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In general it is thought that children with AD/HD have lower IQs than non-affected children. However, the variability in research findings has made it difficult to reach an accurate conclusion regarding the intellectual functioning of children with AD/HD. A primary reason for such inconsistencies appears to be the failure to assess the effects of stimulant medication on test performance. The current study investigated whether changes occur in the WISC-IV test scores of children with AD/HD as a function of stimulant medication usage. Thirty-five male and female children who were diagnosed with AD/HD and taking stimulant medication to treat their symptoms participated in the study. A within-subjects design was used whereby all children were tested on two occasions with a split-half version of the WISC-IV. Children were randomly assigned to be on medication for one testing session and off medication for the other session. As expected, medication usage improved scores on the FSIQ, with an average increase of seven points. This increase in scores appeared to be driven by improved performance on several indices including the Working Memory Index (WMI), Processing Speed Index (PSI), and Verbal Comprehension Index (VCI), with the largest increase seen on the WMI. Children identified as having a positive response to their medication showed the largest improvements on IQ scores. This study provides evidence that children with AD/HD do not necessarily have lower IQs than unaffected children. Implications for the assessment and treatment of children with AD/HD were discussed.

AN EXAMINATION OF THE EFFECTS OF STIMULANT MEDICATION ON THE IQ TEST PERFORMANCE OF CHILDREN WITH AD/HD

by

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CHAPTER I

INTRODUCTION

Attention Deficit/Hyperactivity Disorder (AD/HD) is one of the most common psychiatric disorders in childhood, with an estimated incidence of 3-5% (American Psychiatric Association, 2000). It is a disorder characterized by developmentally inappropriate levels of inattention, hyperactivity and/or impulsivity. Contemporary models of AD/HD link the core symptoms of the disorder to deficits in the prefrontal lobes (Nigg, 2006). Specifically, research has identified functional abnormalities and reduced brain volume in the frontal cortex, basal ganglia, and cerebellar structures as well as problems with catecholamine neurotransmission as pathophysiological mechanisms in AD/HD (for reviews, Barkley, 2006; Faraone et al., 1999). These areas of the brain are believed to be responsible for executive functions (EFs), the capacities that allow individuals to generate voluntary behaviors that are controlled and actively guided (Slattery, Garvey, & Swedo, 2001). The impulsivity and inattention that is common in AD/HD suggest deficits in the voluntary control of behavior. In recent years it has been argued that a core deficit in behavioral inhibition underpins the symptoms of the disorder (Barkley, 2006). This lack of inhibition is believed to disrupt the efficacy of several EFs, causing children with AD/HD to act impulsively and give little thought to the consequences or the appropriateness of their behavior, while also having difficulty sustaining attention and completing tasks.

As a result of poor behavioral inhibition, children with AD/HD often exhibit difficulties in numerous domains of daily functioning. A large body of literature has identified numerous consequences that AD/HD has on a child's ability to learn and make progress in school. Previous studies show that children with AD/HD have a higher incidence of grade retention, poor school performance, and an increased number of school suspensions and expulsions (Barkley, 2006, Forness & Kavale, 2001). Furthermore, studies have shown that up to 80% of children with AD/HD exhibit learning and/or achievement problems (Hoza, Pelham, Dobbs, Owens, & Pillow, 2002; Mayes & Calhoun, 2007; Pastor & Reuben, 2002, Semrud-Clikeman, et al., 2000; Tannock, Martinussen, & Frijters, 2000). In the realm of social functioning, affected children often experience poor peer and family relations, appear less mature compared to their same age peers, and experience high rates of peer rejection (Blachman & Hinshaw, 2002; Nixon, 2001). Children with AD/HD also exhibit problems with motor coordination (Carte, Nigg, & Hinshaw, 1996; Karatekin, Markiewicz, & Siegel, 2003; Mariani & Barkley, 1997; Piek, Pitcher, & Hay, 1999), exhibit poor handwriting, and are more likely to have speech problems (Pitcher, Piek, & Barrett, 2002; Raggio, 1999), compared to children without the disorder.

Academic performance is one of the most frequently affected areas of functioning. Reasons for this impairment are not entirely clear. Some assume such impairment is the direct result of the symptoms of the disorder on a child's ability to learn. Others have suggested these difficulties occur due to the impact of the disorder on intellectual functioning. Specifically, some researchers have proposed that as a

consequence of inefficiencies in executive functioning, children with AD/HD have lower intellectual functioning than those without the disorder (Barkley, 2006). However, this notion has generated controversy due to the variability in findings. For instance, Barkley (1998) has suggested that children with AD/HD score an average of 7 to15 points lower on IQ tests than non-affected children, while others have found that the IQs of children with AD/HD are normally distributed, like those of non-affected children (Carlson, Mann, & Alexander, 2000; Kaplan, Crawford, Dewey, & Fisher, 2000; Ozonoff & Jensen, 1999). Such variability in findings makes it difficult to draw accurate conclusions regarding the intellectual functioning of individuals with AD/HD.

A suspected reason for the differences in IQ scores across studies is the variability in the methodologies used. Specifically, the use of poorly defined diagnostic criteria, inappropriate subject selection, and the use of varying short forms of IQ tests to assess intellectual functioning have created confusing findings regarding the IQs of children with AD/HD. One of the most glaring problems noted is the lack of attention paid to the impact of treatment on the cognitive performance of children with AD/HD. Although stimulant medication is considered the most effective treatment in reducing the core symptoms of AD/HD (MTA Cooperative Group, 2006), little research has been conducted to determine whether the effects of stimulant medication treatment translate into positive changes in IQ scores. The studies that have addressed this topic are characterized by methodological problems such as neglecting to monitor whether children had taken stimulant medication prior to testing or failure to measure medication efficacy prior to testing. Furthermore, most studies look exclusively at group differences

by comparing children with AD/HD to unaffected children rather than assessing for individual differences. This seems to be an oversight as no specific medication or dosage level exists as the universal treatment for AD/HD. Such methodological limitations make it difficult to establish a clear relationship between AD/HD and intellectual functioning.

In light of these circumstances, the objective of the present study was to investigate the effects of stimulant medication on the intellectual test performance of children with AD/HD. By assessing both group and individual differences in children with rigorously defined AD/HD, and by using sound methodological procedures, the intent of this study was to help clear up some of the confusion regarding the IQs of children with AD/HD. If stimulant medication is shown to improve the test behavior and performance of children with AD/HD, it can potentially impact the way in which intellectual and achievement assessments are conducted both in clinical and school settings. Moreover, related research with children with AD/HD may need to be altered.

As background for this study, this paper will begin with an overview of AD/HD, followed by an explanation of a prominent theory of AD/HD and a discussion of the core deficit in AD/HD and the secondary effects on the executive functions and motor control. Subsequently, a description of our current knowledge regarding intelligence, the most prominent theories of intelligence and the measurement of intelligence will be provided. A critical review of the literature on AD/HD as it relates to intellectual functioning is also included. The focus will then be directed to a discussion of the relevant literature regarding stimulant medications and their effects on AD/HD and intellectual functioning.

AD/HD: An Overview

Diagnostic Criteria

The Diagnostic and Statistical Manual-Fourth Edition (DSM-IV; APA, 2000) requires several criteria be met to establish a diagnosis of AD/HD. The first criterion requires the presence of at least six out of nine symptoms of inattention and/or six out of nine symptoms of hyperactivity-impulsivity that are inconsistent with an individual's developmental level. The inattention symptoms include behaviors like difficulty following through on tasks, distractibility, and forgetfulness. The hyperactivity symptoms include behaviors like fidgeting, being "on the go," and excessive talking. The impulsivity symptoms include blurting out, difficulty awaiting one's turn, and interrupting others. Additional criteria include symptom onset before seven years of age, evidence of significant functional impairment in two or more settings, and duration of symptoms lasting at least six months. Symptoms that occur exclusively during the course of a Pervasive Developmental Disorder or that are better accounted for by another mental disorder do not count toward the diagnosis of AD/HD.

Within this triad of symptoms, three main subtypes of AD/HD exist, 1) AD/HD, Combined Type (C), 2) AD/HD, Predominantly Inattentive Type (IA) and 3) AD/HD, Predominantly Hyperactive-Impulsive Type (H-I). Each subtype is diagnosed depending on the prevalence of specific symptoms. AD/HD-C is diagnosed when at least six of nine inattentive symptoms and six of nine hyperactive-impulsive symptoms are endorsed. AD/HD-IA is diagnosed when at least six of nine inattentive symptoms, but fewer than six hyperactive-impulsive symptoms are exhibited. Finally, AD/HD-H-I occurs when at

least six of nine hyperactive-impulsive symptoms and five or less inattentive symptoms are present. The Combined Type is the most common, occurring in 61% of identified cases compared to 30% for IA and 9% for H-I (Faraone, Biederman, & Weber, 1998).

Comorbidity

Children with AD/HD have high rates of comorbid psychiatric and learning problems. In particular, children with AD/HD are often diagnosed with other disruptive behavior problems such as Oppositional Defiant Disorder (ODD) and Conduct Disorder (CD). Studies have shown that between 32-40% of children with AD/HD have comorbid ODD, while 12-30% have comorbid CD (Barkley, 2006). Another 10-40% of children with AD/HD have anxiety disorders, with 9-32% having major depression. Elevated rates of learning disabilities have also been reported in the child AD/HD population, with approximately one-third of affected children exhibiting a learning disability (Barkley, 1998; Mayes, Calhoun, & Crowell, 2000).

Barkley's Theory of AD/HD

Several models of AD/HD have been proposed, ranging from the idea that the disorder stems from generalized deficits in self-regulation (Douglas, 1999), to deficits in response inhibition (Quay, 1988), delay aversion (Solanto et al., 2001), or arousal and energetic pools (Sergeant & Van der Meere, 1990). Though research continues on the merits of these models, many investigators view AD/HD as manifesting impairments in inhibitory control (Barkley, 1994, 1997; Nigg, 2006; Schachar, Tannock, Marriott, & Logan, 1995). These deficits in behavioral inhibition cause an individual to have difficulty inhibiting or delaying responses. Studies consistently show these impairments

are attributed to deficits in the prefrontal regions of the brain (Barkley, 1997; Nigg, 2006), the same areas of the brain where stimulant medications appear to act. One model that seems to synthesize this information is that proposed by Barkley (1997). Specifically, he proposed that AD/HD is comprised of a developmental delay in, or acquired impairment of, the behavioral inhibition networks of the brain that disrupt self-regulation—an assertion for which there is substantial research support.

Barkley's model hypothesizes that inefficient execution of behavioral inhibition has a direct influence on the motor system, and causes secondary impairments in four specific executive functions that depend on inhibition to work efficiently (See Figure 1). These four functions include working memory (i.e., the capacity to hold a mental representation in one's mind to guide behavior), self-regulation of affect/motivation/arousal (i.e., an individual's ability to motivate themselves to behave), internalization of speech (i.e., the self-directed speech individuals engage in to guide their behavior), and reconstitution (i.e., taking apart incoming information and then using the parts or creating new parts to produce a verbal or behavioral response). AD/HD disrupts these functions by impairing the first action required for their efficient operation—inhibition of responding.

