to define the disorder (Barkley, 2002).

Etiology of ADHD.

The cause of ADHD can be viewed from both an environmental and biological perspective (Goldstein, 1997). Possible prenatal causes of ADHD include poor maternal nutrition, maternal substance abuse, viral infections, and exposure to toxins such as lead (Maxmen & Ward, 1995; Mick, Biederman, Faraone, Sayer, & Kleinman, 2002). Accumulating evidence from genetic, biochemical, neurobehavioral, and neuroimaging studies strongly supports a neurological etiology in most children with ADHD (Ernst, Zametkin, Matochik, Jons & Cohen, 1998; Ernst, Zametkin, Phillips, Cohen, 1998; Faraone, Doyle, Mick & Biederman, 2001; Giedd, Blumenthal, Molloy & Castellanos, 2001). From a biological perspective, ADHD can be viewed as the result of a dysfunction in brain chemistry. Neurotransmitters involving dopamine, serotonin, and norepinephrine have all been implicated as essential building blocks for effective attention and impulse control (Goldstein, 1997). Moreover, ADHD has been regarded as a disorder of disinhibition of the frontal cortex by Douglas (1983) and Gualtieri, Ondrusek, & Finley (1985), respectively. The frontal lobe hypothesis of ADHD was based on the notion that hyperactivity was the result of impairments in cortical inhibition (Barkley, Grodzinsky, & DuPaul, 1992). Other researchers have found decreased blood flow in the frontal lobes of children diagnosed with ADHD (Lou, Henriksen, & Bruhn, 1984).

Genetic Factors.

Genetic factors are hypothesized to be a contributor to the etiology and expression of ADHD in children, adolescents, and adults. Generally, the literature indicates that approximately 20% to 32% of siblings and parents of ADHD children share some degree of ADHD characteristics (Faraone et al., 2001). A recent study concluded that the rate of ADHD in children of adults with ADHD was significantly greater than for controls (Biederman, Wilens, Mick, Milberger & Spencer, 1995). The authors conclude that childhood cases of ADHD that persist into adulthood may represent a subgroup with a more predominant biological or genetic etiology. Moreover, the findings in the adoption literature, support the hypothesis of a genetic transmission of ADHD (Wender, 1995).

Longitudinal and follow-up studies from researchers who initially worked with children have begun to show that at least 30 to 70% of those diagnosed with ADHD as a child do not outgrow their symptoms (Faraone et al., 2000; Weiss & Hechtman, 1993; Weiss et al., 1999; Wender, 1995). Instead, their symptoms continue into adolescence and adulthood and have even more far reaching negative consequences academically, socially, and occupationally than was initially realized (Biederman et al., 1993; Fischer et al., 2002; Nadeau, 1995; Spencer, Biederman, Wilens, Faraone & Li, 1994; Wender, 1995). In addition, Barkley (2002) found that adults diagnosed with ADHD tend to have lower socioeconomic status, move more often, change jobs more often, and have more part-time employment.

Research on subtype differences.

A recent study examined the neuropsychological functioning of a group of 105 young adults diagnosed with attention deficit-hyperactivity disorder (Murphy et al., 2001). No differences were found in the ADHD group as a function of ADHD subtype. A number of neuropsychological studies assessing the frontal lobe functioning of ADHD children with and without hyperactivity, have not found any significant differences between the groups in terms of one subtype having greater frontal lobe dysfunctions than the other (Barkley et al., 1992; Hynd, Lorys, Semred-Aikeman & Nieves, 1991; Lorys, Hynd & Lahey, 1990). Lorys et al. (1990) compared 48 children with ADHD-combined type to 26 children of the predominantly inattentive type on various cognitive measures. These included the WISC-R, and the Luria-Nebraska Neuropsychological Battery-Children's Revision. The results were not able to distinguish deficient neurocognitive processes in the subtypes of ADHD. A more comprehensive review of 22 neuropsychological studies of frontal lobe functions in children with attention deficit disorder with and without hyperactivity did not find any differences between the groups. However, the findings did suggest that those children with ADHD predominantly inattentive type, had more problems with perceptual motor speed and those with ADHD-Combined type had more problems with response inhibition, persistence of attention, and resistance to distraction (Barkley et al., 1992). Another study examined whether children diagnosed as having either attention deficit disorder with or without hyperactivity could be distinguished on a series of cognitive tasks (Hynd, Lorys et al., 1991). The results did not find any significant differences in cognitive ability between the groups. A recent study found that children with ADHD-Predominantly Inattentive Type displayed more problems with selective attention and had a sluggish tempo of information processing when compared to children with ADHD-Combined Type (Milich, Balentine & Lynam, 2002).

Diagnosis of ADHD in adults.

At present, there is no single instrument or procedure that can adequately diagnose ADHD. It has been suggested that ADHD is diagnosed only by a combination of measures that allow a clinician to determine how well the individual's symptoms fit the profile of ADHD relative to other possible diagnoses (Barkley, 2002). Adult ADHD can be difficult to assess because of the presence of comorbid disorders that mimic ADHD-like symptoms. Comorbid disorders particularly troublesome in differential diagnosis include anxiety, depression, disorders of conduct, learning disorders, and the effects of drugs and alcohol (APA, 1994; Barkley & Grodzinsky, 1994; Biederman et al., 1993; Fischer et al., 2002).

Biederman et al. (1993) found that approximately 31% of ADHD adults in their sample met full DSM-II-R criteria for major depression, 52% met criteria for at least two major anxiety disorders, 29% met criteria for oppositional defiant disorder (ODD), 20% met criteria for conduct disorder (CD), and 12% met criteria for Antisocial Personality Disorder. In another study, Biederman et al. (1995) found that 40% of ADHD adults in their sample met criteria for substance abuse.

A recent study found that of the 147 young adults with ADHD, 26% met DSM-IV criteria for major depressive disorder, 12% met criteria for histrionic personality disorder, and 21% met criteria for antisocial personality disorder (Fischer et al., 2002).

It has been suggested that the use of psychometric assessment techniques may be particularly useful in diagnosing adults with ADHD since these instruments are capable of detecting more subtle symptoms such as inattention (Barkley & Grodzinsky, 1994). Measures believed to be sensitive to attentional deficits in adults with ADHD include computerized continuous performance tests, such as the Test of Variables of Attention (TOVA), Brief Test of Attention, Stroop Color-Word Interference Test, Trails A and B, Logical Memory and Visual Reproduction subtests of the Wechsler Memory Scale-Third Edition, selected subtests of the Rey Auditory Verbal Learning Test, and the Wechsler Adult Intelligence Scale for Adults-Third Edition (WAIS-III). Such measures have been shown to discriminate between those with ADHD and nonclinical populations (Brown, 2000).

In 1994 the American Psychiatric Association published the DSM-IV, which provides new diagnostic criteria for ADHD (see Table 1). To qualify for the diagnosis of ADHD under DSM-IV criteria, an individual needs to not only display the symptoms listed, but also be impaired by at least some of those symptoms in two or more settings, for example, at school, at work, or at home. The list of symptoms has been categorized to form three basic types. These new terms for the basic types are Attention-Deficit/Hyperactivity Disorder, Predominantly Inattentive Type; Attention-Deficit/Hyperactivity Disorder, Combined Type; and Attention-Deficit/Hyperactivity Disorder, Predominantly Hyperactive-Impulsive Type. This third category was added for cases in which hyperactive-impulsive symptoms occur without significant inattention symptoms, and it is most likely to be useful for diagnosis of preschool children because although they may display significant problems of hyperactivity and impulsivity, they are usually not expected to demonstrate much sustained attention at such a young age (Applegate, Lahey, Hart, Waldman & Biederman, 1997; Brown, 1995).

One factor that may complicate the differential diagnosis of ADD versus ADHD in adults is that the majority of those who exhibited hyperactive behaviors as children often show a decrease in hyperactive symptoms in adulthood (Barkley, 1997a; Brown, 1995; Faraone, et al., 2000). Therefore, more adults with ADHD tend to be classified as ADHD-predominantly inattentive subtype because they may be a few symptoms shy of the ADHD-combined subtype. This poses a problem of contamination of the ADHD-predominantly inattentive type by formerly ADHD-combined type cases, and adds to the greater heterogeneity of the ADHD-predominantly inattentive type in adulthood (Murphy et al., 2002).

Self-report measures can be used as another valuable diagnostic tool. Murphy and Barkley (1995a) offer the ADHD Behavior Checklist for Adults, as this checklist parallels the DSM-IV diagnostic criteria for ADHD. Another self-report questionnaire that is becoming increasingly popular is The Attention-Deficit Scales for Adults (ADSA). This instrument consists of 54 items that address, either directly or indirectly, symptoms associated with Attention-Deficit/Hyperactivity Disorder (ADHD) (Triolo & Murphy, 1996).

Treatment of ADHD in Adults

The recommended treatment of adults with ADHD is similar to the treatment of children with ADHD. Treatment is multimodal, including both medication and psychoeducation to explain the symptoms and help the individual understand their impact on functioning. Current research supports the efficacy of stimulant medication in reducing adult ADHD symptoms (Wilens, Spencer, & Biederman, 2001). Findings from a series of double-blind studies using medication demonstrated that up to three quarters of adults will respond to methylphenidate (Spencer, Biederman & Wilens, 1995), Adderall (Spencer, Biederman, & Wilens, 2001), buproprion (Wilens, Spencer & Biederman, 2001) and desipramine (Wilens, Biederman & Prince, 2001).

No controlled studies were found in the literature with respect to the psychological treatment of ADHD in adults. Most of the discussion of components of psychological treatment for adult ADHD is based on clinical experience rather than on empirically derived information. Clinicians recommend that treatment sessions with ADHD have a psychoeducational component and should be directive, structured and focused (Weiss, Murray & Weiss, 2002). As well, Weiss et al., 2002, suggest that various accommodations in the educational setting have been found to be particularly helpful. These include taking extra time for tests, working in a quiet environment or with white noise, breaking tasks into smaller steps, obtaining written instructions, delegating tasks to others, using computers and sticky notes.

Now that some of the issues related to this disorder have been reviewed, Barkley's model of frontal lobe dysfunction in those with ADHD will be discussed next.

Barkley's Model of Frontal Lobe Disinhibition in ADHD

Barkley (1997b, 1998a), a leading expert in the area of Attention Deficit Hyperactivity Disorder (ADHD) concludes that most of the abilities found to be discrepant in ADHD individuals fall within the domain of executive functions in the field of neuropsychology and is considered to be mediated by the frontal cortex, particularly the prefrontal lobes. These include: (1) motor coordination and sequencing; (2) working memory and mental computation; (3) planning and anticipation; (4) verbal fluency and confrontation communication; (5) effort allocation; (6) application of organizational strategies; (7) internalization of self-directed speech; (8) adherence to restrictive instruction; and (9) self-regulation of emotional arousal.

He developed a model of ADHD that is founded on prior theories of the neuropsychological functions of the brain's prefrontal lobes. The model provides a linkage between the ability to inhibit a response and four executive functions that depend on such inhibition for their own effective performance. In other words behavioural inhibition allows the proficient performance of four executive abilities: (a) non-verbal working memory; (b) verbal working memory; (c) self-regulation of affect-motivation-arousal; and (d) reconstitution (behavioural analysis and synthesis). These four executive functions are believed to bring behaviour under the control of internally represented information and they allow greater goal-directed action and task persistence. In particular, this model predicts that poor behavioral inhibition, as in ADHD should lead to secondary deficiencies in these four abilities and motor control. It should be noted that two of the executive functions (e.g. verbal and nonverbal working memory) are believed to comprise the phonological loop and visuospatial sketchpad components of Baddeley's model of working memory (Barkley, 1997b, 1998a).

There are three components to Barkley's model. These components are arranged in a hierarchical manner and interact with one another. The first component, behavioural inhibition, involves three processes that include the inhibition of a prepotent response to an event, the stopping of an ongoing response and interference control. The second component of Barkley's model includes the four executive functions that are classified as non-verbal working memory, verbal working memory, the self-regulation of affect-motivation-arousal and reconstitution. The third component to Barkley's model is named motor control/fluency/syntax. Each of these components will now be reviewed.

Behavioural Inhibition.

Behavioural inhibition enables a person to slow down their response to an event. Moreover, behavioural inhibition influences the functioning of the four executive functions and has a direct influence on the third component, the motor control system. As previously mentioned, there are three kinds of behavioural inhibition: inhibiting a prepotent response, stopping an ongoing response, and interference control. These three types will now be reviewed.

The first type of behavioural inhibition includes the inhibition of a prepotent response. The prepotent response has been defined as that response for which immediate reinforcement is available or has been previously associated with that response. The second type of behavioural inhibition involves the stopping of an ongoing and ineffective response. These first two types of behavioural inhibition serve to delay a response in order to allow the executive functions to occur. It has been suggested that these first two types of behavioural inhibition enable a person to self-monitor and are critical to self-control (Barkley, 1997b, 1998a).