Behavioral inhibition is believed to play a critical part in the performance of the executive functions (EFs) because it provides a delay in responding that sets the stage for these functions to take action. In particular, Barkley posits that behavioral inhibition provides individuals with three abilities important to executive functioning. These include the ability to stop a dominant, habitual response (a pre-potent response) from

emerging when they know their interests are better served by suppressing it, the ability to stop an ongoing response, and the ability to tolerate interferences, which could disrupt ongoing mental processes. When behavioral inhibition is compromised, as in a child with AD/HD, the executive functions cannot operate properly, leading to a failure to self-regulate and impaired motor control, producing the symptoms that constitute AD/HD.

Deficits in the processes that control and regulate thought and actions cause impairments in planning, decision-making, complex reasoning, problem solving, and regulating everyday behavior, which are considered hallmarks of intelligence (Sternberg, 1988). Furthermore, numerous studies have found moderate to strong relations between inhibition, working memory, and intelligence (see Ackerman, Beier, & Boyle, 2005; Friedman, Miyake, Corley, et. al., 2005; Salthouse, Atkinson, & Berish, 2003). Thus, it is conceivable that AD/HD could have a negative impact on intellectual functioning.

Treatment of AD/HD

Recommendations by the American Academy of Pediatrics (AAP, 2001) for the treatment of school-aged children with AD/HD indicate that stimulant medications and/or behavior therapy are appropriate and safe treatments for AD/HD. Though many clinicians believe a multimodal approach is the best treatment plan for children with AD/HD, most children receive only stimulant medication. This seems to occur due to the fact that stimulants have been identified as the most effective treatment in reducing the core symptoms of AD/HD (Abikoff et al., 2004; MTA Cooperative Group, 2004). Studies show that approximately 70-80% of people with AD/HD are positive responders to stimulants, meaning their symptoms are effectively treated with the use of a stimulant

(Bosco & Robin, 1980: Greenhill, Halperin, & Abikoff, 1999; Lerner & Wigal, 2008; Wigal, et al., 1999). Hence, stimulants have become the current mainstay of treatment.

Currently, there are two classes of stimulants prescribed to treat AD/HD. These include amphetamine (AMP; Adderall and Vyvanse) and methylphenidate products (MPH; Ritalin, Metadate CD, and Concerta), with MPH products being the most frequently prescribed (Greenhill, Halperin, & Abikoff, 1999, MTA Cooperative Group, 2004). Though the mechanism of action of stimulants is not completely understood, it is believed they facilitate the uptake and release of neurotransmitters in the prefrontal cortex (PFC; Arnsten & Li, 2005; Arnsten, Scahill, & Findling, 2007; Pliszka, 2005). For instance, MPH is believed to be involved in the uptake and release of dopamine, a neurotransmitter associated with motivation and reward (Volkow, et al., 2001). By increasing the amount of dopamine available, individuals are capable of maintaining attention and motivation during uninteresting tasks.

Research regarding the immediate effects of stimulants has shown that children who respond favorably to medication exhibit decreases in activities such as talking, fidgeting, and engaging in off-task behaviors following the administration of stimulant medication (DuPaul & Rapport, 1993; Konrad, Gunther, Heinzel-Gutenbrunner, & Herpertz-Dahlmann, 2005). Numerous studies examining performance on measures of inattention and impulsivity such as continuous performance tasks (CPT) consistently show CPT performance improves following methylphenidate administration (Losier, McGrath, & Klein, 1996; Nigg, Hinshaw, & Halperin, 1996; Riccio, Waldrop, Reynolds, & Lowe, 2001). In fact, studies have shown that following a dose of stimulant medication

children with AD/HD exhibit significant decreases in commission and omission errors and improved reaction times (MTA Cooperative Group, 2006; Riccio et al., 2001).

Although less is known about the effects of stimulants on cognitive processes, they are believed to enhance the executive functioning of children with AD/HD (Barnett, et al., 2001; Berman, Douglas, & Barr, 1999; Mehta, Goodyer, & Sahakian, 2004; Rapport & Kelly, 1991). Stimulants have been shown to improve underlying cognitive difficulties in tasks dependent on intact fronto-striatal structures. Mehta et al. (2004) found that following a dose of stimulant medication, children with AD/HD demonstrated significant improvements in performance on tasks of working memory, visual search, and attentional-set shifting. Similarly, Kempton, et al. (1999) found that affected children taking stimulant medication exhibited improved performance on the executive functions of spatial short-term memory, spatial working memory, set-shifting ability, and planning ability in comparison to un-medicated affected children. Thus, the evidence suggests that stimulants are associated with better executive functioning.

Despite the fact that these studies have identified important differences in performance when on and off medication, many of these studies focused on differences between groups rather than assessing for individual differences. These kinds of analyses mask significant variations between individuals. This information is important to consider given there are large individual differences in response to medications and doses (Chacko, et al., 2005; Chronis, et al., 2001; Swanson, et al., 1998). Studies have also identified significant medication dosage effects on CPT performance (Nigg, et al., 1996; Sunohara, Malone, Rovet, et al., 1999). Such findings highlight the need to identify the

optimal dosage for a given individual. Otherwise, these studies are somewhat limited in their generalizability.

Though stimulant medication is considered the most effective treatment for AD/HD, little research has been conducted to determine whether treatment with stimulants translates into positive changes in IQ scores. Nonetheless, it is often assumed that cognitive performance is enhanced, given that the medication works to alleviate the symptoms of the disorder (MTA Cooperative Group, 2004). Therefore, it is reasonable to speculate that if stimulant medication improves executive functioning, this should result in improvements in IQ test performance.

Intelligence

Throughout history, theorists have tried to demystify the construct of intelligence by attempting to define it and develop tests that could measure it. As a result, the definition has evolved from simplistic notions such as 'intelligence is what intelligence tests measures,' to ones based on theoretical ideas. Additionally, intelligence tests have developed from crude measures of reaction time into complex batteries assessing multiple domains of abilities. Thus, to understand our current conceptualization of human intelligence, it is first necessary to describe the theories of intelligence, and then discuss how these theories have influenced the development of intelligence tests.

Theories of Intelligence

Theories of intelligence are abundant, with each taking a different approach to answering the same question. Is intelligence one thing or many things? One of the first people to address this question was Spearman (1927), who proposed that intelligence was

one general ability, labeled *g*, that represents what is general or common to all the abilities that constitute so-called IQ (intelligence quotient). From his research using factor analytic strategies, Spearman identified that numerous cognitive abilities were intercorrelated, which implied that intelligence was a single factor.

Although Spearman's introduction of factor analytic techniques was a breakthrough in the field, support for a broader conceptualization of intelligence stems both from modern theories and research on intelligence. Horn and Cattell's theory of Fluid and Crystallized Intelligences (1966), for example, has broader notions of the abilities constituting intelligence than Spearman's hypothesis. In their original theory, Horn and Cattell (1966) postulated that intelligence was not the single construct *g*, instead it was composed of two broad factors called fluid intelligence (*Gf*) and crystallized intelligence (*Gc*) that were supported by many specific factors called primary abilities.

Horn and Cattell (1966) viewed fluid intelligence as a biologically influenced dimension of *g* that decreases over the course of life. This form of intelligence is more dependent on physiological structures that support intellectual behavior. Thus, as a person ages, these structures begin to deteriorate, thereby explaining why, according to this theory, intelligence begins to decrease over time. Fluid intelligence is best measured by tasks that require adaptation to new situations, and those for which prior learning is not helpful. Therefore, tests of fluid intelligence tend to require more concentration, abstract reasoning skills, problem solving, and perceptual speed.

Crystallized intelligence is influenced by education and experience, and does not decline with age. Instead, it is believed to increase with age as a result of formal and

informal educational factors. This form of intelligence is more closely related to factual knowledge and acquired skills. It is best measured by assessing an individual's ability to solve problems using information learned as a result of education and cultural experiences. Tests of verbal ability, like vocabulary and arithmetic, are measures of crystallized intelligence. These tests appear to tap retrieval processes and the application of general knowledge abilities.

As with most constructs, ongoing research has resulted in changes to Horn and Cattell's original theory. For instance, Carroll (1993) built on the *Gf-Gc* model by proposing that intelligence is hierarchical in nature, with three strata of cognitive abilities. Current research has identified that an amalgam of the Cattell and Horn's *Gf-Gc* theory (Horn & Noll, 1997) and Carroll's three-stratum theory (Carroll, 1993, 1997), called Cattell-Horn-Carroll (CHC) Theory of Cognitive Abilities (McGrew & Flanagan, 1998), is the most viable psychometric theoretical model of human cognitive abilities (Daniel, 2000; Snow, 1998; Sternberg & Kaufman, 1998) available to date. This theory was the result of factor analytic research, which suggests that *g* does exist and that this construct contains numerous cognitive abilities that vary by degree of breadth. Thus, CHC theory blends Carroll's theory with Horn and Cattell's *Gf-Gc* theory by proposing that intelligence is composed of three strata—general intelligence or *g* (stratum III), which is composed of 9 broad cognitive abilities (stratum II; see Table 1 for a description) that are composed of 70 narrow cognitive abilities (stratum I; see Figure 2). Although theories such as the aforementioned have largely been divorced from the development of measures to assess intelligence, many of the intelligence tests used today incorporate

elements of CHC theory into their structure.

Measurement of Intelligence: The WISC-IV

The vast enterprise of modern testing evolved from psychologists' pioneer work to measure general intelligence or *g*. One of the first IQ tests developed to measure *g* was the Binet-Simon scale (1905), which was later revised by Binet and Terman (1916) and became known as the Stanford-Binet. The Stanford Binet became the standard of comparison for subsequent IQ tests due to its introduction of the "intelligence quotient" scoring scheme, which made it possible to compare the scores of children of different ages. Today, there are over 2,600 published psychological assessment measures designed to assess a diverse array of mental abilities. However, the most well-known and utilized IQ tests are the Wechsler scales. Over the past five decades, psychologists have overwhelmingly relied on the Wechsler scales to make decisions about special education services and programming issues (Esters, Ittenbach, & Han, 1997; Wilson & Reschly, 1996).

The current version of the Wechsler scales used to assess the intellectual ability of children is the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003). The WISC-IV was developed in 2003 and includes many of the same features as its predecessor, the WISC-III (Wechsler, 1991). It is used to measure the intellectual abilities of children 6 to 16 years of age, and was standardized on 2,200 children who were selected to match the 2002 U.S. Census data. It is extremely reliable with internal consistency reliability coefficients of .72 or above for all age ranges covered by the test. Consistent with the CHC theory, the WISC-IV is composed of three strata:

subtests (narrow cognitive abilities), indices (broad cognitive abilities), and FSIQ (*g*). However, it is important to note that not all of the abilities proposed as part of CHC theory are assessed by the WISC-IV.

Subtests

The WISC-IV has a total of 15 subtests (10 core subtests and 5 supplemental subtests), each of which represent the most specific measures of intellectual abilities such as spatial relations, perceptual speed, and visual memory. The 10 core subtests are Similarities, Vocabulary, Comprehension, Block Design, Picture Concepts, Matrix Reasoning, Digit Span, Letter-Number Sequencing, Coding, and Symbol Search. The five supplementary subtests are Information, Work Reasoning, Picture Completion, Arithmetic, and Cancellation. Descriptions of the subtests and their CHC classifications are provided in Table 2. As seen in Figure 3, each subtest loads on one of four indices.

Indices

As a result of factor analysis, four indices were identified as the best model to describe the WISC-IV. Consequently, the VIQ and PIQ scales from the WISC-III were dropped and several indices were restructured and renamed to accurately reflect the constructs they measure. The Freedom From Distractibility factor was replaced with the Working Memory Index (WMI), and the Perceptual Organization Index was renamed the Perceptual Reasoning Index (PRI). The WISC-IV indices are the Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and the Processing Speed Index (PSI). The following is a description of each of the indices.

Verbal Comprehension Index (VCI). The VCI is comprised of five primary subtests (Similarities, Vocabulary, Comprehension, Information, and Word Reasoning) and two supplementary subtests (Information and Word Reasoning). This factor provides valuable information about a child's crystallized intelligence or *Gc*. It offers insight into a child's comprehension of verbally presented information, ability to process verbal information and think with words, and the application of verbal skills and information to the solution of new problems. Children with high scores on this factor often have high achievement orientation, demonstrate readiness to master school curriculum, possess knowledge of the cultural milieu, and maintain good scholastic aptitude.

Perceptual Reasoning Index (PRI). This index consists of the Block Design, Picture Concepts, and Matrix Reasoning subtests, and the supplementary subtest Picture Completion. The PRI was structured to reflect an increased emphasis on fluid reasoning abilities (*Gf*). Thus, the subtests measure a child's ability to think in terms of visual images, and provide insight into a child's ability to organize and interpret visual information and form abstract concepts and relationships without the use of words. Factors including a child's level of alertness, persistence, interests, and visual-motor organization can significantly affect performance on these subtests.

Working Memory Index (WMI). The subtests of the WMI include Digit Span, Letter-Number Sequencing, and the supplemental subtest Arithmetic. This index provides information regarding the broad ability of short-term memory (*Gsm*). The subtests assess a child's ability to hold information in mind temporarily and to perform some operation or manipulation with the information, all while filtering out distractions in order to

produce a correct result. The WMI subtests require children to hold numbers or letters, presented either visually or orally, in mind in order to act on this information. The WMI also offers information regarding a child's numerical and encoding abilities, use of rehearsal strategies, flexibility in performing mental operations, and ability to self-monitor. Children with low scores on this index often have difficulty rapidly shifting mental operations on symbolic material, and are easily distracted.

Processing Speed Index (PSI). This index includes the Coding and Symbol Search subtests and the supplemental subtest Cancellation. It is considered a measure of an individual's cognitive processing speed (*Gs*), the speed at which an individual can process incoming information. Each subtest is timed in order to capture the speed at which an individual completes basic cognitive functions, such as simple discriminations or item identification. The PSI also provides information about a child's psychomotor speed, short-term visual memory, cognitive flexibility, and level of concentration. Children who have difficulties on these subtests often exhibit poor motivation, anxiety, problems working under time pressure, visual defects, distractibility, impulsivity, and deficient concentration skills.

FSIQ

The Full Scale IQ (FSIQ) is considered the best measure of general intellectual ability. It measures general intelligence, scholastic aptitude, and readiness to master a school curriculum (Sattler, 2001). The FSIQ score is derived from the 10 core subtests included in the four indices. This is a significant change from the WISC-III, where the sum of the verbal and performance IQ scores was used to obtain the FSIQ. This change

means that the FSIQ now includes greater contributions from working memory and information processing speed. Accordingly, FSIQ scores are often affected by a child's level of motivation, interests, neurological integrity, attention span, ability to process verbal information, ability to process visual information, and psychomotor ability.

Application of IQ Theory and Measurement to AD/HD

Given the overlap between the abilities assessed by IQ tests and those proposed by Barkley to be affected by AD/HD, it is reasonable to speculate that children with AD/HD might exhibit lower levels of intellectual functioning. For instance, working memory, which is assessed by the WISC-IV, is an ability affected by the lack of behavioral inhibition in children with AD/HD. Consequently, affected children would be expected to perform poorly on working memory tasks, resulting in lower WMI scores. Moreover, since the WMI score is included in the calculation of the FSIQ score, as proposed by CHC theory, one can assume that a low WMI would result in a lower FSIQ score. Although these are rather logical propositions, the literature reveals mixed results, especially in regards to the FSIQ scores of children with AD/HD. A review of the literature will be helpful in elucidating this point. Since the WISC-IV is relatively new, and little research has been conducted with this measure, this review will focus primarily on findings from studies of the WISC-III.

WISC Index Scores and AD/HD

Few studies have assessed between-groups differences in WISC-III index scores, especially in regards to the Verbal Comprehension Index (VCI) and the Perceptual Organization Index (POI; similar to WISC-IV PRI). In fact, no studies were found that

addressed differences in the VCI and POI scores of children with AD/HD. Instead, the majority of studies focus on whether affected children exhibit lower Processing Speed Index (PSI) and Freedom From Distractibility (FFD; similar to WISC-IV WMI) scores than non-affected children. The results of these studies suggest that these scores are lower for children with AD/HD. This is not surprising considering the types of deficits children with AD/HD face as a result of poor behavioral inhibition and impaired executive functioning. What is surprising is the amount of variability seen across studies in the size of the score differences.

WMI and AD/HD

Various investigations have shown that a substantial relationship exists between working memory and intelligence. Using structural equation modeling, Engle, Tuholski, Laughlin, and Conway (1999) found a considerable link between intelligence and working memory. However, Engle and Kane (2004) proposed that the relationship between working memory and general fluid intelligence was mediated by attentional control. Thus, the ability to maintain attention, even in the event of distraction, plays an important role in an individual's ability to hold information in an active and easily accessible state. As a result, children with higher levels of inattention would be expected to receive lower scores on IQ tests that measure working memory and fluid intelligence.

Studies of children with AD/HD appear to support this finding. Although no studies exist that address the relationship between AD/HD and the WMI, studies assessing the relationship between AD/HD and the WISC-III Freedom From Distractibility (FFD) factor, the predecessor to the WMI, were identified. In particular,

several studies found that children with AD/HD score significantly lower on the FFD than children without the disorder (Hinshaw, 2002; Rucklidge & Tannock, 2001; Snow & Sapp, 2000; Toplak, et al., 2003). Hence, tasks that put a premium on retaining a representation in an active and easily accessible state prove difficult for children with AD/HD. Therefore, preliminary evidence suggests that AD/HD affects performance on the FFD, which should translate into lower scores on the WMI. Nonetheless, the variability in scores across studies suggests these findings may not be accurate. For instance, in the Toplak et al. (2003) study only preadolescent girls with AD/HD and a comorbid reading disorder exhibited significant differences in FFD scores compared to controls. Girls with only AD/HD did not exhibit significant differences on the FFD in comparison to non-affected girls. These disparities potentially resulted from the tendency for group-based analyses to conceal critical individual differences. A study by Anastopoulos, Spisto, and Maher (1994) highlighted this by conducting both group and individual-based analyses to study the FFD of children with AD/HD. Their results indicated that at a group level, affected children obtained lower FFD scores compared to their scores on the VCI and POI. However, when individual level analyses were conducted, a substantial number of affected children did not exhibit this same pattern of differences. Such findings emphasize the importance of conducting both group and individual level analyses when assessing the test performance of children with AD/HD.

PSI and AD/HD

The subtests of the PSI place a premium on speed within a timed context. Barkley (1997) has proposed that individuals with AD/HD have a poor subjective sense of time

due to working memory deficits that make it difficult to hold sequences of events in mind and to make comparisons among them. This suggests that children with AD/HD would score lower on the PSI than those without the disorder. Several studies have found that scores on the PSI are significantly lower for children with AD/HD compared to unaffected children (Hinshaw, 2002; Rucklidge & Tannock, 2001; Snow & Sapp, 2000; Toplak, et al., 2003). However, the findings vary across studies, with PSI scores ranging from 6 to 19 points lower.

Although these findings indicate that AD/HD has a negative impact on an affected child's performance on the PSI subtests, the variability across studies suggests the actual effect of AD/HD on a child's processing speed is not being adequately measured. This may be the result of different methodologies used in these studies. In particular, some of the studies looked at gender differences, while others grouped both genders or studied only one gender. For example, Hinshaw (2002) investigated differences in the IQ scores of preadolescent females, while Rucklidge and Tannock (2001) looked at the differences in males and females with AD/HD. In the study by Rucklidge and Tannock (2001) males with AD/HD scored approximately 10 points lower on the PSI compared to females with AD/HD. Thus, gender differences in the IQ scores of children with AD/HD may exist, which could affect the results. Another interesting finding comes from Toplak et al. (2003). Here, two studies were conducted; the first was to compare differences between children with AD/HD and those with AD/HD and a reading disability. The second looked at differences between these groups and healthy controls. Oddly, in the first study the mean PSI score for children with AD/HD aged 6-11 was 107, whereas in the second

study, which used a sample of children aged 13-16, the mean PSI score was 99. This difference suggests that age may also play a role in the findings regarding AD/HD and IQ. Though these studies bring to light the importance of studying group differences such as age and gender, neither looked at the role of individual differences and the impact this could have on the findings.

WISC FSIQ Score and AD/HD

Sixteen studies were identified that assessed differences in WISC-III FSIQ scores of children with and without AD/HD. Of these, the majority (10 studies) suggests that children with AD/HD score anywhere between 7 to 12 points lower on measures of intelligence than the general population (Beebe, Pfiffner, & McBurnett, 2000; Frazier, Demaree, & Youngstrom, 2004; Hinshaw, Carte, Sami, Treuting, & Zupan, 2002; Lorch, et al., 2004; Kuntsi, Oosterlaan, & Stevenson, 2001; Rucklidge & Tannock, 2001; Tripp & Alsop, 2001; Tripp, Ryan, & Peace, 2002; Toplak, et al., 2003; Wu, Anderson, & Castiello, 2002). Although these findings seem convincing, they must be interpreted with caution due to the variance in methodologies used to reach these conclusions, and the failure to consider the effects of possible confounds. In particular, only four of these studies used the DSM-IV criteria to diagnosis AD/HD, administered the WISC-III in its entirety to obtain FSIQ, and identified the medication status of children with AD/HD prior to testing. Given that the diagnosis of AD/HD has changed greatly over the years, it seems the use of other criteria may cause variable findings. Additionally, Sattler (2001) has warned against using only a few subtests to estimate FSIQ, given these estimates often yield erroneous classifications. It also seems imperative that studies assess whether

participants are on or off medication during the time of testing. This is important not only to ensure that the groups being studied are equivalent, but also because individuals being treated with medication may perform better as a result of treatment.