The third type of behavioural inhibition is termed interference control. Interference control involves a period of delay that is protected from disruption by competing events and responses. As with the other two behavioural inhibitory types, interference control enables the four executive functions to occur. Moreover, these three inhibitory functions exert a controlling influence over the motor control system. Behavioural inhibition can be assessed by performance on cognitive or behavioural tasks that require the withholding of a response, a delay in responding, the stopping of ongoing responses, and resisting distraction by competing events.

Current research on ADHD is emphasizing poor behavioral inhibition as the central impairment of the disorder (Schachar, Tannock, Marriott, & Logan, 1995). Barkley contends that individuals with ADHD experience problems with each of the three types of behavioural inhibition. Difficulties with behavioural inhibition would negatively influence the four executive functions and the motor control system. In the next section, a general review of executive functions and a description of the four executive functions included in Barkley's model will be provided.

Executive Functions.

Executive functions are known to be associated with the frontal lobes of the brain and are associated with higher level processing, including various control and regulatory mechanisms. Moreover, executive functions are believed to involve the inhibition and delay of responding. Barkley's frontal lobe hypothesis (1997b, 1998a) addresses the issue of executive functioning and its relationship with behaviour. The four executive functions in Barkley's model include 1) non-verbal working memory, 2) verbal working memory (internalisation of speech), 3) self-regulation of arousal-motivation-emotion, and 4) reconstitution (analysis and synthesis). Barkley contends that each of the four executive functions interacts with one another and they help the person to self-regulate his or her own behaviour. As well, the executive functions assist an individual with directing behaviour towards a goal.

Non-Verbal Working Memory.

Non-verbal working memory involves the individual's ability to hold information in support of efforts to analyze, manipulate, and respond to the information, which may include various combinations of sensory inputs. Barkley (1997b; 1998a) predicts that individuals with ADHD would display impairments in non-verbal working memory (i.e., visual working memory). Deficits in this area are thought to result in an inability to hold events in mind and an inability to manipulate or act on such events. Moreover, individuals with ADHD are thought to have difficulty imitating complex sequences as well as defective hindsight and forethought, poor anticipatory set and planning ability, a diminished sense of time and limited self-awareness.

Verbal Working Memory (Internalisation of Speech).

Verbal working memory involves the ability to internalize speech and can be referred to as private speech. This function progresses developmentally from an outer-directed form to verbal thoughts in adulthood (Barkley, 1997b, 1998a). One important aspect of private speech is the control language has over motor behaviour. Internalized speech helps the individual to reflect on an event prior to responding to the event. Barkley posits that individuals with ADHD would have impairments in this area.

Dysfunction within the verbal working memory area result in reduced verbal description and cognitive reflection, deficient rule governed behaviours, deficient problem solving abilities, ineffective rule generation, impaired reading comprehension and developmental delays in moral reasoning.

Self-Regulation of Affect, Motivation and Arousal.

The self-regulation of affect, motivation, and arousal, refers to the ability to regulate emotional states in accordance with the information that is being processed internally. This function is thought to play an important role in the development and maintenance of goal-directed behaviours. Barkley (1997b, 1998a) predicts that individuals with ADHD would have difficulties with the self-regulation of affect, motivation and arousal especially when related to goal directed behaviours. Such impairments would include limited emotional self-control and decreased objectivity and social perspective taking.

Reconstitution.

The concept of reconstitution refers to the capacity to take apart the internal images described above, and subsequently put them back together into new sequences in an effort to generate new and flexible behaviours. As with the other three executive functions, Barkley (1997b, 1998a) contends that individuals with ADHD would have difficulties with reconstitutive abilities. Impairments in this area result in decreased verbal and behavioural fluency, rule-governed behaviours, goal-directed behaviors, analysis and synthesis of behaviour.

Behavioural inhibition and the four executive functions interact in order to control the motor control/fluency/syntax component of Barkley's model. This third component will now be reviewed.

Motor control/fluency/syntax.

The motor control component of Barkley's model is directly influenced by behavioural inhibition and the four executive functions, as they attempt to bring the motor system under internal control. This internal control of behaviour prevents the external environment from controlling behaviour. For example, the working memory executive function provides feedback from previous responses held in mind in order to change subsequent responses. Barkley's model predicts that individuals with ADHD would show impairments in the motor control/fluency/syntax area. They would be more controlled by outside influences than the internal environment of the brain and they would have reduced goal-directed persistence. Other impairments include behavioural inflexibility, the inability to profit from corrective feedback, perseverative responding, and difficulties returning to a task after disruption.

In the preceding paragraphs, the reader was provided with a description of Barkley's model of frontal lobe disinhibition in individuals with ADHD. In the next section, there will be a review of research in support of his hypothesis.

Research in Support of Barkley's Frontal Lobe Hypothesis

As outlined above, frontal lobe deficits or executive dysfunctions, are currently hypothesized to play a primary role in the etiology, development, and manifestation of the various cognitive and behavioural symptoms associated with ADHD (Barkley, 1997b, 1998a). Empirical evidence in support of the frontal lobe hypothesis comes from various investigations within neuroscience and neuropsychology.

Neurochemical evidence.

Neurotransmitters known as catecholamines are thought to control activity level, reward, motivational learning, inhibition of attention, and restlessness (Ernst, Zametkin, Matochik et al., 1998; Hynd, Hern, Voeller & Marshall, 1991). Dopamine and norepinephrine are specific catecholamines that maintain strong connections with the frontal lobes. For example, the frontal lobes have interconnections with the substantia nigra and the striatum, which contain significant concentrations of dopamine. Ernst et al. (1998) found that prefrontal dopaminergic dysfunction mediates ADHD symptoms in adults.

Castellanos, Giedd, Eckburg, Marsh, Vaituzis et al. (1994) reported a positive correlation between levels of the principle dopamine metabolite homovanillic acid (HVA) in the cerebrospinal fluid and hyperactivity in a sample of ADHD boys. In another study, the same authors noted that concentration of HVA in the cerebrospinal fluid was the best predictor of response to stimulant medication in a separate sample of ADHD boys (Castellanos, Giedd, Marsh, Hamburger, Vaituzis et al., 1996).

Zametkin, Nordahl and Gross (1990) examined brain glucose metabolism in 25 adults with ADHD. PET scanning was used to measure cerebral glucose metabolism while subjects completed an auditory attention task. Results indicated that glucose metabolism in the premotor cortex and the superior prefrontal cortex was lower in the adults with ADHD compared to normal controls. These areas are considered to be responsible for the control of attention and motor activity.

Neuropsychological Impairments in Adults with ADHD: Research Evidence

Objective measures such as neuropsychological tests that document differences between ADHD and non-ADHD adults provide further evidence of ADHD as a valid disorder of adulthood.

Johnson, Epstein, Waid, Latham and Voronin (2001) assessed the neuropsychological functioning of 56 adults with ADHD and 38 normal comparison adults. A diagnosis of ADHD was determined by meeting the DSM-IV criteria for one of the three types of ADHD and via the Schedule for the Assessment of Conduct, Hyperactivity, Anxiety, Mood and Psychoactive Substances (CHAMPS) interview. Participants were excluded from this study if they had a current mood or substance use disorder or if they were taking psychotropic medication. The neuropsychological testing battery consisted of tests that measured verbal learning and memory, psychomotor speed, sustained attention and reaction time. The results indicated that ADHD adults demonstrated verbal memory deficits and decreased psychomotor speed compared to normal controls. The researchers noted that data from the Trail Making Test, 3RT Test and Gordon Diagnostic Systems indicated that psychomotor speed and reaction time in ADHD subjects was comparable to normal controls when the tasks were simpler in nature. However, as the tasks became more complex there seemed to be a slowing of psychomotor speed and reaction time in ADHD subjects compared to the control group.

Riordan et al. (1999) examined the neuropsychological functioning of 21 adults with ADHD based on DSM-IV criteria, 19 adults with ADHD and comorbid affective disorder, and 15 normal control subjects. Adults with ADHD were found to have relatively intact verbal reasoning and visual memory but demonstrated impaired performance on measures of verbal memory, motor and processing speed, visual scanning, and auditory and visual distractibility. The Digit Symbol subtest from the WAIS-R was used to measure processing speed.

In a recent study Murphy et al. (2001) compared 105 young adults with attention deficit hyperactivity disorder (ADHD) to a control group of 64 adults on 14 measures of executive functioning. The diagnosis of ADHD was established by meeting the criteria from the DSM-IV (APA, 1994), results from the ADHD Rating Scale for Adults and by the judgment of an expert clinician. Since no differences were found in the ADHD group as a function of ADHD subtype all participants were combined into a single group. This study also examined the impact of comorbidity on the results and found that comorbid depression influenced the results of only one test (Digit Symbol). Results indicated that the ADHD group performed significantly worse than controls on 11 measures. Difficulties in five areas of executive functioning were noted: response inhibition, poor sustained attention, interference control, verbal and nonverbal working memory. This study employed seven measures to represent the major domains of executive functioning. The Conners Continuous Performance Test (CPT) was used as a measure of sustained attention and response inhibition. The Stroop Color and Word Test was used to assess the ability to inhibit competing responses in the presence of conflicting information. The Digit Span subtest from the Wechsler Adult Intelligence Scale-III, WAIS-III was used to evaluate verbal working memory. The Simon game was used as a measure of nonverbal working memory. The Digit Symbol subtest from the WAIS-III was used to assess attention. The Verbal Fluency (F-A-S) Test from the Controlled Oral Word Association Test (COWAT) and the Object Usage Test were employed as measures of fluency or the ability to generate responses. Significant group differences were found on measures of response inhibition (CPT commission errors), interference control (two of three Stroop measures), inattention (CPT omission errors, CPT RT variability, and WAIS-III Digit Symbol), verbal working memory (WAIS-III Digit Span), nonverbal working memory (Simon game), and verbal fluency (COWAT verbal fluency task).

Using the same sample of subjects from the previous study, Barkley, Murphy and Bush (2001) investigated time perception and reproduction in young adults with attention deficit hyperactivity disorder (ADHD). Once again the results were unaffected by ADHD subtype and as such those with ADHD were combined into a single group. The two dependent measures included a time estimation task and a time reproduction task. While the ADHD group did not show impairments in the perception of time, they made shorter time reproductions and greater reproduction errors compared to the control group. The researchers concluded that ADHD might impair time reproduction through the connection that exists between impaired inhibition, interference control, and working memory. In other words, the poor inhibition and interference control in the disorder will leave working memory prone to disruption when temporal information must be processed thereby interfering with accurate time reproductions. Barkley et al. (2001) contend that the problem is not due to an inadequate sense of time but rather to an inadequate management of behaviour relative to time durations.

In another study Jenkins et al., 1998, found that adults with a history of ADHD exhibited greater impairments on measures of attention and executive functioning as measured by the Paced Auditory Serial Addition Task, Revised (PASAT), and the Controlled Oral Word Association Test (COWAT).

These results support the conceptualization of ADHD as a disorder with chronic, consistent deficits that persist beyond the elementary school years. The neuropsychological research conducted on adults with ADHD has demonstrated a pattern of deficits quite similar to what is seen in children with the disorder. Moreover, findings from the above mentioned studies lend support to Barkley's (1997b) frontal lobe dysfunction hypothesis of ADHD.

WAIS-R and WAIS-III Third factor in Adults with ADHD

Intraindividual comparisons of performance have confirmed that individuals with ADHD tend to perform more poorly on a cluster of subtests that are concentration sensitive than on verbal and spatial subtests. Using the subtests of the WAIS-R, Biederman et al. (1993) found that 84 adults diagnosed with ADHD obtained significantly lower Freedom From Distractibility Index scores when compared to adults without the disorder.

Murphy et al. (2001) examined the cognitive functioning of 105 young adults with ADHD. The Digit Span subtest from the Wechsler Adult Intelligence Scale-III (WAIS-III) was used to evaluate verbal working memory. Results indicated that the ADHD group had significantly lower Digit Span scores compared to the control group.

The WAIS-III Technical Manual (1997) refers to a pilot study in which the WAIS-III was administered to a group of 30 individuals diagnosed with ADHD. Although the mean intellectual functioning of the sample with ADHD was within the average range, their mean Working Memory Index scores were lower than their mean

Verbal Comprehension scores. However, the manual was careful to point out that individuals with learning disorders showed a similar pattern of performance on the WAIS-III.

PS Index in Adults with ADHD

Research indicates that performance on tasks that are similar to the PS factor tasks is lower in adults with ADHD (Klee et al., 1986). In their study, performance on the WAIS-R Digit Symbol subtest was poorer for 12 adult males with ADHD. One limitation of this study is the small sample size.