Interestingly, one of the 16 studies was a meta-analysis of 123 studies from 1980 to 2002 (Frazier, et al., 2004). The results indicated the overall cognitive ability of children with AD/HD was approximately 9 points lower than those without the disorder (weighted mean effect size of .61). This finding is complimentary to the proposal by several theorists that the difference between children diagnosed with AD/HD and comparison children should be around 7 to 12 IQ points (Crosbie & Schachar, 2001; Mariani & Barkley, 1997; Rucklidge & Tannock, 2001). However, many of the studies included in the analysis lack sound methodologies, making it difficult to assess the specific impact AD/HD has on intellectual functioning. In particular, although analyses were conducted to determine if different methodological variables, such as differences in DSM criteria, type of IQ test, and method for estimating overall IQ, influenced the findings, other possible confounds were not assessed. Many studies did not control for subtyping, few addressed issues of comorbidity, and many used only a 2-4 subtest short form of an IQ test to assess FSIQ.

Upon closer inspection of the six studies with null findings, it was noted that methodological limitations were also evident. Specifically, a study by Mayes and Calhoun (2002) used controls that were referred for academic problems associated with low average IQ, making it difficult to make accurate comparisons. Also, two studies did not report medication status during the time of testing (Nigg, 1999; Snow & Sapp, 2000).

Other problems included small sample sizes, the use of a 2-subtest WISC-III short form to estimate FSIQ, and the inclusion of children with various comorbid diagnoses. Interestingly, one study actually suggested that the IQs of children with AD/HD are normally distributed, basing this information on a 2-subtest WISC-III short-form that used WISC-R norms to calculate the FSIQ (Kaplan, et al., 2000).

According to the WISC-IV special group studies, children with AD/HD were found to score significantly lower on the WMI, PSI, and FSIQ compared to children without the disorder (Wechsler, 2003). In fact, a moderate effect size for the group mean difference was found for the PSI, while small effect sizes were noted for the VCI, WMI, and FSIQ. These results indicated that children with AD/HD score approximately seven points lower on the WISC-IV than unaffected children. Nonetheless, a major weakness was observed in this study. Specifically, 64% of children in the AD/HD group were taking medication during the time of testing. With over half of the sample receiving treatment at the time of testing, it is inappropriate to assume the results are an accurate representation of the IQ scores of children with AD/HD.

Like most areas of research, there are numerous methodological problems with which investigators must cope (e.g. problems related to subject selection, design, and measurement). Thus, it is no surprise that some of the studies assessing the IQs of children with AD/HD exhibit these kinds of problems. However, it is surprising that none of these studies assessed the impact of treatment of AD/HD on the intellectual functioning of children with AD/HD. Treatments for AD/HD are not only aimed at reducing the core symptoms of AD/HD, but also address the fundamental problems of the

disorder— poor behavioral inhibition and impaired executive functioning. It seems that a failure to consider the effects of treatment on the cognitive functioning of children with AD/HD is a major limitation in the AD/HD and IQ literature. Moreover, the lack of attention paid to studying individual differences is surprising, especially given findings like those from the Anastopoulos et al. (1994) study.

As previously mentioned, stimulant medications are the most frequently used method to treat AD/HD because of their known efficacy in alleviating the symptoms of the disorder (MTA Cooperative Group, 1999). Despite this knowledge, the majority of the studies included in this review, as well as those in the meta-analysis conducted by Frazier et al. (2004), failed to consider the immediate or long-term effects of treatment with stimulants on the intellectual functioning of children with AD/HD. In fact, most studies failed to report whether the children were on or off medication at the time of testing, while others included mixed groups of children, with some children being on medication and others not. This seems to be a gross oversight considering stimulant medication may affect a child's performance on an IQ test. Such methodological flaws make it difficult to establish a clear relationship between AD/HD and IQ.

The Effects of Stimulant Medication on IQ

Despite extensive studies regarding the effects of stimulant medication on behavior in AD/HD, few studies have investigated its effects on intelligence test performance, especially at the individual level. In fact, most studies addressing this relationship were carried out over 25 years ago and were based on group findings, which, as mentioned earlier, tend to mask clinically relevant individual differences. Moreover,

the findings from these studies are mixed, with some suggesting moderate group increases in FSIQ scores (Barkley, 1977; Sandoval, 1977; Whalen & Henker, 1976), while others suggest minimal changes in scores that are believed to represent normal variance (Finnerty, Soltys, & Cole, 1971; Sykes, Douglas, Weiss, & Minde, 1971; Wolraich, 1977). Variability is also evident in the findings regarding the effects of stimulants on the Verbal IQ and Performance IQ and the index and subtest scores.

Like the studies assessing IQ differences in children with AD/HD, inspection of the studies on the effects of stimulants on intellectual functioning in children with AD/HD reveal numerous methodological differences that may be creating the variability in findings. Important among these differences are the criteria used to define AD/HD, the attention given to the assessment of intellectual functioning, the ways in which children were identified as treatment responders, the design used to assess differences, and the difference between immediate and long-term effects of stimulants. Published studies include children who met criteria for DSM-III to DSM-IV, as well as those described as hyperactive but who do not meet DSM criteria for AD/HD. Methods used to identify if children met these diagnostic criteria also vary widely across studies. Several studies did not titrate doses of stimulant medication to find the most effective dose for the participants, which could affect test performance. Also, many studies make between-group comparisons to assess the effects of stimulant medication, while others make within-group comparisons. Such differences could account for the variability in findings.

Recent studies that have addressed the relationship between stimulant medication and IQ test performance have focused on the long-term effects of medication on IQ

scores. Gillberg et al. (1997) found that after 15 months of treatment with a stimulant medication, Swedish children exhibited a mean increase of 4.5 points on the WISC-R. A more recent investigation found that children with AD/HD demonstrated significant improvements in WISC-III IQ scores following 1 year of stimulant medication treatment (Gimpel, et al., 2005). Although these findings are promising, these studies were beset by methodological issues that may have resulted in flawed findings. Particularly, issues like symptom severity, efficacy of stimulant medication treatment, and the effects of other treatment methods were neglected.

In summary, the literature regarding the effects of stimulant medication on IQ test performance is inconsistent, with findings varying from large improvements in IQ scores to no change in scores. These inconsistencies are possibly due to methodological differences across studies. As a result, we do not know whether treatment with stimulant medication results in improved IQ scores.

Summary and Hypotheses

In general it is thought that children with AD/HD have lower IQs than non-affected children. However, the wide range of variability in research findings makes it difficult to reach an accurate conclusion. A primary reason for such inconsistencies appears to be the failure to assess the effects of stimulant medication on test performance. Studies have shown that stimulants improve performance on tests of behavioral inhibition and executive functioning (Barnett, et al., 2001; Epstein et al., 2003; Kempton, et. al., 1999; Mehta, et al., 2004; MTA Cooperative Group, 2004). Thus, it is reasonable to assume that treatment with stimulant medication would affect a child's performance on

an IQ test.

The objective of the present study, therefore, was to investigate the effects of stimulant medication on the IQ test performance of children with AD/HD. Specifically, this study investigated whether changes occur in the WISC-IV test scores of children with AD/HD as a function of stimulant medication usage. Based on Barkley's theory, one would expect children with AD/HD to obtain lower scores on the WISC-IV, given its inclusion of measures of working memory and processing speed in the calculation of the FSIQ score, as implicated by CHC theory. Furthermore, since children have different responses to medication, an assessment of both group-based and individual-based differences was performed to determine whether group-based findings are applicable to individual children. With this in mind, the following hypotheses were made:

1. Given that stimulant medication has been shown to improve executive functioning, it is hypothesized that children with AD/HD will exhibit improved scores on the WISC-IV FSIQ and index scores when on stimulant medication.
2. Consistent with prior research and theory, the largest increases would be expected on the indices and subtests that measure abilities controlled by executive functions. Thus, scores on both the WMI and PSI should increase significantly when compared to scores on these indices from the un-medicated session.
3. Finally, children who are considered positive treatment responders should show the greatest improvements in IQ scores compared to children who are taking medication, but it is not as effective in treating their symptoms.

CHAPTER II

METHOD

Participants

To be eligible for the study, each child met the following criteria for participation: (a) chronological age between 8 years 0 months and 14 years 11 months; (b) a diagnosis of AD/HD, any type; (c) current use of stimulant medication to treat symptoms of AD/HD; and (d) considered a positive responder to stimulant medication treatment. Children with the additional diagnoses of oppositional defiant disorder (ODD), conduct disorder (CD), or learning disability (LD) were allowed to participate in the study due to the high comorbidity of these disorders with AD/HD.

The diagnosis of AD/HD was established on the basis of parental responses to the AD/HD module of the Computerized Diagnostic Interview Schedule for Children (C-DISC-IV; Shaffer, Fisher, Lucas, et al., 2000), accompanied by clinically significant T-scores at or above the 93rd percentile on the attention problems and/or hyperactivity subscales of the BASC-II or ADHD Rating Scale–IV completed by parents and/or teachers. Only children currently taking stimulant medication to treat their AD/HD symptoms were allowed to participate in the study. Thus, children taking other forms of psychotropic medications were not eligible for participation. Each child's prescribing physician was contacted to verify the prescription information, provide a rating of the child's response to treatment with stimulant medication, and give approval for the child

to be off medication for the un-medicated testing session.

Exclusionary conditions for the study included evidence of psychosis, mental retardation, anxiety, depression, head injury, birth trauma or pervasive developmental disorders. Evidence of such difficulties was obtained from the BASC-II (completed by the child's primary caregiver and/or teacher), parental responses to the C-DISC-IV, and responses to specific questions included on the Participant Information and Demographic Questionnaire completed by the child's primary caregiver. Children with scores $\geq 93^{rd}$ percentile on the Anxiety or Depression subscales of the BASC-II and a diagnosis of a mood or anxiety disorder on the C-DISC-IV were excluded from participation. Children with an estimated WISC-IV FSIQ score of <70 were also excluded.

A summary of demographic variables and sample characteristics is presented in Table 3. A total of 44 male and female children were recruited from a university-based AD/HD clinic to participate in a study on "The effects of stimulant medication on IQ scores." All children had undergone a comprehensive multi-method AD/HD assessment, with portions of the assessment data being used to determine eligibility to participate in the study. Nine children who began the study dropped out or were found ineligible for various reasons including: adding a non-stimulant medication to their medication regimen (N = 3), having to stop taking the stimulant due to the development of a tic disorder (1), repeatedly missing scheduled testing appointments (2), and no longer meeting diagnostic criteria (3).

The final sample of 35 children consisted of 25 boys with AD/HD and 10 girls with AD/HD. The participants' ages ranged from 8.0 to 14.0 years, with a mean age of

10.9 years. Racial backgrounds were slightly different than that observed in the community, with 88.6% Caucasian children and 11.4% African-American children participating in the study. All three types of AD/HD were represented with 57.1% of participants diagnosed with AD/HD-C, 34.3% with AD/HD-IA, and 8.6% with AD/HD-H-I. Thirty-seven percent of participants were taking Concerta, 25.7% Adderall XR, and 11.4% Ritalin LA. The remaining 25.7% were taking other kinds of stimulant medications like Vvyanse, Daytrana, etc. The average amount of time the children had been on their stimulant medication was thirty months. Most children had an Individualized Education Plan (IEP) and were receiving special classroom accommodations due to their diagnosis; however, the majority of participants had never failed a subject, repeated a grade, or been suspended or expelled from school. Rates of comorbid diagnoses were also somewhat lower than those seen in the community. In particular, 22.9% of children were diagnosed with a Learning Disability, 5.7% were diagnosed with ODD, and only 2.9% were diagnosed with CD. These lower rates of comorbidity and academic difficulties indicate that the sample may represent a higher functioning group of children with AD/HD.

Measures

Computerized Diagnostic Interview Schedule for Children. The computerized Diagnostic Interview Schedule for Children (C-DISC-IV; Shaffer, Fisher, Lucas, et al., 2000) is a reliable and valid structured interview designed to assess DSM-IV psychiatric disorders and symptoms in children and adolescents 6 to 17 years of age. It includes a parent and a child version, both of which ask about the child's psychiatric symptoms. It

generates information about symptom counts, age of symptom onset, diagnoses, and functional impairment. The items are organized by diagnosis and the responses to most of the questions are coded as No (0), Yes (1), Not Applicable (8), or Don't Know (9).

The C-DISC-IV was administered to each participant's primary caregiver to determine if the child met DSM-IV criteria for a diagnosis of AD/HD and/or other psychiatric conditions that may cause the child to be excluded from participation. The caregiver was asked if their child exhibited specific symptoms during the past year and the past 4 weeks; follow-up questions were asked in the case of positive endorsement. In addition to AD/HD, other diagnoses covered as part of this study included: simple and social phobia, separation anxiety, panic disorder, conduct disorder, oppositional defiant disorder, enuresis, encopresis, tic disorders, major depression, dysthymia, and mania.

ADHD Rating Scale. The ADHD Rating Scale-IV (ADHD-RS; DuPaul, Power, Anastopoulos, & Reid, 1998) is a psychometrically sound instrument for diagnosing AD/HD in children and adolescents. There are two versions of the scale, a parent questionnaire on home behaviors and a teacher questionnaire on classroom behaviors—both of which contain 18 items that are linked directly to DSM-IV diagnostic criteria for AD/HD. Each item is rated on a Likert scale from 0-3, ranging from "not at all" to "very often." Both versions consist of a Total Score scale and two subscales, Inattention (nine items) and Hyperactivity-Impulsivity (nine items). Only the subscales were used in the current study. Raw scores for the subscales were converted to percentile scores by using the appropriate scoring profile (presented in the manual) based on the child's gender and age. Scoring profiles are available for boys and girls aged 5-17, and are based on

nationally representative norms. The two subscale scores were used to provide evidence that participants exhibit developmentally deviant symptoms of AD/HD, a criterion required for a DSM-IV diagnosis of AD/HD.

Behavior Assessment System for Children-Second Edition. The Behavior Assessment System for Children-Second Edition (BASC-2; Reynolds & Kamphaus, 2004) is a nationally standardized, normed, and psychometrically sound rating scale that uses a multidimensional approach for measuring behavior and emotions of children and adolescents. There are several forms of the BASC-2; however, only the Parent Rating Scales (BASC-P) and Teacher Rating Scales (BASC-T) for the child (ages 6-11) and adolescent (ages 12-21) versions were used in the current study. These forms contain 100-160 items depending on the age of the child, require a fourth grade reading level, and take about 10–20 minutes to complete. Individuals provide ratings of the frequency of the child's behavior on several dimensions of functioning such as externalizing behaviors (e.g., conduct problems, aggression, hyperactivity), internalizing problems (e.g., depression, anxiety), and adaptive functioning (e.g., social skills). Validity and response set indexes are available to help judge the quality of completed forms. A computer scoring system generates T scores and percentiles for each dimension based on age and gender norms. The scores from the various externalizing and internalizing scales were used to assess the developmental deviancy of symptoms, and identify whether other conditions exist that may exclude a child from participation in the study.

Wechsler Intelligence Scale for Children-Fourth Edition. The Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV; Wechsler, 2003) is one of the

most widely used measures for assessing the general cognitive ability of children aged 6 to 16. It includes 10 core and 5 supplemental subtests, all of which demonstrate good reliability. All 10 core subtests were administered for the current study. However, participants were administered a split-half form of each subtest at each testing session rather than entire subtests. The split-half forms of the WISC-IV were created so that form A included all odd numbered items on the subtests, while form B used all even numbered items.

Given that the subtests on the Processing Speed Index (PSI) are timed, a split-half procedure using odd and even numbered items could not be easily implemented. Therefore, alternate forms of the core PSI subtests were created that lend themselves to the split-half procedure. For the alternate form of the Coding subtest, the key from the original subtest was re-arranged so each number in the key was paired with a different symbol (e.g., the 1 was paired with the symbol that was originally paired with the 9 and vice versa). This way, the subtest was still able to assess the child's speed of mental operation while reducing the amount of practice effects. For the Symbol Search subtest the alternate form involved administering the protocol in reverse order, meaning that the child started with the last page of the protocol first and worked toward the first page.

The process for halving the Block Design and Letter-Number Sequencing subtests also had to be modified because the two forms were not equivalent. For Block Design, when the subtest was halved the total score on the even form was potentially two points higher than the odd form. To make the forms equal, the first item on the odd form was scored as a four-point response instead of a 2-point response. For the Letter-Number

Sequencing subtest, the odd form was found to be easier than the even form because the odd form had two items of the same difficulty level compared to that of the even form, where all items administered increased in difficulty. In particular, the odd form went from having the child put 2 letters/numbers in correct sequence, to three letters/numbers, to another set of three, to a set of five, and then a set of seven. In contrast, the even form went from 2 letters/numbers, to three, to four, to six, to eight. Although several ways exist to correct this problem, it was decided that for the even form the last item would not be administered; instead, the child's score on the item requiring ordering of three letters/numbers would be doubled as if the child had been administered a second set of three letters/numbers like that of the odd form.

Each alternate form of the WISC-IV was scored to provide FSIQ and Index scores to be used for comparisons. To accomplish this, raw scores from each subtest on each form were doubled to resemble a typical subtest score, had the full subtest been administered. These scores were then converted into standard scores based on the child's age. The processes for deriving the FSIQ and Index scores were the same as that described in the WISC-IV manual.

Conners' Continuous Performance Test. The Conners' Continuous Performance Test (CPT II) Version 5 for Windows (Conners & MHS Staff, 2000) is a reliable and valid test that is widely used in AD/HD research and clinical assessments for individuals aged 6 or older. The test is administered on a computer and takes approximately 20 minutes to complete the standard protocol, which includes a practice administration and then the full test. The standard protocol uses the short practice exercise prior to the

administration of the full test to ensure the respondent understands the task. Participants are told that letters of the alphabet will appear on the screen and that they are to press the spacebar when any letter except the letter 'X' appears on the computer screen.

Though the CPT II provides numerous measures that assess deficits in attention, activation/arousal, and vigilance, only the Error scores, Clinical Confidence Index, Hit Reaction Time, Hit Reaction Time Standard Error, and Variability were used in the present study. These measures were selected due to their sensitivity to change in children with AD/HD following a dose of stimulant medication. In particular, studies show that use of stimulant medications generally result in fewer errors of commission and omission, as well as decreased reaction times and decreased variability (Conners, 2000). The two types of errors analyzed in the CPT include: (1) misses, or omission errors, which are considered a measure of inattention; and (2) false alarms, or commission errors, which are considered a measure of impulsivity. The Clinical Confidence Index is a discriminant function that indicates whether the participant's overall performance on the CPT better matches a clinical versus non-clinical profile. Hit Reaction Time measures the mean response time for all target responses, whereas Hit Reaction Time Standard Error is the consistency of response times expressed in standard error for responses to target.

Participant Information and Demographic Questionnaire. This questionnaire was created and used in this study to obtain information regarding important variables used in determining study eligibility. The child's primary caregiver completed the questionnaire prior to participation in the study. Requested information addressed: the child's age, gender, ethnicity, diagnosis(es), prescribing physician, name of current prescribed

medications, prescribing physician's instructions regarding the medication, length of time on current medication, person responsible for administering the medication, whether or not the child is responding positively to the medication, and whether or not the family is compliant with the physician's orders regarding medication administration. Parents were also asked if their child receives special education services in school, attends remediation classes, or receives help from a tutor to determine if the child is learning disabled. Questions regarding the child's mental and emotional status were also asked to assess for the presence of other diagnoses such as a pervasive developmental disorder or mental retardation. Information regarding history of neurological impairment, closed head injury, prenatal or peri-natal birth trauma, chronic physical illness, sensory or motor impairment was also obtained.

Physician Questionnaire. This questionnaire was created and used in this study for three purposes; 1) to request approval from the child's prescribing physician for the child to participate in the study, 2) to obtain information regarding the child's diagnosis(es) and medications, and 3) to provide a rating of the efficacy of the child's medication. The medication efficacy question requested the physician to rate how effective the child's medication was on a scale of 1-5, with 1 being "not effective" and 5 being "extremely effective." Only children who received an efficacy rating of 3 or higher were eligible to participate in the study.

Procedure

Participants were recruited from a group of children who had been evaluated by the AD/HD Clinic at the University of North Carolina at Greensboro (UNCG). Mothers

of children aged 8-14 diagnosed with AD/HD were approached to request their child's participation in a study of the effects of stimulant medication treatment on IQ scores. Interested participants were given a detailed description of the study. Parents provided written informed consent for their child to participate, and child assent was also obtained prior to participation. Parental consent was also obtained to allow the researcher to contact the child's physician to obtain written approval for the child to participate in the study. All eligible participants were then assessed using the WISC-IV and CPT on two occasions approximately 2-6 weeks apart. The average interval between testing sessions was twenty-five days (M = 24.67, SD = 35), with a median of 15 days and a mode of 14.

Children were randomly assigned to receive their medication prior to the first testing session or to be off their medication the day of their first testing session. Efforts were made to keep the principal investigator blind to the on/off medication sequence assigned to each child by having a research assistant assign and inform the parents of the on/off status of the child. The day before testing sessions parents were called by a research assistant to be reminded of the child's on or off medication status. Despite these efforts, several accidental disclosures by the child and/or parent did occur (e.g. while reading the assent form, one child stated, "But I didn't take my medicine today.")

The testing sessions were conducted by a trained graduate student and lasted approximately 60-90 minutes. For the medicated session, parents administered their child's medication at least 90-120 minutes before testing to ensure peak psychostimulant medication clinical effect (Gualtieri et al., 1982; Swanson, Kinsbourne, Roberts, & Zucker, 1978). For the un-medicated session, children were required to be medication-

free for the day of testing. Since many children with AD/HD need their medication to function appropriately at school, the testing sessions were held on days when this would not interfere with school (i.e., Saturday mornings or school holidays).

For both testing sessions, children completed the CPT and then a split-half form of the WISC-IV. The CPT was administered at the start of the sessions to ensure the length of time it took to administer the IQ test did not interfere with CPT ratings. The order of the split-half forms of the WISC-IV was randomly assigned to reduce the possibility of order effects. Once both testing sessions were completed, participants were thanked and paid $40 for their participation. The primary caregiver was also mailed a summary letter describing their child's IQ test performance on and off medication. All participants were treated in accordance with the American Psychological Association's ethical guidelines.

CHAPTER III

RESULTS

Preliminary analyses

An examination of the distributions of each continuous variable, along with skewness and kurtosis statistics, indicated all of the variables were approximately normally distributed.