Another study (Murphy et al., 2001) examined the cognitive functioning of 105 young adults with ADHD. Results from the WAIS-III Digit Symbol-Coding subtest indicated that the ADHD group had significantly lower Digit Symbol-Coding scores compared to the control group.

Riordan et al. (1999) examined the processing speed abilities of 21 adults with ADHD based on DSM-IV criteria, 19 adults with ADHD and comorbid affective disorder, and 15 normal control subjects. Adults with ADHD demonstrated impaired performance on the Digit Symbol subtest from the WAIS-R when compared to the control group.

In the preceding pages the reader was provided with a description of the WAIS-III as a measure of intelligence. As well, there was a review of the information-processing framework to describe human intelligence. Baddeley's model of working memory and Jensen's model of intelligence were conceptualized within the information-processing framework. Moreover, Baddeley's model was applied to the WAIS-III Working Memory Index and Processing Speed Index, and Jensen's model was used in the interpretation of the WAIS-III Processing Speed Index. This was followed by a review of ADHD in adulthood and Barkley's model of ADHD. A review of the literature indicated few studies that have investigated the relationship between adults with attention deficit hyperactivity disorder, working memory and processing speed functioning.

The purpose of this investigation is to explore the hypothesis of working memory and processing speed impairments in adults with ADHD. This literature review ends with a review of the study research questions.

Research Questions

1. Does the mean WAIS-III Working Memory Index score differ significantly from the mean Verbal Comprehension Index score for the ADHD sample?
2. Does the mean WAIS-III Working Memory Index score differ significantly from the mean Perceptual Organization Index score for the ADHD sample?
3. Does the mean WAIS-III Working Memory Index score differ significantly from the mean Processing Speed Index score for the ADHD sample?
4. Does the mean WAIS-III Processing Speed Index score differ significantly from the mean Verbal Comprehension Index score for the ADHD sample?

5. Does the mean WAIS-III Processing Speed Index score differ significantly from the mean Perceptual Organization Index score for the ADHD sample?
6. Does the mean WAIS-III Working Memory Index score for the ADHD sample differ significantly from the mean Working Memory Index score of the WAIS-III standardization sample?
7. Does the mean WAIS-III Processing Speed Index score for the ADHD sample differ significantly from the mean Processing Speed Index score of the WAIS-III standardization sample?
8. What percentage of the ADHD sample shows significant WMI<VCI, and WMI<POI factor differences?
9. What percentage of the ADHD sample shows significant PSI<VCI, and PSI<POI factor differences?
10. How do those percentages from the ADHD sample showing significant WMI<VCI, and WMI<POI factor differences, compare with the estimated base rates or the frequency of such differences occurring in the standardization sample?
11. How do those percentages from the ADHD sample showing significant PSI<VCI, and PSI<POI factor differences, compare with the estimated base rates or the frequency of such differences occurring in the standardization sample?
12. Does the mean difference between the Digits Forward and Digits Backward components of the WAIS-III Digit Span subtest from the

ADHD sample differ significantly from those scores of the WAIS-III standardization sample?

13. How do the percentages of differences between Digits Forward and Digits Backward from the ADHD sample compare with the frequency of such differences occurring in the WAIS-III standardization sample?

Chapter Three

Research Design and Methodology

Participants

The participants were a clinical, non-random sample of 34 male (71%) and 14 female (29%) adults aged 18 to 40 years who were referred for psycho-educational assessments from January 1, 1998 to December 31, 1999. Subjects were referred by various community sources, including family physicians, career counsellors, family members, spouses and some self-referrals for purposes such as determining strengths and weaknesses, evaluating learning difficulties and social/emotional functioning.

Subjects were included in this study if all of the study variables were available. Specifically, information on each of the VC, PO, WM and PS subtests and indexes had to be available for analysis, as well as gender, age, level of education and diagnostic information. The total sample mean age was 24.49 years (SD = 6.28) and the modal age was 19.11 years. Subjects' level of education ranged from grade 9 to an undergraduate degree. There were 32 subjects (21 male/11 female) in the ADHD predominantly inattentive group and 16 subjects (13 male/ 3 female) in the ADHD Combined group. None of the participants met DSM-IV criteria for ADHD Hyperactive/Impulsive type in adulthood. Twenty-two subjects were diagnosed with ADHD as children. Of those who were previously diagnosed, 18 were prescribed medication to treat the symptoms of this disorder. None of the participants were taking medication at the time of the assessment.

Gender, age and education demographic information for the two groups and the total sample is presented in Table 2.

Table 2

Gender, Age and Education Demographic Data For Groups and Total Sample

	Group Description		
	ADHD- Inattentive Type	ADHD-Combined Type	Total Sample
Gender			
Males	21	13	34
Females	11	3	14
Age			
18-19	8	4	12
20-24	9	10	19
25-29	6	0	6
30-34	5	2	7
35-44	4	0	4
Years of Education			
9-11	9	9	18
12	15	4	19
13-15	9	2	11

Research Procedures

First, ethical approval was obtained from the ethical review committee of the Department of Educational Psychology at the University of Alberta. Next, data were collected from previously administered WAIS-III's from a sample of 34 male adults and 14 female adults between the ages of 18 to 40 years who were referred to a private psychological firm. The WAIS-III was administered by qualified personnel under the supervision of a doctoral level psychologist specializing in educational, psychological and neuropsychological assessment. All of the protocols, test results, and assessment reports were examined individually and data was collected from clients' files. To maintain confidentiality and to protect the anonymity of the files and test results, the subjects' names were replaced with codes. WAIS-III descriptive statistics, such as means and standard deviations, were calculated for all of the scales.

Each subject had a WAIS-III Full Scale IQ (FSIQ) score greater than 90, had normal hearing and vision, and was not taking any medication. Participants were excluded from this study if there was a previous diagnosis of a neurological disorder such as epilepsy, brain tumor, or head injury. Participants were excluded from this study if they had a comorbid learning disability, mood disorder, anxiety disorder, personality disorder and substance use disorder.

ADHD classification.

For the purposes of this investigation ADHD was operationalized in the following manner: 1) The participants were diagnosed with ADHD according to clinical interviews, DSM-IV diagnostic criteria including age of onset, behavioural indices, work-related problems, job-changes, and past school history, 2) A T-Score above 70 on the Total Score scale of the Attention-Deficit Scales for Adults (ADSA), 3) Achievement test results within one standard deviation below the mean, 4) Conditions that can produce ADHD-like symptoms (e.g. Depression, anxiety disorders, personality disorders, substance abuse, and schizophrenia) were ruled out with the administration of the Personality Assessment Inventory (PAI). Participants needed to obtain T-Scores below 70 on the following (PAI) subscales: Anxiety, Anxiety Related Disorders, Depression, Mania, Schizophrenia, Borderline Features, Antisocial Features, Alcohol Problems, and Drug Problems. Following the assessment, each participant was provided with a clinical debriefing and a psychological assessment report.

Clinical Diagnostic Interviews.

The clinical interview is a very important part of the diagnostic process. Each participant took part in a clinical interview that lasted approximately 60 minutes. The examiner documented the participant's developmental, school, family, employment, medical, social, legal, substance use and psychiatric history. In addition to inquiring about Axis I disorders, the examiner recorded any past and present problems with attention and learning, conduct problems and oppositional defiant disorder.

Whenever possible, the interview included the participants' parents or spouse. As well, the examiner reviewed any past school report cards, when available, and any other sources of information (e.g. prior professional reports) that the participants brought with them to the evaluation.

DSM-IV Diagnostic Criteria for ADHD.

The present investigation followed the criteria outlined in the DSM-IV (see Table 1) for diagnosing ADHD in adulthood. The DSM-IV criteria for ADHD include a list of 18 symptoms and require onset of symptoms before age 7, the symptoms must be present in at least two settings, and there must be clinically significant impairment. The DSM-IV separates difficulties with inattention from difficulties with hyperactivity/impulsivity.

Age of Onset.

To be included in this study, participants had to meet DSM-IV criteria for ADHD with onset of symptoms producing impairment before 7 years of age. As such, each participant was asked to recall whether they experienced any ADHD symptoms prior to age seven. In addition, the examiner reviewed archival data (e.g. teacher comments in report cards and professional reports) and obtained reports from a collateral rater who knew the subject in childhood (e.g. a parent).

Current ADHD Symptomatology.

The next step in the diagnostic process was to determine whether each participant had current significant difficulty with the symptoms of inattention and/or the symptoms of hyperactivity and impulsivity. These symptoms had to be present for the last six months. In addition to meeting DSM-IV criteria for ADHD, the examiner assessed pervasiveness of the symptoms and significant impairment. Pervasiveness was determined by asking the participant about the presence of ADHD symptoms in different settings including work, home, school and social situations. Impairment was assessed throughout the interview.

Rating Scales.

In addition to using DSM-IV diagnostic criteria for ADHD in adults, participants completed a rating scale to assess the broad range of difficulties associated with ADHD.

The Attention Deficit Disorder Scales For Adults (ADSA) is a self-report questionnaire that assesses symptoms associated with ADHD in adults. Each participant needed to score in the clinically significant range (i.e. T-score above 70) on the ADSA Total Score scale.

Achievement Tests.

Each participant was screened for learning disabilities with the administration of the Wide Range Achievement Test-Third Edition (WRAT-3) and the Woodcock Reading Mastery Test-Revised (WRMT-R): Passage Comprehension subtest. In order to be included in this study, the WRAT-3 single word reading, spelling, arithmetic and the WRMT-R-passage comprehension standard scores had to be above 85 (i.e., within one standard deviation below the mean or higher).

Personality Test.

As mentioned in the literature review, adults with ADHD often present with comorbid difficulties, such as anxiety, mood, and substance use disorders (Biederman et al., 1993). As such, clinicians must determine whether symptoms such as poor concentration are due to ADHD or to a comorbid condition. The present study ruled out conditions that can produce ADHD-like symptoms including depression, anxiety disorders, personality disorders, substance abuse and schizophrenia. Each participant completed the Personality Assessment Inventory in order to fulfill this requirement. After a validity check, the profile and the subscales were examined for elevations. Subjects needed to obtain T-Scores below 70 on the following subscales: Anxiety, Anxiety Related Disorders, Depression, Mania, Schizophrenia, Borderline Features, Antisocial Features, Alcohol Problems, and Drug Problems.

Research instruments

In this section of the paper, test instruments, test administration, and the reliability and validity of the intelligence, achievement, personality, and behaviour rating scales used in this study will be reviewed.

WAIS-III.

The WAIS-III, the latest version of the Wechsler scales for adults, was published in 1997. It was designed for adults' ages 16 to 89 years. The main reason for revision was to update the norms. The American standardization sample of 2,450 adults divided into 13 age bands is stratified along the variables of age, sex, race, education level, and geographic region. The standardization sample included an equal number of males and females in each age group. The new WAIS-III contains 14 subtests, with seven subtests in the Verbal scale and seven in the Performance scale. The Verbal scale consists of the following subtests: Vocabulary, Similarities, Information, Comprehension, Arithmetic, Digit Span, and Letter-Number Sequencing. The Performance scale consists of the following subtests: Block Design, Matrix Reasoning, Picture Completion, Object Assembly, Picture Arrangement, Digit Symbol-Coding, and Symbol Search. It should be noted that Object Assembly is a supplementary subtest.

Norms Development.

Each age group's subtest raw scores were converted to percentiles and then to a scale with a mean of 10 and a standard deviation of 3. After preparing cumulative frequency distributions of raw scores for each age group, the distributions were normalized and any minor sampling fluctuations were smoothed.

For each group, the means and standard deviations of the sums of scaled score distributions were calculated. Since an analysis of variance did not reveal statistically significant variation by age group in the mean scores for the scales and indexes, the age groups were combined to construct the tables of IQ and Index score equivalents of sums of scaled scores. This resulted in the conversion of the distribution of the sums of scaled scores to a scale with a mean of 100 and a standard deviation of 15.

WAIS-III Reliability.

In the WAIS-III Technical Manual (Wechsler, 1997) evidence of the reliability of the WAIS-III is reviewed. Reliability of a test refers to the accuracy, consistency, and stability of test scores across situations (Borg & Gall, 1989). The WAIS-III has excellent reliability. Over the entire age range, the three scales (Verbal, Performance and Full Scale) have internal consistency reliability coefficients ranging from .93 to .98. The average internal consistency reliability coefficients, based on the 13 age groups, are .98 for the Full Scale IQ, .97 for the Verbal Scale IQ, and .94 for the Performance Scale IQ (Sattler, 2002).

The subtest reliability correlation coefficients are lower than those for the three scales. Within the Verbal scale, the lowest average reliability coefficient based on the 13 age groups is .82 (Letter-Number Sequencing) to a high of .93 (Vocabulary); within the Performance scale, the lowest reliability coefficient is .70 (Object Assembly) to a high of .90 (Matrix Reasoning).

The test-retest reliability after a 2 to 12 week period (mean=34.6 days) with 394 adults evenly divided into 13 age groups showed that the WAIS-III scores possess adequate stability across time and for all age groups. Performance IQ scores are somewhat less stable than Full Scale and Verbal IQ scores (Wechsler, 1997). For purposes of statistical analysis, these age groups were combined to form 4 groups, and the stability coefficients were .91, .96, .96 and .96 for the Full Scale IQ, .91, .95, .97, and .95 for the Verbal IQ, and .83, .88, .91, and .93 for the Performance IQ. The stability coefficients for the subtests ranged from a low of .48 for Letter-Number Sequencing at 16-29 years to a high of .94 for Information at 75-89 years.

WAIS-III Validity.

As the WAIS-III is a fairly newly published test there are few experimental studies examining the validity of the test; however, since many of the test items have not changed (70%), much of the research on the validity of the WAIS-R is applicable to the WAIS-III. Overall, the WAIS-III appears to show adequate concurrent, criterion, and construct validity (Wechsler, 1997).

Concurrent Validity.

The WAIS-III technical manual (1997) reviews a study that examined the relationship between the WAIS-III and the WAIS-R with 192 adults. The results indicate that the two tests show similar scale and subtest scores. The correlation coefficients for the sample are .94, .86, and .93 for the VIQ, PIQ, and FSIQ scores, respectively. The Full Scale IQ scores were 2.9 points lower on average for the WAIS-III than the WAIS-R.

In another validity study (Sattler, 2002), twenty-six normal individuals were administered both the WAIS-III and the Stanford-Binet:IV (Thorndike, Hage, & Sattler, 1986b). The mean composite score on the Stanford-Binet:IV was 114.8 (SD=12.1), and the mean WAIS-III Full Scale IQ was 113.3 (SD=12.2). Correlations between the

Stanford-Binet:IV and WAIS-III were .78 for the Verbal Scale IQ, .89 for the Performance Scale IQ, and .88 for the Full Scale IQ.

Construct Validity.

Construct validity is defined as the extent to which the test instrument measures the theoretical construct of interest (Messick, 1995). Overall, there is support for the construct validity of the WAIS-III. The factor analyses cited in the WAIS-III manual (Wechsler, 1997) indicate that the test adequately measures the constructs it was designed to measure. The results from Sattler's (2002) factor analyses of the WAIS-III standardization sample indicated that all 14 subtests measure (g) or general intelligence with a moderate or high degree of success. As well, the pattern of intercorrelations provided evidence of convergent and discriminant validity.

Achievement tests.

The Wide Range Achievement Test-3rd Edition (WRAT-3) and the Passage Comprehension subtest from the Woodcock Reading Mastery Test-Revised (WRMT-R) were used in this study. Research suggests that these tests demonstrate adequate reliability and validity (Sattler, 1992). The WRAT-3 is an individually administered test of achievement that is an acceptable screening instrument for potential learning problems. This achievement test is for children aged 5 to adults aged 74 years. It measures performance in the areas of spelling, reading and arithmetic. The spelling subtest measures the ability to write words from dictation; the reading subtest measures the ability to read single words; and the arithmetic subtest measures written and oral mathematical computations and problem solving. The test takes about 20 minutes to administer. The standard score mean is 100 and the standard deviation is 15. The test-retest reliabilities ranged from 0.79 to 0.90 for individuals 16 years and older. This instrument has adequate validity. It is strongly recommended that the WRAT-3 should only be used for screening purposes (Sattler, 1992).

The Woodcock Reading Mastery Test-Revised (WRMT-R) assesses reading skills for children aged 5 years to adults aged 75 years. There are six individually administered subtests. For the purposes of this study, only the passage comprehension subtest was administered. This task is a modified cloze procedure that requires the examinee to use a variety of comprehension and vocabulary skills. A correct response indicates that the examinee has comprehended all of the sentences in the passage. On this test the standard score mean is 100 and a standard deviation of 15. Split-half reliabilities range from about 0.34 to 0.98. The passage comprehension subtest has very good concurrent validity with other achievement measures (e.g. 0.87 with PIAT reading; 0.90 with WJ Reading Achievement).

Behaviour rating scale.

The Attention-Deficit Scales for Adults (ADSA) is a self-report questionnaire that consists of 54 items that address, either directly or indirectly, symptoms associated with Attention-Deficit/Hyperactivity Disorder (ADHD) (Triolo & Murphy, 1996). The items on the ADSA were specifically developed in order to be sensitive to problems among adults with ADHD. Each subject is asked to choose one of five categories with respect to each item: Never; Seldom; Sometimes; Often; or Always. The ADSA is comprised of the ADSA Total Score, and the following nine subscales: (I) Attention-Focus/Concentration; (II) Interpersonal; (III) Behavior-Disorganized Activity; (IV) Coordination; (V) Academic-Theme; (VI) Emotive; (VII) Consistency/Long-Term;

(VIII) Childhood; and (IX) Negative-Social. The ADSA is equipped with a consistency check, to ensure that items have been responded to in a consistent manner.

The normative group consisted of 306 subjects (139 female; 167 male), and had a mean age of 33.95 with a standard deviation of 11.61. Subjects in the normative group met the following criteria: (1) 17 years old or older; (2) no childhood history of problems with attention or hyperactivity; (3) an IQ of 80 or above as estimated by the Shipley Institute of Living Scale (1940); (4) no reported history of drug and/or alcohol abuse; and (5) no reported history of a criminal record.

The Cronbach alpha (internal consistency) value for the 54 items was highly significant at 0.8912. The interrater reliability is good at 0.7329. Cronbach alpha reliability coefficients were also conducted on the nine subscales. The highest coefficients were obtained on the Emotive (.8232), Attention-Focus/Concentration (.7630), and Behavior-Disorganized Activity (.7865) subscales. Low coefficients on the Academic Theme (-.1130) and Childhood (.0196) subscales suggest interpretive caution.

The instrument has above average discriminant validity. The validity study consisted of 89 clinical subjects previously diagnosed with ADHD. No significant differences were found with respect to age and socioeconomic status when comparing the ADHD group to the norm group. With respect to the ADSA total score, the difference between the norm and ADHD group was highly significant with a 45-point difference between the group means. This difference spans approximately two standard deviations.

A step-wise discriminant analysis procedure to predict group membership accepted four subscales in the following order: Consistency/Long-Term, Attention-Focus/Concentration, Behavior-Disorganized Activity, and Negative Social. These subscales provided sufficient discriminant power to classify 88.86% of the entire subject pool correctly. Of the 89 clinical subjects, 73 (82%) were classified correctly, reflecting the sensitivity of this test.

After ensuring that the Internal Consistency score is not above a T-score of 70, the most important clinical score is the total, calculated from all of the 54 items. A T-score greater than or equal to 70 on the ADSA total score is suggestive of clinical impairment. However, a diagnosis of ADHD cannot be made on the basis of this instrument alone.

Personality Test.

The Personality Assessment Inventory (PAI) was developed by Psychological Assessment Resources Inc (Morey, 1991) to provide a standardized clinical assessment of adult personality (18 years and older). The instrument is self-administered and contains 344 items. The manual recommends that "fourth grade reading level" is needed to complete the inventory. The instrument offers a simple scoring procedure aided by an answer sheet. The client's profile is comprehensive and contains four major sections that include 4 validity scales, 11 clinical scales, 5 treatment scales and 2 interpersonal scales. Nine of the clinical scales comprise subscales that offer more sensitive measurement information. For example, the clinical scale 'depression' includes 'cognitive', 'affective' and 'physiological' sub-scales, while the scale 'schizophrenia' includes three subscales; a 'psychotic experiences' subscale, a 'social detachment' subscale and a 'thought disorder' subscale. The four validity scales include: inconsistency, infrequency, negative impression and positive impression. The PAI has 11 clinical scales that measure the following: Somatic Complaints, Anxiety, Anxiety Related Disorders, Depression, Mania, Paranoia, Schizophrenia, Borderline Features, Antisocial Features, Alcohol Problems, and Drug Problems. The treatment scales include the following: Aggression, Suicide Ideation, Stress, Non-support, and Treatment rejection. The PAI has two scales that measure interpersonal characteristics along the dimensions of dominance and warmth.

Results are expressed as T scores with a mean of 50 and a standard deviation of 10. Scores over 70 are interpreted as clinically significant. The normative data are based on a general population (N=1000), a student population (N=1051) and a clinical population (N=1246). The internal consistency (coefficient alpha) values for the three samples range from .81 to .86. Test-retest correlations ranged from .29 to .94 for the full scales and from .67 to .90 for the subscales over a 24-day period. The instrument has above average construct validity, and discriminant validity (Morey, 1991).

Chapter Four

Results

Preliminary Examination of Differences Between ADHD Subtypes

The sample was initially divided into two groups. One group consisted of those diagnosed currently with ADHD-Inattentive Type (n=32). The second group consisted of those participants having ADHD-Combined Type (n=16). A multivariate analysis of variance (MANOVA) procedure was used to investigate whether there were differences for group on the WAIS-III FSIQ, VIQ, PIQ, VCI, POI, WMI, and PSI variables. The results of this analysis were not significant, Wilks' Lambda=0.78, F (7, 40)=1.59, p=.165. The power effect for group was 0.58. Table 3 shows a summary of the WAIS-III IQ and factor index means by group.

Table 3

Summary of IQ and Factor Index Means by Group

Measures	Group		F (1,46)
	ADHD (Inattentive)	ADHD (Combined)	
FSIQ	108.97 (12.77)	105.06 (11.07)	1.08
VIQ	108.68 (14.24)	105.62 (10.60)	0.57
PIQ	107.47 (12.80)	103.18 (12.25)	1.22
VCI	110.15 (14.82)	111.25 (11.13)	0.06
POI	110.90 (13.43)	106.50 (14.97)	1.06
WMI	97.81 (11.64)	94.18 (12.03)	1.01
PSI	97.46 (11.31)	97.68 (13.07)	0.03

Note: *$p< 0.05$
Standard deviations enclosed in parentheses.

In order to maximize the sample size for the group with ADHD and hence statistical power for all subsequent analyses, all participants with ADHD were recombined into a single group (N=48). General descriptive statistics for the total sample will be provided, followed by inferential statistics.

Sample Characteristics

Table 4 illustrates the means and standard deviations for FSIQ, VIQ, PIQ, VCI, POI, WMI and PSI scores for the total sample. The FSIQ, VIQ and PIQ means were within the average range. The mean verbal comprehension index score was within the high average range, and the remaining mean index scores were in the average range.

Table 4

WAIS-III Mean IQ and Factor Index Scores for the Total Sample

	Mean	SD
ADHD (N=48)		
Verbal IQ	107.67	13.11
Performance IQ	106.04	12.66
Full Scale IQ	107.67	12.25
Verbal Comprehension	110.52	13.59
Perceptual Organization	109.44	13.96
Working Memory	96.60	11.77
Processing Speed	97.54	11.79

Subtest Scores

Table 5 displays the total sample means and standard deviations for the WMI and PSI subtests. The mean Digit Span subtest score fell within the low average range, while the remaining subtest scores fell within average limits.

Table 5

WAIS-III Mean Subtest Scores for Sample

	Mean	SD
Arithmetic	10.23	3.24
Digit Span	8.79	2.86
Letter/Number Sequencing	9.35	2.06
Digit Symbol-Coding	9.27	2.45
Symbol Search	9.89	2.46

Stage One Of Data Analysis

The Statistical Package for the Social Sciences (SPSS) was used to analyze the data and to answer research questions one through five. A Repeated Measures multivariate analysis of variance (MANOVA) procedure with four dependent variables was used to investigate whether there were significant differences on each of the variables. This procedure is essentially a more complex and powerful form of a Repeated Measures ANOVA. Research questions one to five were addressed through planned contrasts within the MANOVA. The Bonferroni post hoc test was used to compare group mean differences. The purpose for using the Bonferroni post-hoc comparison method was that it allows any number of simple or complex planned contrasts while keeping the Type-I error rate down. (Glass & Hopkins, 1984).

The WAIS-III factor index scores VCI, POI, WMI and PSI served as dependent variables. An alpha level of .05 was used for the MANOVA analysis and post-hoc analyses.

MANOVA Results.