Group Differences. Comparisons to assess for differences between the participants who completed the study (completers) and those who did not (non-completers) were conducted. Independent sample t-tests revealed no differences in age ($t = 1.97$, $p = .72$), severity of Inattention ($t = 1.57$, $p = .84$), severity of Hyperactivity-Impulsivity ($t = .90$, $p = .67$), or length of treatment with medication ($t = .61$, $p = .22$). Given the small sample size, which resulted in less than 10 children per cell, chi-square tests of independence could not be performed. Thus, statistical analyses using Fisher's exact test (FET) were conducted. Results revealed no differences in gender ($p = .27$, FET), race ($p = .73$, FET), AD/HD type ($p = .70$), or medication type ($p = .06$). No significant differences were evident regarding rates of Learning Disability Diagnosis (LD; $p = .42$, FET), Oppositional Defiant Disorder Diagnosis (ODD; $p = .52$, FET), or Conduct Disorder diagnosis (CD; $p = .38$, FET). Furthermore, no significant differences were evident regarding any of the academic variables including having failed a subject ($p = .15$, FET), having repeated a grade ($p = .62$, FET), history of being suspended ($p = .46$,

FET), history of psychological treatment (p = .10, FET), or rates of Individualized Education Plans (IEP; p = .06, FET). Taken together, these results indicate that the completers and non-completers did not differ in any significant ways. Thus, the children in the completers group are believed to be a good representation of typical children in the AD/HD population.

Order Effects. Additional analyses were conducted to assess for the possibility of order effects. In particular, these analyses assessed whether the order of the child's on-off medication sequence or the order of the IQ form had an effect on the findings. A 2 (Medication Order) X 2 (Medication Status) repeated measures analyses of variance (ANOVA) revealed no significant interactions between the variables. Specifically, the interactions between medication order and medication status $F(1, 32) = .15$, $p = .70$) was not significant. The 2 (Form Order) X 2 (Medication Status) was also not significant, $F(1, 32) = .92$, $p = .35$). Also of note, no significant main effects occurred due to the order of either variable (medication order; $F(1, 32) = .16$, $p = .69$; Form order, $F(1, 32) = .00$, $p = .97$). Since no order effects were observed, these variables were not included in any of the following analyses.

Correlational Analyses. Correlational analyses were performed to assess the relationships between the IQ and CPT variables when the children were on and off medication. As shown in Tables 4 and 5, the four IQ indices were highly correlated with FSIQ across medication conditions. The correlations ranged from .50 to .80 and were significant regardless of medication status. Though the correlations between FSIQ and the VCI and PRI were similar to those reported for the normative sample, the correlations

between FSIQ and the WMI and PSI were somewhat lower.

As seen in Table 5, the correlations for the IQ and CPT variables were non-significant for all comparisons when the children were off medication. In contrast, when on medication, significant negative correlations were evident among many of the IQ and CPT variables. These correlations ranged from -.34 to -.50. For instance, small negative correlations were observed between FSIQ and the CPT variables of Omissions (-.38), Hit Reaction Time (-.34), Hit Rate Standard Error (-.38), and Variability (-.38). These findings indicate that when the children were medicated, a negative relationship was evident among IQ scores and CPT performance, whereby higher IQ scores were related to fewer errors on the CPT.

Group-Based Analyses Of Medication Effects

To test the effect of stimulant medication on the performance of children with AD/HD on the WISC-IV, a repeated measures analysis of variance (ANOVA) was performed for the FSIQ and Index scores. Mean scores and standard deviations for the on and off medication groups are presented in Table 6.

FSIQ. The analyses revealed that the use of stimulant medication produced significant increases on many dimensions of the WISC-IV. As seen in Table 6, the use of stimulant medication resulted in a significant increase in the FSIQ score, $F(1,34) = 26.12$, $p < .001$. This increase in score was equivalent to approximately 7 points. The partial eta squared value was .44, which is considered a large magnitude of effect (Cohen, 1988). Thus, at a group-based level, affected children obtained higher FSIQ scores when medicated.

Indices. To explore what components of the WISC-IV were causing the increase in FSIQ, repeated measures ANOVAs were computed for each index score. These analyses revealed that the source of change seen in FSIQ scores was due to a significant effect of medication in performance on several of the index scores. Specifically, when on medication participants' scores increased significantly on the VCI ($F(1,34)$, = 11.62, $p < .01$), WMI ($F(1, 4) = 6.40$, $p < .05$), and the PSI ($F(1,34) = 7.35$, $p < .01$). On average an increase in score of approximately 6 to 7 points was considered significant on these indices. The effect sizes as measured by partial eta squared ranged from .16 for the WMI, .18 for the PSI, and .26 for the VCI. No significant differences were seen for PRI scores, $F(1,34) = 1.92$, $p = .18$. These findings indicate that the change seen in FSIQ was most likely due to the combined impact of several indices.

Individual-Based Analyses of Medication Effects

The individual analyses of IQ test differences were computed using Jacobson and Truax's Reliable Change Index (RCI), a statistical procedure used to determine whether clinically meaningful change has occurred as the result of the implementation of a treatment. It is calculated for each participant and corrects the change score between two points of assessment by the unreliability (test–retest reliability) of the instrument used to assess treatment effects. It is calculated by dividing the difference between the pre-treatment and post-treatment scores by the standard error of the difference between the two scores. If the resulting RCI is greater than 1.96, then the difference is considered reliable—a change of this magnitude would not be expected due to chance findings.

For the purposes of this study, the RCIs were computed by subtracting the un-medicated session IQ scores from the medicated session IQ scores. Thus, if a positive difference was noted, it would in the expected direction (IQ scores increase with the use of stimulant medication). Additionally, the RCIs were calculated using the normative population age and gender specific test information when available data from the WISC-IV and CPT manuals. For instance, the CPT manual provided information on the standard error of difference statistic broken down by age groupings and gender, whereas the WISC-IV provided this information only specific to age groupings.

RCIs were calculated for the FSIQ and each of the four indices. Once these scores were obtained, new categorical variables were created that identified each child as a responder or non-responder based on whether they exhibited a positive reliable change on each of the IQ variables. For instance, children demonstrating a reliable change on their FSIQ score were labeled FSIQ responders and coded a 1, while children who did not demonstrate a reliable change on FSIQ were labeled FSIQ non-responders and were coded with a 0. The percentage of children demonstrating reliable change (improvement) on FSIQ and the four indices is shown in Table 7.

FSIQ. RCIs for the thirty-five participants ranged from –3.81 to 9.25 on the FSIQ. On average an improvement of 8 points on the FSIQ was considered a reliable change, a finding similar to that of the group-based analyses. Forty-eight percent of the children showed a significant positive change in FSIQ (M=1.97, SD= 2.28).

Indices. RCIs for each of the indices ranged from -2.14 to 6.13 on the VCI, from -2.67 to 4.81 on the PRI, from -6.01 to 8.73 on the WMI, and from -3.13 to 4.13 on the

PSI. On average an increase of 11 points on the VCI, PRI, and WMI, and 14 points on the PSI constituted a reliable change in scores. Percentages for the four indices were somewhat smaller than that for the FSIQ, with 31% exhibiting reliable change on the VCI, 20% on the PRI, 46% on the WMI, and 29% on the PSI.

Overall IQ Response. Given the importance of identifying the percentages of children who exhibited any significant improvements on the WISC-IV due to medication usage, counts of the children who showed a positive reliable change on any of the IQ scores were computed. These counts revealed that a total of 89% of children (N = 31) exhibited a reliable improvement in their scores on either the FSIQ or one of the four indices after taking their stimulant medication. Thus, the majority of children showed some kind of reliable increase in their scores on the WISC-IV due to medication use. Nonetheless, four children had no response on any of the five IQ variables, which suggests that just being on medication is not enough for some children to exhibit significant improvements in their IQ test performance.

Check on Experimental Manipulation

As a check on whether the medication the children were taking was actually effective, additional group-based analyses were conducted. Specifically, repeated measures ANOVAs were conducted looking at the difference between the off medication and on medication testing results for each of the CPT variables. Results from this analysis revealed that when on medication, children showed significant differences in their performance on several of the CPT variables. As shown in Table 8, significant differences were noted on the AD/HD Clinical Confidence Index, $F(1, 34) = 21.51$, $p <$

.001. In particular, children with AD/HD were less likely to exhibit performance on the CPT that resembled that of a clinical AD/HD population. In addition, significant differences were also seen in Hit Reaction Time, $F(1, 34) = 35.01$, $p < .001$, Hit Reaction Time Standard Error, $F(1, 34) = 24.39$, $p < .001$, and on Variability, $F(1, 34) = 14.92$, $p < .001$. These results indicate that children with AD/HD had improved reaction times, exhibited less variability in their reaction times, and had less variability in their responses in general, after taking stimulant medication. Interestingly, no significant group-based differences emerged in regards to the number of commission, $F(1, 34) = 1.39$, $p = .25$, or omission errors, $F(1, 34) = 3.18$, $p = .08$, children made after taking medication.

Because children exhibit individual differences in their response to stimulant medication, further analyses were conducted to identify which children were considered as having a positive response to their medication. This was achieved by computing RCIs for each child based on their performance on the CPT. Though scores on several CPT indices were recorded, only the Clinical Index, Commissions, Omissions, Hit Reaction Time scores, and Variability were used in calculating the RCIs. This decision was based upon information in the manual and research findings indicating that these variables are most sensitive to effects of medication, and these variables exhibit a moderate to high test-re-test reliability coefficient (Conners, 2000; Epstein et al. 2003; Riggio et al., 2001). Thus, if a child showed a positive reliable change of 1.96 or higher on any of these CPT indices, he/she was classified as a CPT medication responder. Children who did not show a reliable change on any of the aforementioned CPT variables were labeled CPT non-

responders. Table 9 provides a breakdown of the percentages of children who showed a reliable change on each of the CPT variables.

Based on the RCI results, 77.1% percent of children (N = 27) were labeled CPT medication responders, due to their having exhibited a reliable change on at least one of the CPT variables following the use of stimulant medication. The remaining eight children showed no significantly reliable differences in their scores on any of the five CPT variables. Thus, when using the CPT to assess medication efficacy, not all children in the sample were identified as being on a medication that seemed to effectively control their symptoms of AD/HD, particularly symptoms of inattention and impulsivity.

CPT Medication Responder vs. Non-Responder Analyses

Given the findings regarding medication efficacy, analyses were conducted to assess for possible differences in IQ test performance between the groups of children labeled as CPT medication responders and non-responders. This was achieved using 2 (CPT Medication Responder) x 2 (Medication Status) repeated measures ANOVAs.