A repeated measures MANOVA procedure was used to investigate whether there were differences among the four dependent variables. The MANOVA results were interpreted using the Hummel and Sligo two-stage approach (Finn, 1974). In the first stage the omnibus MANOVA result, such as Wilks' Lambda, was examined. The results of this analysis revealed that the multivariate main effect was supported, Wilks' Lambda = 0.48, F (3,44) = 15.96, p<.001. The effect size was 0.52. Table 6 displays a summary of the MANOVA results.

Table 6

Summary Repeated Measures MANOVA Design

Source	Wilks' Lambda	df	F	Power
Factor One	.48	3	15.96*	1.00
Error		44		

Note *p<.008

MANOVA Results for Gender, Age and Education Groups.

Repeated Measures multivariate analysis of variance (MANOVA) procedures with four dependent variables were used to investigate whether there were significant differences on each of the variables across groups (i.e. gender, age and education). The MANOVA results for gender, Wilks' Lambda = 0.94, F (2, 45) = 1.49, p =.24, age, Wilks' Lambda = 0.64, F (4, 39)=0.88, p =.61, and education, Wilks' Lambda = 0.91, F (8, 84)=0.52, p =.83 were not significant.

Research Question 1:

Does the mean Working Memory Index score differ significantly from the mean Verbal Comprehension Index score for the ADHD sample?

The Bonferroni post-hoc test was used to compare group mean differences. The alpha level was set at 0.05. Results from the pairwise comparisons indicated significantly lower WMI scores compared to VCI scores for the ADHD sample (t (47) = -7.35, p<.001).

Research Question 2:

Does the mean Working Memory Index score differ significantly from the mean Perceptual Organization Index score for the ADHD sample?

The Bonferroni post-hoc test was used to compare group mean differences. The alpha level was set at 0.05. Results from the pairwise comparisons indicated significantly lower WMI scores compared to POI scores for the ADHD sample (t (47) = -6.20, p<.001).

<u>Research Question 3:</u>

Does the mean Working Memory Index score differ significantly from the mean Processing Speed Index score for the ADHD sample?

The Bonferroni post-hoc test was used to compare group mean differences. The alpha level was set at 0.05. Results from the pairwise comparisons did not indicate any significant differences between WMI and PSI scores for the ADHD sample (t (47) = 0.46, p=0.65).

<u>Research Question 4:</u>

Does the mean Processing Speed Index score differ significantly from the mean Verbal Comprehension Index score for the ADHD sample?

The Bonferroni post-hoc test was used to compare group mean differences. The alpha level was set at 0.05. Results from the pairwise comparisons indicated significantly lower PSI scores compared to VCI scores for the ADHD sample (t (47) = -5.81, p<.001).

<u>Research Question 5:</u>

Does the mean Processing Speed Index score differ significantly from the mean Perceptual Organization Index score for the ADHD sample?

The Bonferroni post-hoc test was used to compare group mean differences. The alpha level was set at 0.05. Results from the pairwise comparisons indicated significantly lower PSI scores compared to POI scores for the ADHD sample (t (47) = -5.01, p<.001).

In summary, results indicated significantly lower mean Working Memory Index scores compared to the mean Verbal Comprehension Index and Perceptual Organization

Index scores for the ADHD sample. The mean Working Memory Index score did not differ significantly from the mean Processing Speed Index score for the ADHD sample. The mean Processing Speed Index scores were significantly lower than the mean Verbal Comprehension and Perceptual Organization Index scores for the ADHD sample.

Stage Two Of Data Analysis

Independent Samples T-Tests (Welch t' test) were used to answer research questions six and seven.

Research Question 6:

Does the mean Working Memory Index score for the ADHD sample differ significantly from the mean Working Memory Index score of the standardization sample?

WM Factor, AR, DS and LNS Subtest Variables

Results from Independent Samples T-Test.

The ADHD sample (N=48) was compared to the WAIS-III standardization sample (N=2450) on the WMI factor. Independent Samples T-Tests (Welch t' test) were used to investigate whether there were differences for group (i.e. ADHD sample and standardization sample) on the WMI factor, DS, LNS and AR variables. The standardization sample has a mean of 100 and a standard deviation of 15 on the Working Memory Index. The standardization sample has a mean of 10 and a standard deviation of 3 on the individual subtests.

The ADHD sample (M = 96.60, SD = 11.77) had a significantly lower mean Working Memory Index score compared to the standardization sample (M = 100.00, SD = 15.00), $t'(50) = -1.96$, $p<.05$. The effect size was 0.23. The ADHD sample had significantly lower mean DS (M = 8.79, SD = 2.85) subtest (t'(49) = -2.89, $p<.05$), and LNS (M = 9.35, SD = 2.05) subtest (t'(49) = -2.14, $p<.05$) scores compared to the standardization sample. The effect sizes were 0.40 and 0.22 respectively. Results indicated no group differences on the Arithmetic subtest (M = 10.22, SD = 3.24) compared to the standardization sample (M = 10.00, SD = 3.00), t'(49) = 0.48, $p>.05$.

Research Question 7:

Does the mean Processing Speed Index score for the ADHD sample differ significantly from the mean Processing Speed Index score of the standardization sample?

PS Factor, DS-Coding and SS Subtest Variables

Results from Independent Samples T-Tests (Welch t' test).

The ADHD sample (N=48) was compared to the WAIS-III standardization sample (N=2450) on the PSI factor. Independent Samples T-Tests (Welch t' test) were used to investigate whether there were differences for group on the PSI Factor, DS-Coding and SS Subtest Variables. The standardization sample has a mean of 100 and a standard deviation of 15 on the Processing Speed Index. The standardization sample has a mean of 10 and a standard deviation of 3 on the individual subtests.

The ADHD sample (M = 97.54, SD = 11.78) did not have a significantly lower mean Processing Speed Index score compared to the standardization sample (M = 100.00, SD = 15.00), t'(50) = -1.42, $p>.05$. The ADHD sample (M = 9.27, SD = 2.45) had a significantly lower mean DS-Coding score compared to the standardization sample (M = 10.00, SD = 3.00), t'(55) = -2.02, $p<.05$. The effect size was 0.24. Results indicated no group differences on the Symbol Search subtest (M = 9.89, SD = 2.46), $t'(56) = -0.28$, $p > .05$ compared to the standardization sample.

Stage Three Of Data Analysis

Profile analysis was used to answer research questions eight, nine, ten and eleven. Sattler (2002) suggests a combined approach to profile analysis whereby differences between IQ and scaled scores are evaluated based on statistical significance, as well as on base rates of such differences that occur in the standardization sample.

Research Question 8:

What percentage of the ADHD sample shows significant WMI<VCI and WMI<POI differences?

To answer this question, differences were calculated between the WMI and VCI, WMI and POI factors for the ADHD sample. Next, the differences were examined for statistical significance at the $p < .05$ level according to the tables found in Appendix B, Table B.1 of the WAIS-III Administration and Scoring Manual. The values for a specific age group were used to examine differences between an examinee's factor index scores. A summary of the percentages of the ADHD sample showing significant WMI<VCI and WMI<POI factor differences derived from the WAIS-III tables is presented in Table 7.

Table 7

Percentage of ADHD Sample showing significant WMI<VCI, and WMI<POI score differences.

	ADHD Sample (N=48)
WMI<VCI	62.50
WMI<POI	56.25

Note: WMI<VCI=difference between Working Memory and Verbal Comprehension factor index scores; WMI<POI=difference between Working Memory and Perceptual Organization factor index scores. Level of Significance<.05. Calculations based on tables in Appendix B, Table B.1 of the WAIS-III Administration and Scoring Manual. (Wechsler, 1997).

Research Question 9:

What percentage of the ADHD sample shows significant PSI<VCI, and PSI<POI factor differences?

Differences were calculated between the PSI and VCI, and PSI and POI factors for the ADHD sample. Next, differences were examined for statistical significance at the $p<.05$ level according to the tables found in Appendix B, Table B.1 of the WAIS-III Administration and Scoring Manual. The values for a specific age group were used to examine differences between an examinee's factor index scores.

A summary of the percentages of the ADHD sample showing significant PSI<VCI and PSI<POI factor differences, alpha<.05, derived from the WAIS-III tables is presented in Table 8.

Table 8

Percentage of ADHD Sample showing significant PSI<VCI, and PSI<POI score differences.

	ADHD Sample (N=48)
PSI<VCI	52.00
PSI<POI	54.17

Note: PSI<VCI=difference between Processing Speed and Verbal Comprehension factor index scores; PSI<POI=difference between Processing Speed and Perceptual Organization factor index scores. Level of Significance<.05. Calculations based on tables in Appendix B, Table B.1 of the WAIS-III Administration and Scoring Manual. (Wechsler, 1997).

Summary

Results indicated that approximately 63% of the ADHD sample had significantly lower WMI factor index scores compared to their VCI factor index scores, and 56% of the ADHD sample had significantly lower WMI factor index scores compared to their POI factor index scores. In addition, results indicated that 52% of the ADHD sample had significantly lower PSI factor index scores compared to their VCI factor index scores, and 54% of the ADHD sample had significantly lower PSI factor index scores compared to their POI factor index scores.

Although the WAIS-III manual and Sattler (2002) recommend using the statistical significance of the difference between two index scores as one approach to interpreting index score differences, several authors contend that difference score interpretations should be approached with caution (Caruso, Witkiewitz, Youngstrom & Glutting, 2001; Charter, 2001). The main problem with interpreting difference scores is that they tend to be unreliable because the scores on which they are based are often strongly correlated. The high degree of correlation among the IQ, factor and subtest scores produces large confidence intervals. Charter (2001) suggests that when using a regression-based approach on a VIQ-PIQ discrepancy, those examinees with a VIQ-PIQ score of 15 points, 95% will have true discrepancy scores between 2.1 and 20.4 points. The wide range of possible true difference scores makes it difficult to interpret.

Therefore, using a dual approach to interpreting index score differences is recommended (Sattler, 2002). The second approach involves comparing WAIS-III index score differences to the frequency of the differences in the standardization sample. Caruso et al. (2001) suggest that the dual approach is stronger because measurement reliability can be taken into account when determining the statistical significance of the difference and then examine the importance of the difference by associating the examinee's difference score with a relevant comparison group. Knowing the frequency with which a particular difference occurs in the standardization sample allows us to assess the rarity or abnormality of that difference. Research questions ten and eleven were analyzed using this approach.

Research Question 10:

How do those percentages of the ADHD sample showing significant WMI<VCI and WMI<POI factor differences compare with the estimated base rates or the frequency of such differences occurring in the standardization sample?

Since base rates for a given difference between indexes vary across ability levels with larger differences being less significant and more frequent in higher ability groups, the sample percentages were compared to the cumulative percentages in the standardization sample that are listed in Tables D.3 to D.5 (pages 304-309) in the WAIS-III/WMS-III Technical Manual. Sattler (2002) recommends that since the cumulative percentages in Table D.3 to D.5 are absolute values (i.e. they include values for both directions), the frequencies in Tables D.3 to D.5 can be divided by two to get an estimate of the base rate in one direction in the standardization sample.

For this study the amount of discrepancy that was found to occur in the standardization sample less than or equal to 15% of the time in one direction was considered unusual or rare (Sattler, 2002). This cut-off score was used in the calculation of percentages for the study sample. Table 9 shows the percentage of the ADHD sample WMI<VCI and WMI<POI score differences that occurred in less than 15% of the standardization sample in one direction.

Table 9

Percentage of ADHD Sample showing significant WMI<VCI and WMI<POI score differences that occurred in less than 15% of the standardization sample in one direction.

	ADHD Sample (N=48)
WMI<VCI	47.92
WMI<POI	45.83

Note: WMI<VCI=difference between Working Memory and Verbal Comprehension factor index scores; WMI<POI=difference between Working Memory and Perceptual Organization factor index scores. Calculations based on Tables D.3 to D.5 of the WAIS-III/WMS-III Technical Manual.

Research Question 11:

How do those percentages from the ADHD sample showing significant PSI<VCI, and PSI<POI factor differences compare with the estimated base rates or the frequency of such differences occurring in the standardization sample?

To answer this question, the percentages from this sample were compared to the cumulative percentages in the standardization sample that are listed in Tables D.3 to D.5 (pages 304-309) in the WAIS-III/WMS-III Technical Manual. The amount of discrepancy that occurred in the standardization sample less than or equal to 15% of the time in one direction was considered rare or unusual and was used as a cut-off score for the present study. The cumulative percentages in Tables D.3 to D.5 were divided by two to get an estimate of the base rate in one direction in the standardization sample. Table

10 shows the percentage of the ADHD sample PSI<VCI and PSI<POI score differences that occurred in less than 15% of the standardization sample in one direction.

Table 10

Percentage of ADHD Sample showing significant PSI<VCI and PSI<POI score differences that occurred in less than 15% of the standardization sample in one direction.