FSIQ. Analyses revealed a significant interaction between CPT medication response and medication status on FSIQ score, $F(1, 33) = 4.22$, $p < .05$. Specifically, FSIQ scores varied as a function of medication usage and response to the CPT. This difference was considered a noticeable effect based on the partial eta squared value of .11. A one-way ANOVA revealed that the significant difference between the groups of CPT medication responders and non-responders was on FSIQ score when on medication. In particular, when on medication, children labeled CPT medication responders obtained significantly higher FSIQ scores than non-responders, $F(1, 33) = 5.45$, $p < .05$. For CPT

medication responders the mean FSIQ score on medication was 107.6, (SD = 12.23) compared to 95.63 (SD = 14.31) for non-responders. Thus, it appears that children who exhibited a positive response to their medication as measured by CPT scores, obtained FSIQ scores when on medication that were approximately 12 points higher than those obtained by children whose medication was not as effective. A one-way ANOVA also showed that a significant difference emerged between groups in the amount of change that occurred in FSIQ scores due to medication usage, $F(1, 33) = 4.22$, $p < .05$). The mean score difference in FSIQ for CPT medication responders was 8.75 points (SD = 8.17) compared to 2.13 (SD = 7.32) for non-responders. See Figure 4 for a summary of these differences.

Indices. Repeated measures ANOVAs of group-based differences in index scores revealed that children who were effectively medicated scored higher only on one index. Scores for CPT medication responders and non-responders were different on the VCI following use of medication, $F(1, 33) = 6.18$, $p < .05$. The partial eta squared value for this effect was .16. A one-way ANOVA revealed that VCI scores obtained after taking medication were higher for CPT medication responders compared to non-responders, $F(1, 33) = 5.49$, $p < .05$. In fact, the CPT medication responders obtained a mean VCI score of 107.6 (SD = 14.19) compared to non-responders who obtained a mean score of 94.3 (SD = 13.97). Interestingly, significant differences were also evident in the amount of change that occurred due to medication use, $F(1, 33) = 6.18$, $p <. 05$. The mean change in scores for CPT medication responders was approximately 8 points (SD = 9.35) compared to non-responders who exhibited a decrease in scores of 1.38 (SD = 7.35) when

medicated. Thus, non-responders actually scored higher on the VCI when not medicated; however, these differences were not significant, $F(1, 7) = .28$, $p = .61$. This same pattern was evident regarding PRI scores for non-responders; yet the differences were not significant $F(1, 7) = .71$, $p = .43$). In sum, these analyses revealed that when taking a medication that effectively treats one's symptoms, children with AD/HD score higher on the FSIQ and VCI. Moreover, their scores are significantly higher than children taking ineffective stimulant medication.

Percentages of the CPT medication responders and non-responders who exhibited a reliable change in FSIQ and each of the indices were computed to compare with the previously obtained percentages (see Table 10). Analyses of the counts revealed results somewhat similar to those obtained using the entire sample. Specifically, 59% of CPT medication responders (N = 16) showed a reliable change in FSIQ compared to 12% of CPT non-responders (N = 1). On the VCI, 37% of CPT medication responders (N = 10) showed a reliable change compared to 12% of the non-responders (N = 1). On the PRI, 26% of CPT medication responders (N = 7) showed a reliable changed while none of the non-responders evidenced an RCI of 1.96 or higher. On the WMI, 48% of CPT medication responders (N = 13) had reliable changes in scores compared to 38% of non-responders (N = 3). And finally, on the PSI, 22% (N = 6) of children labeled as having a positive response to their medication showed a reliable change in scores compared to 50% of non-responders (N = 4). Overall, the percentages for CPT medication responders were slightly larger than those based on all thirty-five children; however, two interesting findings emerged. First, the percentage of CPT medication responders who responded on

the PSI was smaller than that of the total sample, and second the number of non-responders who exhibited a reliable change on the PSI was much higher than that of CPT medication responders.

Exploratory Analyses

Additional analyses were conducted to assess for the presence of variables that could impact IQ test performance. The variables included in these analyses were gender, race, type of AD/HD (excluding the Hyperactive-Impulsive type), and type of stimulant medication (i.e. amphetamine-based medication compared to methylphenidate-based medication). Each of these variables were analyzed using 2 x 2 repeated-measures ANOVAs. The results revealed no significant interactions between gender and medication status, $F(1, 33) = .52$, $p = .48$) or race and medication status, $F(1, 33) = .40$, $p = .53$. The same was true for type of stimulant medication and medication status, $F(1, 33) = .04$, $p = .85$, and AD/HD type and medication status, $F(1, 33) = .32$, $p = .58$. However, the observed power for each of these analyses was extremely low, with rates ranging from .05 to .27, making it difficult to identify any possible differences.

Interestingly, a main effect was found for gender, $F(1, 33) = 7.12$, $p < .01$. The partial eta squared for this effect was .18. Follow-up analyses revealed that females with AD/HD ($M = 93.3$, $SD = 3.51$) scored lower than males with AD/HD ($M = 104.4$, $SD = 2.22$). In sum, though none of the variables appeared to have an impact on whether a child exhibited a reliable change in FSIQ due to medication use, there were significant differences between males and females regarding their FSIQ scores, with females with AD/HD generally having lower FSIQ scores than males with the disorder.

CHAPTER IV

DISCUSSION

According to Barkley's theory, children with AD/HD exhibit deficits in the processes that control and regulate thought and actions. These deficits cause impairments in executive functioning, which negatively impact an affected child's ability to plan, organize, make decisions, problem-solve, and regulate their behavior. These executive functions, which have been identified by Cattell-Horn-Carroll's theory (CHC) as components of the construct of intelligence, are commonly measured by intelligence tests such as the WISC-IV. Given this knowledge, it has generally been thought that children with AD/HD have lower IQs than children without the disorder. However, variability in research findings has made it difficult to reach an accurate conclusion regarding the intellectual functioning of affected children. A primary reason for such inconsistencies appears to be the failure to assess the effects of stimulant medication on test performance. Though stimulant medication has been shown to be the most efficacious treatment for AD/HD, few studies have focused on whether treatment with stimulants actually results in improvements in IQ scores.

In an effort to help clarify this situation, the primary purpose of this study was to determine whether stimulant medications have a significant effect on the IQ test performance of children identified as having AD/HD. More specifically, it was proposed that children with rigorously defined AD/HD would exhibit significant increases in FSIQ

scores following a dose of their stimulant medication. Although it was believed that scores would be improved on all four indices, the WMI and PSI were expected to show the largest increases because of their relationship to the executive functions, proposed by Barkley, to be deficient in children with AD/HD. In addition, rather than assuming the children were taking a medication that was effectively treating their symptoms, analyses were conducted to assess medication efficacy and whether this had an effect on test performance. Accordingly, children who exhibited a positive response to medication were expected to exhibit larger increases in scores than those whose medication was not as effective in managing their symptoms. The final aim of this study was to clarify the relationship between group-based and individual-based analyses by conducting both types of analyses and making comparisons of the results.

General Findings

The results of the group-based findings were supportive of the first hypothesis. Analyses revealed that at a group-based level, a main effect for medication was present. Hence, after taking stimulant medication children with AD/HD obtained significantly higher IQ scores. Overall, children showed an improvement of about seven points on the FSIQ. This magnitude of change is equivalent to about half of a standard deviation on the WISC-IV and was considered strong, as evidenced by a partial eta squared effect size of .44.

Regarding the changes in indices, the hypotheses were partly supported by the finding that children with AD/HD exhibited improved performance on three of the four indices. Affected children obtained significantly higher scores on the VCI, WMI, and PSI

following a dose of their stimulant medication, with the differences in scores averaging six to seven points higher on these indices. Though it was proposed that significant increases would occur on all of the indices as a result of medication usage, no significant changes were evident in regard to PRI scores. As expected the largest increases in scores occurred on the WMI and PSI. However, an interesting finding emerged, which indicated that though the improvements on the VCI were the smallest of the significant improvements, the VCI had a more noticeable effect. Specifically, the partial eta squared effect size of .26 indicates that approximately 26% of the total variability in VCI scores was attributable to the use of medication, compared to 16% and 18% for the WMI and PSI, respectively. This is an interesting finding in light of the fact that previous research has identified that stimulants have the strongest effects on tasks of working memory and speed of information processing (Kempton, et al., 1999; Mehta et al., 2004). Taken together, these findings imply that stimulants had a slightly stronger effect on tasks measuring verbal abilities, and that the increase seen in FSIQ was the result of a collection of changes instead of being attributable to one particular index.

As previously noted, another purpose of this study was to examine the results at both the group and individual levels. While most studies in the field have focused on group-based findings, it is not clear whether such findings are also applicable to individual children. Given the findings by Anastopoulos et al. (1994), it is plausible that individual children do not exhibit the same pattern of test scores as indicated by group averages. This can occur when a small number of subjects' results are supplying the driving force behind the group-based findings.

According to the results, the individual and group-based analyses were somewhat similar. In particular, both resulted in the finding that medication improves IQ test performance, and that this improvement was due to increased scores obtained on several indices. However, several differences emerged. First, though the FSIQ was shown to increase at the group level, only forty-eight percent of children had a reliable change in FSIQ. Secondly, according to the group-based analyses, the change seen in FSIQ was attributable to an improvement of about seven points on the VCI, WMI, and PSI. Conversely, at the individual level, a reliable change on these indices was equivalent to an increase of eleven to fourteen points. And, though forty-six percent of children demonstrated a reliable change on the WMI, only about a third of children showed a reliable change on the VCI and PSI. Such differences highlight the need for caution in interpreting group-based results and argue against a "one size fits all" approach.

Given the MTA study (2004) findings showed that subjects who were treated by physicians in the community responded less favorably on outcome measures than those whose medication response was objectively assessed and titrated throughout the course of the study, analyses were conducted to assess medication efficacy. In particular, though the children in the community arm of the project exhibited significant improvements in their behavior in several domains, these improvements were not as great as those for the children in the medication management group. Therefore, rather than assume that participants' were on an effective medication, analyses were conducted to examine each child's response to their stimulant medication and to assess if differences in response rates produced variability in IQ test performance. This was accomplished by using the

RCI procedure developed by Jacobsen and Truax (1996) to identify the presence of reliable change on CPT scores due to medication response. According to these results, over three-quarters of children exhibited a positive reliable change on at least one of the CPT variables. Thus, many of the children were taking medication that was considered effective, as measured by their CPT responses.

As expected, children who responded positively to medication obtained significantly higher IQ scores than those who did not respond to their medication. In fact, children taking an effective medication scored an average of twelve points higher on FSIQ than those whose medication was not effective. A similar finding was also noted for their scores on the VCI, which were thirteen points higher. Also, the amount of change between off and on FSIQ and VCI test scores for medication responders was significant, which was not the case for non-responders. In particular, responders showed an increase of eight points in FSIQ and VCI scores when on medication. These differences are almost equivalent to a full standard deviation on most intelligence tests used today. Such substantial differences bring to light the importance of assessing medication efficacy and appropriately titrating medication dosages.

Interestingly, unlike the group-based analyses of all children in the study, no significant improvements were observed for the other indices. Thus, while stimulants have a general impact on working memory and speed of information processing, they appear to have a stronger impact on a child's verbal abilities when appropriately prescribed and titrated. Hence, taking stimulant medication will indeed improve test performance yet, taking a medication that effectively manages a child's symptoms results

in larger improvements in the abilities measured by IQ tests.