	ADHD Sample (N=48)
PSI<VCI	43.75
PSI<POI	47.92

Note: PSI<VCI=difference between Processing Speed and Verbal Comprehension factor index scores; PSI<POI=difference between Processing Speed and Perceptual Organization factor index scores. Calculations based on Tables D.3 to D.5 of the WAIS-III/WMS-III Technical Manual.

Summary

Results indicated that approximately 48% of the ADHD sample had discrepancies between their Working Memory and Verbal Comprehension factor index scores, and approximately 46% of the ADHD sample had Working Memory and Perceptual Organization factor index score discrepancies that were deemed to be rare in the standardization sample. In addition, results indicated that approximately 44% of the ADHD sample had Processing Speed and Verbal Comprehension factor index score discrepancies that were considered rare in the standardization sample. Results suggested that approximately 48% of the ADHD sample had Processing Speed and Perceptual Organization factor score discrepancies that were considered rare in the standardization sample.

Research Question 12:

Does the mean difference between the Digits Forward and Digits Backward components of the Digit Span subtest from the ADHD sample differ significantly from those scores of the standardization sample?

Results from Independent Samples T-Tests (Welch t').

Independent Samples T-Tests (Welch t' test) were used to investigate whether there were differences for ADHD sample on the Digits Forward and Digits Backward components of the Digit Span subtest when compared to the standardization sample. Sample means and standard deviations were compared to the All Ages category means and standard deviations from Table B.7 (p. 213) of the WAIS-III Administration and Scoring Manual. Results were not significant, $t'(83) = -1.95$, $p > .05$, suggesting that the mean differences between Digits Forward and Digits Backward for the ADHD sample did not differ from mean differences in the standardization sample. Table 11 presents a summary of the means and standard deviations of the differences between Digits Forward and Digits Backward for the ADHD sample and the standardization sample.

Table 11

Summary of Mean Differences Between Digits Forward and Digits Backward for the ADHD Sample and Standardization Sample

Measures	Group		
	ADHD Sample (N=48)	Standardization Sample (N=2450)	(t')
DF-DB (All Ages)	1.42 (1.07)	1.72 (1.35)	-1.94

Note: *p<0.05
DF-DB= Digits Forward minus Digits Backward. Standard deviations enclosed in parentheses. Calculations based on All Ages category of Table B.7 (p.213) of the WAIS-III Administration and Scoring Manual

Digits Forward-Digits Backward Age Group Comparisons

Independent Samples T-Tests (Welch t' test) were used to investigate whether there were differences for age group on the Digits Forward and Digits Backward components of the Digit Span subtest when compared to the standardization sample. Sample means and standard deviations of each age group were compared to the separate age group means and standard deviations from Table B.7 (p. 213) of the WAIS-III Administration and Scoring Manual. Results were not significant for any of the comparisons suggesting that the mean differences between Digits Forward and Digits Backward for each age group in the sample did not differ from mean differences in the corresponding age group from the standardization sample. Table 12 presents a summary of the means and standard deviations of the differences between Digits Forward and Digits Backward for each age group of the ADHD sample and the standardization sample.

Table 12

Summary of Mean Differences Between Digits Forward and Digits Backward of Each Age Group for the ADHD Sample and Standardization Sample.

Age	Group		
	ADHD Sample (N=48)	Standardization Sample (N=2450)	(t')
18-19	1.50 (0.85)	1.62 (1.41)	-0.45
20-24	1.36 (1.06)	1.70 (1.31)	-1.27
25-29	2.00 (1.41)	1.64 (1.48)	0.62
30-34	1.00 (1.15)	1.74 (1.39)	-1.68
35-44	1.50 (0.57)	1.70 (1.38)	-0.66

Note: $^{*}p<0.05$
Mean differences between Digits Forward and Digits Backward. Standard deviations enclosed in parentheses. Calculations based on separate age groups of Table B.7 (p. 213) of the WAIS-III Administration and Scoring Manual.

Research Question 13:

How do the percentages of differences between Digits Forward and Digits Backward from the ADHD sample compare with the frequency of such differences occurring in the standardization sample?

To answer this question, the percentages of differences between Digits Forward and Digits Backward from the ADHD sample were compared to the percentages of such differences found in Table B.7 (p. 213) of the WAIS-III Administration and Scoring

Manual. Table 13 presents a summary of percentages of differences between Digits Forward and Digits Backward for the ADHD sample and the standardization sample.

Table 13

Percentage of Differences Between Longest Digits Forward and Digits Backward Spans for the ADHD Sample and Standardization Sample.

Longest Forward Span Minus Longest Backward Span	Total Sample (N=48)	Standardization Sample (N=2450)
7 points	0.00	0.00
6 points	0.00	0.30
5 points	0.00	1.80
4 points	2.10	7.30
3 points	14.58	17.30
2 points	29.17	29.10
1 point	29.17	27.30
0 points	22.92	13.10
-1 point	2.10	2.90

Results of this analysis suggest that the percentages of differences between Digits Forward and Digits Backward in the study sample are comparable to the percentages of such differences in the standardization sample.

Summary

In summary, results indicated that the mean Working Memory Index score for the ADHD sample was significantly lower than the Verbal Comprehension Index and Perceptual Organization Index scores. The mean Working Memory Index score did not differ significantly from the mean Processing Speed Index score for the ADHD sample. In addition, the mean Processing Speed Index score was significantly lower than the mean Verbal Comprehension and Perceptual Organization Index scores for the ADHD sample. The ADHD sample obtained a significantly lower mean Working Memory Index score compared to the standardization sample. Although significant groups differences were noted on the Digit Span and Letter-Number Sequencing subtests, no group differences were found on the Arithmetic subtest. The mean differences between Digits Forward and Digits Backward for the ADHD sample did not differ from mean differences in the standardization sample. The ADHD sample did not have a significantly lower mean Processing Speed Index score compared to the standardization sample. However, the ADHD sample had a significantly lower mean DS-Coding subtest score compared to the standardization sample.

With respect to the frequency of discrepancy scores in the standardization sample, results indicated that approximately 48% of the ADHD sample had discrepancies between their Working Memory and Verbal Comprehension factor index scores, and approximately 46% of the ADHD sample had Working Memory and Perceptual Organization factor index score discrepancies that were deemed to be rare in the standardization sample. In addition, results indicated that approximately 44% of the ADHD sample had Processing Speed and Verbal Comprehension factor index score discrepancies that were considered rare in the standardization sample. Results suggested that approximately 48% of the ADHD sample had Processing Speed and Perceptual Organization factor score discrepancies that were considered rare in the standardization sample. The next chapter will review present study findings within the context of theoretical implications and directions for future research.

Chapter Five

Discussion

We begin this chapter with a review of the WAIS-III Working Memory and Processing Speed Index results. Findings are interpreted within the information-processing framework that was outlined in Chapter Two. Specifically, Working Memory Index results are conceptualized within Baddeley's model of working memory. Processing Speed Index results are conceptualized within the following two models: Baddeley's model of working memory and Jensen's model of intelligence. In addition, present study findings are conceptualized within Barkley's theory of frontal lobe disinhibition in ADHD. Next, findings from this study are compared to previous research. Diagnostic and treatment implications are reviewed, followed by a description of study limitations, delimitations, recommendations for future research and conclusions.

Working Memory Index results.

Results indicated significantly lower mean Working Memory Index scores compared to the mean Verbal Comprehension Index and Perceptual Organization Index scores for the sample of adults with ADHD. In other words the ADHD sample achieved higher scores on tasks that measured their long-term memory for factual information, verbal reasoning and expression skills when compared to their auditory working memory abilities. Moreover, the ADHD sample obtained significantly higher scores on tasks that measured nonverbal visual reasoning and spatial skills compared to their auditory working memory abilities. The mean Working Memory Index score did not differ significantly from the mean Processing Speed Index score for the ADHD sample.

The ADHD sample had a significantly lower mean Working Memory Index score compared to the WAIS-III standardization sample. In addition, the ADHD sample had significantly lower mean Digit Span and Letter-Number Sequencing subtest scores compared to the standardization sample. No differences were found between groups on the Arithmetic subtest.

Furthermore, results indicated that approximately 48% of the total sample had discrepancies between their Working Memory and Verbal Comprehension Index scores, and approximately 46% of the total sample had Working Memory and Perceptual Organization Index score discrepancies that were deemed to be rare in the standardization sample.

No significant differences were found between the ADHD sample and the standardization sample on the Digits Forward and Digits Backward components of the Digit Span subtest.

Baddeley's model of working memory

Since this model was discussed in the literature review, only a general review of the model is provided. Working memory can be defined as a dynamic short-term memory storage system of limited capacity, used to hold information that is being processed. Baddeley's model of working memory consists of two interacting subsystems, and a central executive. The two subsystems are the phonological loop, where verbal material is stored and processed, and the visuospatial sketchpad, where visual and spatial material is stored and processed (Baddeley, 2002). The phonological loop component involves some process of subvocal rehearsal to maintain the memory trace.

The WAIS-III Working Memory Index emphasizes the verbal (phonological loop) component of Baddeley's model of working memory because the tasks require the storage and processing of auditory material. The arithmetic subtest requires verbal rehearsal strategies, the storing and manipulation of information, and mental computation. The Digits Forward task emphasizes the storage component of working memory, while the Digits Backward task emphasizes both the storage and processing of information simultaneously. The Letter-Number Sequencing is a more complex working memory task because it emphasizes the storage and manipulation of material.

Given that the tasks on the Working Memory Index involve the phonological loop component of Baddeley's model, present study findings suggest that the ADHD sample may have verbal working memory impairments. It is generally accepted that the phonological loop system is affected by speed of articulatory rehearsal. The faster information is rehearsed subvocally, the more items can be maintained within the phonological loop. Therefore, it is suggested that a reduction in the speed of rehearsal would have a negative impact on verbal working memory functioning. The phonological loop seems to have evolved to aid phonological long-term learning as in the case of acquiring new words in either one's native or a foreign language. In addition, reduced verbal working memory capacity has been associated with reading comprehension deficits.

Processing Speed Index results

The mean Processing Speed Index scores were significantly lower than the mean Verbal Comprehension and Perceptual Organization Index scores for the ADHD sample. This suggests that the ADHD sample had better developed verbal reasoning, and visual spatial abilities when compared to their ability to work quickly on a series of paper and pencil copying tasks. However, the mean Processing Speed Index score for the ADHD sample did not differ from the standardization sample. With respect to the individual subtests, the ADHD sample had a significantly lower mean DS-Coding score compared to the standardization sample. Results indicated no differences between the ADHD sample and the standardization sample on the Symbol Search subtest. This suggests that while the ADHD sample may have psychomotor speed impairments, no difficulties were noted with respect to mental speed.

In addition, results indicated that approximately 44% of the total sample had Processing Speed and Verbal Comprehension Index score discrepancies that were considered rare in the standardization sample. Results suggested that approximately 48% of the total sample had Processing Speed and Perceptual Organization Index score discrepancies that were considered rare in the standardization sample.

Baddeley 's Model of Working Memory

The Processing Speed Index can be interpreted within the visuospatial sketchpad component of Baddeley's model of working memory. The visuospatial sketchpad is a working memory system where visual images are maintained and manipulated. The tasks on the Processing Speed Index involve the visuospatial sketchpad because the examinee is required to maintain visual information in working memory before providing a motor response. Kaufman and Lichtenberger (1999) suggest that a weak visual working memory can lower the Processing Speed Index score because the Digit Symbol-Coding and Symbol Search subtests depend to a considerable extent on the ability to retain abstract visual stimuli for brief periods of time.

Present study findings can be viewed as supporting visual working memory impairments in adults with ADHD. Given that the Processing Speed Index and subtests are largely visual in nature and emphasize visual working memory, the ADHD sample may be showing impairment of the visuospatial sketchpad component of Baddeley's model of working memory. Impairments to the visuospatial sketchpad component would interfere with the ability to use imagery for learning. The Processing Speed Index also measures speed of processing visual information, which can be better explained within Jensen's model of intelligence. The next section explains the PSI results within this theory.

Jensen's model of intelligence

Jensen's (1982 a, b, 1998) model of intelligence hypothesizes that processing speed is directly related to intelligence. It is assumed that the brain is an information processing system with a limited capacity. Therefore, speed is an important component because more operations can be done within a certain amount of time without overloading the system.

Overall, the relationship between processing speed and intelligence has been supported in several reaction time experiments (Kranzler & Jensen, 1989, Vernon, 1998). The Processing Speed Index can be interpreted within Jensen's model of intelligence because the Digit Symbol-Coding and Symbol Search subtests are highly speed dependent. With respect to speed of processing, Symbol Search taps mental speed, whereas Digit Symbol-Coding measures both mental and psychomotor speed. The supplemental Digit Symbol-Copy subtest helps to determine whether perceptual accuracy and speed are affecting a person's score while ruling out the effect of memory.

Prifitera, Weiss and Saklofske (1998) argue that the Processing Speed Index is related to higher order cognitive functions because learning involves a combination of simple information processing (e.g. reading) and complex processing (e.g. reasoning). For example, if an adult is slower at processing routine information such as visual scanning and tracking, they may find the task of understanding new information more time-consuming and challenging.

Present study findings can be viewed as supporting processing speed difficulties in adults with ADHD. Next, results for the ADHD sample will be further explored within Barkley's theory of frontal lobe disinhibition.

Barkley's theory of frontal lobe disinhibition

Since this model was more fully explained in the literature review section, only a brief review of the model is provided. There are three components to his model. The first component involves three kinds of behavioral inhibition: 1) inhibition of a prepotent response, 2) stopping an ongoing response, and 3) interference control). The second component includes the four executive functions: 1) non-verbal working memory, 2) verbal working memory, 3) self-regulation of affect/motivation/arousal, and 4) reconstitution. The third component involves the motor control and execution of behaviors.

The present discussion focuses on those aspects of Barkley's model that are likely related to the WAIS-III WM and PS Indexes. These include non-verbal working memory, verbal working memory, and motor control.

Non-Verbal Working Memory Impairments.

Barkley (1997b, 1998a) predicts that individuals with ADHD would display impairments in non-verbal working memory (i.e., visual working memory). Non-verbal working memory involves the individual's ability to hold information in support of efforts to analyze, manipulate, and respond to the information that may include various combinations of sensory inputs. Nonverbal working memory is believed to comprise the visuospatial sketchpad component of Baddeley's model of working memory (Barkley, 1997b, Barkley et al., 2001). The WAIS-III Processing Speed Index assesses visual working memory ability, visual-motor coordination and speed. Present findings indicated that the ADHD sample scored significantly lower on the PS Index when compared to the VC and PO Indexes. Moreover, the present sample scored significantly lower on the DS-Coding subtest compared to the WAIS-III standardization sample.

These findings are consistent with Barkley's hypothesis that individuals with ADHD show impaired performance on non-verbal working memory tasks. In addition, findings are consistent with research that suggests the PS Index and subtests are lower in adults with ADHD (Klee et al, 1986; Murphy et al., 2001; Wechsler, 1997). Present study results are consistent with research that utilized neuropsychological instruments similar to the subtests on the WAIS-III Processing Speed Index (Johnson et al., 2001).

<u>Verbal Working Memory Impairments.</u>

Barkley (1997b, 1998a) posits that individuals with ADHD would have impairments in verbal working memory. Verbal working memory or internalization of speech, is believed to comprise the phonological loop component of Baddeley 's model of working memory (Barkley, 1997b, 1998a). The WAIS-III WM Index is deemed to be a good measure of verbal working memory ability. Present findings indicated that adults with ADHD scored significantly lower on the WM Index when compared to the VC and PO indexes. Moreover, the mean WM Index score for the ADHD sample was significantly lower than that of the WM Index score of the WAIS-III standardization sample. No significant group differences were found on the Arithmetic subtest. It should be noted that the Arithmetic subtest is not a pure measure of auditory working memory because it also involves numerical ability. Although the mean Digit Span subtest for the ADHD sample was significantly lower than the WAIS-III standardization sample, no differences were found between the Digits Forward and Digits Backward components of the subtest. This finding is interesting because one would predict that the ADHD sample would experience greater difficulty on the Digits Backward task, as it is a more complex working memory task. It is possible that the ADHD sample has difficulty with both the storage and processing components of the Digit Span task.

Present study findings are consistent with Barkley's prediction that individuals with ADHD show impairments in verbal working memory functioning. In addition, findings are consistent with related research that suggests the WAIS-R and WAIS-III Working Memory Index and subtests are lower in adults with ADHD compared to control groups (Biederman et al., 1993; Murphy et al., 2001). Present study results are also consistent with research that utilized neuropsychological instruments considered to be similar to the WM Index subtests (Johnson et al., 2001; Riordan et al., 1999).

Motor Control Impairments.

Barkley (1998a) hypothesizes that individuals with ADHD have difficulties with motor control. The motor control component of Barkley's model is directly influenced by behavioural inhibition and the four executive functions as they attempt to bring the motor system under internal control. For example, the working memory executive function provides feedback from previous responses held in mind in order to change subsequent responses. Therefore, a deficient working memory system would interfere with the motor control component of Barkley's model. The WAIS-III PS Index subtests assess fine motor control or graphomotor output.

Present study findings are consistent with Barkley's hypothesis because the ADHD sample obtained significantly lower Digit Symbol-Coding scores in comparison to the standardization sample. Moreover, these results are consistent with cognitive and neuropsychology research supporting motor control impairments in adults with ADHD (Johnson et al., 2001; Riordan et al., 1999).

In summary, findings from the present study lend support to Barkley's (1997b, 1998a) frontal lobe dysfunction hypothesis of ADHD and to previous research that examined the cognitive and neuropsychological functioning of individuals with ADHD.

ADHD in Adults

The present investigation revealed that adults with ADHD have lower WAIS-III WM and PS Index scores when compared to the VC and PO Index scores. As well, the ADHD sample obtained significantly lower WM Index scores compared to the standardization sample. These findings are similar to WISC-III patterns in children with ADHD (Anastopoulos et al., 1994; Lufi et al., 1990; Reinecke et al., 1999; Saklofske et al., 1994; Wechsler, 1991).

Present study results support findings from longitudinal and follow-up studies that suggest at least 30 to 70% of those diagnosed with ADHD as a child do not outgrow their symptoms (Barkley, 2002; Weiss & Hechtman, 1993; Weiss et al., 1999; Wender, 1995). This wide range in prevalence rates is due to some of the studies including adults with only one impairing symptom such as impulsivity. Many participants in Weiss and Hechtman's study (1993) did not meet full DSM-IV diagnostic criteria for ADHD.

ADHD Subtype results

The present investigation did not find differences between the two ADHD subtypes (inattentive and combined) on the WAIS-III IQ and Factor Index scores. This finding is consistent with previous research examining subtype differences on cognitive and neuropsychological measures (Barkley et al., 1992; Hynd et al., 1991; Lorys et al., 1990; Murphy et al., 2001).

It is possible that the lack of subtype differences in the present study is due to a problem inherent in the DSM-IV diagnostic criteria. Research suggests an age-related decline in hyperactive symptoms (Murphy et al., 2002; Weiss & Hechtman, 1993). Therefore, an adult who was diagnosed with ADHD combined type in childhood may not have enough current symptoms of hyperactivity to qualify for the combined type. Instead, that individual may be diagnosed with ADHD-inattentive type. Samples of adults diagnosed with ADHD-inattentive type are no longer a homogeneous group because some of them actually had the combined type earlier in life and others have been continuously of the inattentive type. As such, the issue of heterogeneity within the ADHD-inattentive subtype may be a confounding factor in studies that examine subtype differences.

Another reason for the lack of subtype difference could be due to the constrained nature of the tasks on the WAIS-III. These tasks are measuring auditory working memory abilities and visual processing speed abilities. Since both subtypes of ADHD (i.e. inattentive and combined types) share at least six of the nine inattention symptoms, it is probable that the third and fourth factors on the WAIS-III are measuring symptoms from the inattentive list of symptoms. This means that both subtypes of ADHD would tend to have difficulty following verbal directions, following conversations, listening to lectures, losing things necessary for tasks and activities, and not giving close attention to details in schoolwork, work or other activities such as driving.

Diagnostic Implications

Although the present study findings are intriguing, WM and PS Index scores alone cannot be used to diagnose ADHD. They can, however, be an important part of the diagnostic process. At the present time there is not a definitive battery of tests used in the diagnosis of adults with ADHD. In the next section, the writer suggests a battery of tests that may be useful in the diagnosis of ADHD in adulthood.

Components of the ADHD assessment.

It is recommended that the diagnosis of ADHD be determined through a multistep process. First, the examiner should explain the nature of the procedures and the issues of confidentiality prior to obtaining consent to proceed with the assessment. The next step in the diagnostic process includes a thorough clinical interview. The interview should include a review of the examinee's developmental, school, family, employment, medical, social, legal, substance use and psychiatric history. Sometimes using a detailed history form can facilitate this process. Barkley (1998a) developed a measure of impairment form especially for ADHD. In addition, a collateral interview with a family member is recommended because such interviews can help obtain information on ADHD symptoms and impairment in activities of daily living that are not reported by the examinee.

Next, the examinee will need to be evaluated using DSM-IV diagnostic criteria for ADHD. However, there is a concern that criteria may be too conservative when applied to adults because criteria were developed based on field trials of children between the ages of 4 and 16 years. Moreover, Barkley and Biederman (1997) argue that the DSM-IV criterion for onset of symptoms be amended to age 12 instead of 7 years of age because no empirical evidence exists to show that this criterion of onset by age 7 distinguishes valid from invalid cases.

A rating scale specifically developed for adult ADHD should be used in conjunction with the DSM-IV criteria. Three examples include the Attention Deficit Scales for Adults (ADSA) (Triolo & Murphy, 1996) described in chapter three, the Conners' Adult ADHD Rating Scales (CAARS) (Conners, Erhardt, & Sparrow, 1999) and the Brown Attention Deficit Disorder Scale (BADDS) (Brown, 1996).

As mentioned in the literature review, adults with ADHD often present with comorbid problems such as a learning disability, anxiety, mood, and substance use disorders. It is important to determine whether symptoms such as poor concentration are due to ADHD or to a comorbid condition. If a learning disability is suspected, the clinician will want to include a cognitive measure (i.e. WAIS-III) and an achievement measure (e.g. Woodcock Johnson Tests of Achievement-Third Edition, Wide Range Achievement Test-Third Edition, or Woodcock Reading Mastery Tests-Revised). Personality tests (e.g. PAI, MMPI-2, Symptom Checklist-90-Revised, or the BDI-II) can be used to rule out or confirm Axis I Disorders.

Neuropsychological and cognitive measures have been shown to discriminate between those with ADHD and nonclinical populations (Brown, 2000; Jenkins et al., 1998; Murphy et al., 2001; Riordan et al., 1999). In those studies, adults with ADHD demonstrated significant deficits in interference control, response inhibition, sustained attention and working memory. Findings from those studies lend support to Barkley's (1997b) frontal lobe dysfunction hypothesis of ADHD.

It is recommended that the following neuropsychological screening and cognitive assessment instruments be included in the testing battery. Computerized continuous performance tests such as the Conners Continuous Performance Test (CPT) can be used to measure sustained attention and response inhibition. The Brief Test of Attention (BTA) can be used to measure auditory divided attention. The Stroop Color-Word Interference Test can be used to assess the ability to block out distracting visual information. The Trail-Making Test from the Halstead-Reitan Neuropsychological Battery can be employed as a measure of perceptual-motor speed and focused attention.

Kaufman and Lichtenberger (1999) suggest that it is best to interpret the WAIS-III Working Memory and Processing Speed Index scores in conjunction with behavioural observations during testing, background information collected on the examinee, and the person's nuances of test performance. Behavioural explanations may account for a low Working Memory Index score. These include distractibility, inattention, difficulty with numbers, hyperactivity and anxiety. Clinical data to support such behavioural interpretations can be obtained during a testing session. For example, adults with weak computational skills may display behaviours such as counting on fingers or writing with their fingers. A testing-of-limits procedure such as allowing the examinee to use paper and pencil on the arithmetic subtest reduces the load on the examinee's working memory. This may help to determine whether the examinee has poor arithmetical knowledge or memory difficulties that inhibit mental computation.

It is recommended that the optional procedures on Digit Symbol-Coding be administered because they were intended to help determine the reason for deficient performance on this task. For example, a low score on Digit Symbol-Incidental Learning, and an average score on Digit Symbol-Copy suggest that the examinee may have performed poorly on Digit Symbol-Coding because the stimuli were not remembered adequately. Alternatively, a low score on Digit Symbol-Copy, and an average score on Digit Symbol-Incidental Learning suggest that the low score on Digit Symbol-Coding may reflect impaired graphomotor speed.

IQ Implications

Results from the present investigation support the notion that intellectual assessment is an important component in the diagnosis of a developmental condition such as ADHD that features impairment of cognitive abilities. The Wechsler Adult Intelligence Scale-III is based on the premise that intelligence is comprised of an array of abilities. In addition to the Full Scale IQ, the WAIS-III provides a large number of scores useful for profile interpretation: the IQ scores, four Index scores, and up to fourteen subtest scores. The objective of profile interpretation is to determine the unique cognitive capabilities of an individual (Sattler, 2002). It should be noted that profile interpretation is used to generate hypotheses and whether a hypothesis can be confirmed will depend upon the availability of other information.

With respect to Index score comparisons, the VCI-WMI difference involves a comparison of acquired knowledge and verbal reasoning skills versus the capacity to hold and process information in memory. Since the total ADHD sample obtained significantly lower mean WM Index scores compared to the mean VC Index scores, this finding may be indicative of memory weaknesses with regard to verbally presented materials. This discrepancy is related to academic difficulties. Although the mean Full Scale IQ for the sample fell within the average range, the discrepancy between the VC Index and the WM Index for the ADHD sample suggests that they may not learn well in the traditional lecture format that prevails in most educational institutions.

The POI-PSI difference provides a comparison of visual-spatial and fluid reasoning skills versus the ability to process nonverbal information quickly. Results suggested that the ADHD sample showed significantly lower mean PS Index scores when compared to the PO Index scores. Therefore, the ADHD sample might display sound reasoning skills with nonverbal materials but function poorly under time pressure. In academic settings, this discrepancy might indicate the need for testing accommodations with timed exams such as providing additional time.

Educational Implications

From an educational standpoint, the present study results support the use of accommodations in a post-secondary setting. Many adults with ADHD tend to be more successful with self-paced learning and a program that offers students the flexibility to focus on specialized areas of interest. With respect to alternative testing arrangements, students with ADHD tend to perform better on take home exams, oral exams, or essay exams. Other exam accommodations include the opportunity to take exams outside the classroom in a quiet setting. One of the most useful accommodations to many students with ADHD is the opportunity to take exams at different time intervals instead of writing several in one week. Adults with working memory and processing speed impairments will need extra time to master lecture material and lengthy reading assignments. As such, they should consider cutting back on their course load, because a reduced course load would free up the time needed to do well in the remaining courses. Due to their difficulties with processing speed, adults with ADHD will require more time to complete exams.

As well, impairments in working memory functioning would likely interfere with reading comprehension skills. They tend to have difficulty with multiple-choice exams because this type of testing requires adequate reading comprehension skills and they are usually timed. Another problem with multiple-choice testing is that it requires the person to correctly write their answers on the correct lines of the computer scan cards.

Accommodations to assist with working memory impairments include tape-recording lectures and obtaining copies of teacher or student notes. Barkley (1997b) notes that methods for compensating for impaired working memory can include external reminders such as daily planners, posters and audiotapes.

Adults with ADHD would benefit from identifying their unique learning styles, and which sensory channel is their strongest. For example, auditory learners should investigate whether reading aloud, taping lectures, and listening to textbooks on tape help with their recall of information. Visual learners are encouraged to use colour coding, outlining so that the structure is more visible and reproducing charts and graphs so that they will have more meaning. Whole-body or kinesthetic learners should write large on a dry-erase board, build models when appropriate, draw a flow chart, or act out a scene using role-playing. Kinesthetic learners tend to do best when instructional techniques actively engage the entire body, and they need a strong hands-on component like drawing, building, writing or manipulating something.

Teaching Strategies

There are many approaches to teaching. These include lectures, student seminars, discussion and cooperative methods, alone or in combinations. There are certain strategies that teachers can use in their courses that will make their classes more effective for students with ADHD who have auditory and visual working memory and processing speed problems. Such strategies include organizational, time-oriented, content delivery, teaching style, environmental, memory, specific area strategies and student strategies that the teacher can facilitate. First the instructor should prepare a course outline that should be available at the first class or before, and would include the course name, instructor's name, office hours, all evaluation criteria and weighting, course objectives, course content, mode of presentation (e.g. lecture & discussion), required textbooks, reading assignments, written assignments, possible modes of student response such as oral, written, single or group, tests and exams that include content, format, cumulative or not and grading policies. When giving a lecture, teachers are encouraged to make it clear what they consider to be the most important points and list them in the introduction, highlight key terms, write them on the board, or use overheads; use colour-coding for emphasis. Always repeat and paraphrase a student's question before answering it in class so that the rest of the class can hear and fully understand it. Time-oriented strategies include the use of advance organizers to alert students to what is coming next. During class teachers should speak at a pace that students can follow easily. For example, using catch-up pauses during lectures, demonstrations, videos, presentations and seminars to permit note-takers to catch up, for answering questions and to allow a student taping the class to flip or replace a cassette. Questioning techniques for individuals with weak working memory and processing speed skills include asking a question such as "Tell me three things…" then allow a brief pause (10-20) seconds before calling on anyone for an answer. This allows the student with ADHD time to process the question and prepare to give or hear an answer. At the end of each class, take the time to wrap up the topic neatly.

With respect to content delivery of course material, teachers are encouraged to determine the lowest entry level of information in the class, and use that as a point of departure. Good quality texts are important, especially for students with ADHD who may have reading comprehension difficulties due to their impairments in auditory and visual working memory. These tasks should be evenly written in simple direct language and have a glossary of technical terms explained in familiar terms. The text should include preview questions and include a chapter summary and review questions. If a course involves lecture notes or detailed overheads, the instructor should make an extra copy available through the library for the use of students with ADHD. Moreover, teachers should consider class presentations that appeal to as many learning channels as possible: auditory, visual, tactile (3-dimensional models), and cooperative learning. Using concrete real-life examples relevant to students would be helpful.

In terms of environmental strategies to facilitate learning, the teacher will want to ensure that the classroom is quiet and free of distractions. Also the teacher should try to minimize their own distracting habits (pacing, and speaking to the walls). Using the chalkboard, wall charts, the overhead projector, videos and films would be helpful. Consideration of the seating arrangements such as the arrangement of chairs into rows, groups, face-to-face pairs, and circles is recommended as are the need for left-handed desks.

Present study results suggest that adults with ADHD are likely to have problems keeping information in working memory long enough to be organized and associated with previously learned material in long-term memory. This is likely due to poor rehearsal strategies. The instructor can help the student with ADHD apply learning strategies by placing all information within a context and organized structure, and connect new ideas to old familiar ones. They should use lots of examples and analogies, proceed more slowly through the material, repeat, remind, rehearse and review, break material into "chunks" or 3 for easier recall, and test frequently.

With respect to evaluation strategies, teachers should keep a file of old exams and encourage students to consult them for review. They may teach test-taking strategies such as teaching students to use the first 10-15 minutes of every exam for reading and planning only. In addition, instructors should make sure in advance that their students understand instructions such as: analyze, criticize, diagram, assess, compare, contrast, identify and evaluate. When setting exam questions, teachers should use completely straightforward language and refrain from using negative questions. Instructors are encouraged to be flexible in their method of evaluation, and they should permit the use of assistive technology where it will help. Students with ADHD would benefit from a choice in exam format such as point-form answers, or essay questions rather than multiple choice. As well, students can be coached through major assignments. The student could submit their work to the teacher as various stages (topic, outline, etc.) for marks. Lastly, the instructor should permit accommodations for tests and exams.

Treatment Implications

Overall, the goal of this research is to help clinicians make more reliable and valid diagnostic conclusions and ultimately to help adults who are experiencing attention and concentration difficulties. For example, psychotherapists who work with ADHD adults could potentially use this information in the development of treatment plans such as retraining cognitive functions, and restructuring the physical and social environment to maximize functioning.

With respect to working memory, Nadeau (1995) offers compensatory strategies for impaired working memory. Firstly, the therapist can help the adult with ADHD to get in the habit of effectively using a day planner in which the individual can write all appointments, commitments, phone calls to make or return, and tasks to accomplish that day. Second, the therapist can assist the client in listing the types of things that she or he repeatedly forgets in order to help strategize for reminders. Electronic reminders such as a watch that beeps throughout the day is useful to remind the ADHD adult to complete routine tasks such attending regularly scheduled meetings or picking up the children after school. Visual reminders can compensate for visual memory problems. For example, placing an item that should be taken to school or work in front of the door will usually be an effective prompt. Notes should be written on coloured paper and be placed in highly visible spots.

Losing or forgetting small personal items frequently poses a problem for adults with ADHD. If reading glasses are essential at work, the client should keep an inexpensive second pair in the desk at work. Extra car keys should be kept at work and house keys need to be duplicated and hidden strategically. The development of daily rituals and routines can also greatly reduce forgetting. Ideally, the evening routine should involve as much preparation for the next day as possible including selecting and laying out clothes, planning and packing lunches, and clustering items that will be needed in the morning preparation. The morning routine should be as brief and uncomplicated as possible.

Adults with ADHD would benefit from learning mnemonic techniques to enhance memory. These include rehearsal, overlearning, developing acronyms, making rhymes, developing webs of associations with previously learned facts, and “chunking” or grouping smaller bits of information together.

Along with helping clients improve their life management skills, the therapist could educate the client with ADHD, thereby providing the client with a better understanding of the neurological basis for the ADHD symptoms.

Limitations of the Study

One limitation of this study is that the research design is causal-comparative making it difficult to establish causality on the basis of collected data (Borg & Gall, 1989). The independent variable (i.e. ADHD group) was not manipulated and participants were assigned to the variable. However, because the experimental manipulation of ADHD is not possible and is unethical, this design was deemed to be the most appropriate at this time. The selection of a comparison group (i.e., the WAIS-III standardization sample) was needed to reduce differences related to the independent variable. Although adults with ADHD differed from the standardization sample with respect to their discrepancies on the WM and PS Indexes, one cannot conclude that this diagnosis is directly related to study findings. It is possible that the differences obtained could result from a third factor.

As well, the study was restricted to a post hoc or retrospective analysis of data due to the difficulty of obtaining large numbers of ADHD adults. In addition, this research relied on other clinicians to administer, score and interpret the psychometric tests. This study was limited to participants who met the specific research criteria outlined in Chapter Three.

This study is limited to clinically referred adults. As such, it would be inappropriate to draw conclusions regarding any relationship between ADHD and working memory and processing speed in other populations based on these findings.

Another limitation of this study involves the inability to generalize present findings from a group level to an individual level. However, examining statistical differences between groups might help us to better understand the cognitive processes that are occurring in adults with ADHD.

Despite the limitations in this study, the findings may generate further discussion and the development of alternative interpretations of the problem under investigation.

Delimitations

This study was limited to adults who had been given the required battery of assessment instruments and who met the specific research criteria outlined in chapter three. As such, study findings can only be generalized to groups of adults who meet the specific research criteria used in this study.

Directions for future research

It is the hope of this investigator that this study be replicated and refined by other clinicians and researchers in future studies, since this is the first time the WAIS-III has been utilized with this population and, this would enhance the generalizability of findings. It is recommended that subsequent studies include a larger sample. The present investigator is highly committed to this area of research and would like to undertake more research investigating the cognitive profiles of adults with ADHD. Future research may include investigating the profiles of adults with ADHD on other cognitive measures such as the Stanford Binet-Fifth Edition.

Moreover, future studies should include the optional Digit Symbol-Coding subtests in the battery of tests because this would determine what elements of the DS-Coding subtest are impaired (i.e. visual working memory or psychomotor speed).

The present investigation examined the utility of the WAIS-III WM and PS indexes in distinguishing between an ADHD sample of adults and the American WAIS-III standardization sample. At the time of this investigation the Canadian WAIS-III normative sample results were not yet published. It is recommended that future studies compare another group of Canadian adults with ADHD to the Canadian WAIS-III standardization sample now that the results are available.

Moreover, subsequent studies should compare clinical groups such as ADHD and Learning Disabled adults to see whether the WAIS-III WM and PS Indexes distinguish between groups.

Conclusions

The purpose of this study was to examine the WAIS-III WM and PS Indexes in adults diagnosed with ADHD. Current findings suggest that the ADHD sample obtained significantly lower WM and PS Index scores when compared to the VC and PO Index scores. The discrepancies for the ADHD sample were significant when compared to the WAIS-III standardization sample. Although the ADHD sample obtained significantly lower WM Index scores compared to the standardization sample WM Index scores, no differences were found between the PS Indexes. Present results are consistent with literature supporting lower scores on the WM and PS Indexes in ADHD populations.

Low WM and PS Index scores should not be used to diagnose the presence or absence of ADHD. They can, however, be an important part of the diagnostic process.

For example, if the assessment information suggests the presence of ADHD and the adult has low WM and PS Index scores, we can be more confident in the diagnosis.

From a theoretical standpoint, present findings lend support to the notion that ADHD individuals show impairments in executive functioning, working memory and nonverbal working memory abilities. As well, the findings contribute to the existing body of literature in the areas of working memory, intelligence testing, and ADHD.

It is hoped that the results of this investigation will increase clinicians' understanding of difficulties in cognitive functioning of adults presenting with ADHD symptomatology. This may help in the development of more useful and effective treatment and cognitive remediation strategies as well as provide appropriate accommodations needed by these individuals in their social, work, and educational realms.

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