Additional analyses were conducted to assess whether any particular variables had an effect on the main findings. Interestingly, a main effect was found for gender whereby girls scored lower on FSIQ than males. The mean difference in scores was approximately eleven points. Though there were only ten girls in the sample, the findings were robust. Rucklidge and Tannock (2001) also identified this difference in their study. This finding indicates the importance of assessing the impact of variables that could differentially affect the relationship between IQ test performance and stimulant medication usage. Though these findings suggest females with AD/HD are not as intelligent as males with the disorder, another reason may explain this finding. Since the criteria for AD/HD was based on the behavior of males, it seems females have to be more impaired in order to meet criteria for the diagnosis. By being more behaviorally impaired, one would expect significantly lower scores on other measures of functioning.

No other variables, including race, stimulant medication type, or AD/HD type were found to have a significant effect on the findings. However, it should be noted that these analyses had insufficient power to adequately detect possible effects of these variables on the findings. Given the limited number of studies addressing this issue, future research will be key in elucidating the relationship between gender, stimulant medication, AD/HD, and IQ test performance.

As previously mentioned, there has been a great deal of uncertainty about whether children with AD/HD have lower IQ scores than children in the general population. The findings from the current study are consistent with previous research indicating that the

IQs of children with AD/HD are normally distributed. Specifically, affected children were found to score in the average range when both on and off medication. However, when effectively medicated, their scores were in the upper end of the average range; but, when not medicated, their scores fell in the lower end of the average range. Therefore, depending on the state in which children are tested, their test performance could result in scores that fall in either the higher or lower ends of the average range like those of unaffected children. This finding might explain why affected children have exhibited lower scores in previous studies, especially in those studies that did not control for medication status prior to testing. For instance, previous studies indicating that children with AD/HD score between 7-15 points lower than unaffected children is possibly an artifact of the child's medication usage and efficacy prior to testing.

The present findings are also important in the context of the MTA findings. Specifically, the group-based analyses for the entire sample showed a significant amount of improvement in test performance when children were medicated. This finding is comparable to that of the results of the MTA community care group, who also exhibited significant improvements when medicated. However, the magnitude of the observed change for both this sample and the community care group was less than that of the group of children who were taking an effective medication, a group analogous to the medication management group. These findings emphasize that a prescription for a stimulant medication is not enough. Instead, children's responses to medication must be objectively and routinely assessed, and the dose titrated accordingly. Otherwise, they are not receiving the full benefit of treatment.

Another interesting finding from this study regards the magnitude of changes evident in the FSIQ and indices when medicated, especially on the FSIQ and VCI. In general, children showed significant increases in scores on the FSIQ that were attributed to improvements in indices measuring working memory, speed of information processing, and verbal comprehension. This is somewhat consistent with prior research; however, the significant increase in VCI scores was surprising, especially the magnitude of change in VCI for the medication responders.

Several factors should help to explain these findings. First, the structure of the WISC-IV is much different than its predecessors, which have been used in past research to assess the intellectual functioning of children with AD/HD. One of the most important changes is in how the FSIQ is calculated. Specifically, rather than include only two of the four WMI and PSI subtests as on the WISC–III, all four of the WMI and PSI subtests are now included in determining FSIQ on the WISC-IV. Additionally, several of the indices have been refined so they are more representative of the *Gf-Gc* abilities as identified by CHC theory. For instance, the WMI now comprises only two subtests that are direct measures of working memory (Digit Span and Letter-Number Sequencing versus Digit Span and Arithmetic on the WISC–III FFD) and is no longer confounded by the inclusion of the Arithmetic subtest—a measure of math ability and fluid intelligence. Furthermore, the PRI now has only one timed visual-motor test (Block Design), in contrast to the three that were on the WISC-III. This change reflects the increased emphasis on fluid reasoning abilities and reduces the impact of speeded performance and motor skill on this index. Overall, these changes have improved the ability of the WISC-IV to assess both

fluid and crystallized intelligence. Furthermore, the inclusion of additional subtests that assess working memory and processing speed in the calculation of FSIQ should result in a higher FSIQ, given the improved performance on WMI and PSI that occurs as a result of stimulant medication use.

In regard to the significant increase in VCI, it appears that children exhibited improvements in the executive function of reconstitution as a result of medication use. In particular, when on medication, especially one that was effective, children exhibited increased verbal fluency and application of knowledge. Verbal fluency is the ability to take apart incoming information and then use parts of this information or create new parts to produce a verbal or behavioral response. It is dependent on behavioral inhibition to provide the delay necessary for the individual to take time to process information from the situation, develop possible responses, and then test out these potential responses before selecting and engaging in one. This process was evident during testing sessions as noted by the fact that, when medicated, many children provided an improved response to verbal subtests. Specifically, their responses were more reflective of 2-point answers, more complex and conceptually correct responses, rather than vague or incomplete responses that were scored as 0 or 1 point. For instance, when off medication, children frequently responded to questions with “ums” and “uhs” while trying to describe concepts, or as soon as the question was posed, they quickly stated, “I don’t know.” Thus, it appears that stimulants provided the inhibition in responding needed to retrieve learned information, organize it, and then present it in a coherent manner. As has often been

reported about children with AD/HD, it is not their lack of knowledge that causes them problems but their difficulty accessing that knowledge when they need it.

Though one could speculate that stimulant medication would have a stronger impact on fluid intelligence given its dependence on the physiological structures that support intellectual behavior, it appears that medication improves crystallized abilities. This is supported not only by the aforementioned VCI findings but also by the fact that no significant changes were evident at a group-based or individual level on the PRI. Fluid intelligence is best measured by tasks requiring adaptation to new situations and those for which prior learning is not helpful. The subtests that comprise the PRI require children to solve novel tasks by forming and recognizing concepts, identifying and perceiving relationships, and drawing inferences. Given these abilities are direct measures of fluid intelligence and children did not exhibit significant changes in PRI scores when medicated, it appears fluid intelligence was not significantly affected by medication use.

Implications

The findings from this study have several implications for research, theory, and clinical practice. Since children with AD/HD were shown to exhibit significant increases in IQ scores as a function of stimulant medication use, researchers must begin to identify the medication status of children prior to testing. Furthermore, medication efficacy needs to be assessed, due to the fact that children who were effectively medicated obtained IQ scores of almost a full standard deviation higher than children who were not effectively medicated. As noted earlier, the variability in findings across studies seems strongly

related to the failure to assess both the effects of stimulant medication on IQ test performance and medication efficacy prior to testing.

Moreover, the findings that the largest improvements in IQ scores were on measures of crystallized abilities suggest that AD/HD is a disorder of functional rather than structural deficits. Specifically, it appears the reason for children's difficulties on an IQ test, among other things, is related to problems applying knowledge rather than one of structural deficits. Though some have theorized that the executive functions are closely related to fluid intelligence, children with AD/HD showed no changes when medicated on the PRI, which is a measure of fluid intelligence. Further research is needed to determine the direction of the relationships between these concepts and their theoretical and clinical implications.

Another area that must be addressed in future studies is the need to examine differences at both the level of groups and individuals. This study, as well as the study by Anastopoulos et al. (1994), draws attention to this point. Children did not exhibit the same responses as those implicated by group analyses. In fact, it seemed that only a small percentage of children actually exhibited the same pattern of scores as suggested by the group-based findings. Response patterns and vital characteristics of individual children are often obscured by large group analyses, which was evident in this study. Thus, reliance on group-based averages may lead to erroneous conclusions.

In practice, the question of whether children with AD/HD should take stimulant medication before undergoing a Learning Disability (LD) or Advanced Learner (AL) evaluation is often asked. Interestingly, many parents think their child should be on

medication for an AL evaluation because they believe this will help him perform "at his best." On the other hand, when preparing for an LD evaluation, parents often choose to take their child off medication in order to demonstrate what their child's functioning is "really like." Based upon the findings of this study, the latter is not a good idea. In fact, being off medication will most likely make it more difficult to identify a learning disability. On average, children in this study exhibited a seven-point difference between their scores when tested off and on medication. This is an extremely significant finding when considered in the context of educational placement assessments. As mentioned earlier, this is equivalent to half of a standard deviation on the WISC-IV. Such a discrepancy could mean the difference between placing children in regular or advanced classes, or worse, placing them in remedial classes that impede them in reaching their true potential.

Consequently, if children with AD/HD receive lower IQ scores because of poor test behavior due to the lack of medication rather than true cognitive ability, clinicians will have more difficultly identifying the presence of a learning disability. When clinicians use an artificially lower IQ score for comparisons, children with AD/HD will need to exhibit a higher degree of impairment on an achievement test to demonstrate the significant IQ-achievement discrepancies required to be diagnosed with a learning disability (LD). This suggests that children who need accommodations may not receive them because their scores will not reflect the required discrepancy necessary for LD classification. This can only add insult to injury, given many children with AD/HD already exhibit poor academic performance.

Limitations

Before concluding, several important limitations need to be discussed. First, the most obvious of these was the fact that this study did not use a double-blind placebo design, which would have been a more scientifically rigorous way of conducting this experiment to eliminate possible bias. However, the design of this study has ecological validity, thereby increasing the generalizability of the findings, given its similarity to the manner in which assessment and treatment are provided in the community. Secondly, the children in the study were taking different stimulant medications. Such differences could have affected test performance. Though we attempted to obviate this issue by categorizing each medication as either an amphetamine-based or methylphenidate-based product, several of the children were on newer medications that are hybrid versions of the older products. For instance, two children were on Vyvanse, a stimulant medication that consists of d-amphetamine coupled with the essential amino acid L-lysine, whereas two other children were taking Focalin XR, a Dexmethylphenidate product. These product formulations could potentially produce differential effects in their management of the symptoms of AD/HD, resulting in differences in performance on an IQ test.

In addition, the short interval between testing sessions could have resulted in practice effects that muddied the waters regarding true test performance differences. Here again, attempts were made to reduce the amount of practice effects; however, this was not entirely possible without changing the structure of the test. Counterbalancing the order of medication status was used as a method for reducing this problem, which seemed effective given the children showed a significant change in the two indices despite having

already encountered the test material. Nonetheless, the effect of practice could have affected the results.

Given that the participants were not naive to stimulant medication, the conclusions should be interpreted with caution when applying the findings to children who are just beginning to take stimulant medication. Specifically, though this study used a short interval between testing sessions, most of the children had been on their medication for at least two years. Thus, it is possible that changes have occurred in the structure or functioning of the frontal lobes as a result of long-term stimulant medication use.

Another caveat that must be considered, is that the sample of children in this study appeared to be functioning at a higher level than those frequently found in a typical group of children with AD/HD. In particular, only a small number of children in the current study had been suspended, failed grades, or had been diagnosed with ODD or a learning disability. Thus, caution must be exercised when applying these findings to a more impaired group of children with AD/HD.

Other limitations include having used one type of IQ test and the limited range in age of participants. Such differences may reduce the generalizeability of the findings. Moreover, though prior research has shown that several of the CPT indices are sensitive to the effects of medication, it is not considered the "gold standard" for assessing medication response or efficacy. And finally, the small sample size did not allow for secondary analyses to determine possible factors that may mediate a child's response to stimulant medication.

Summary

Notwithstanding the limitations of this study, the findings demonstrate how stimulant medications can substantially affect children's performance on tests of intellectual ability. Moreover, the importance of assessing medication efficacy was highlighted by the fact that children taking an effective medication scored higher than those who did not have a positive response to their medication. These findings need to be noted by clinicians who work with children with AD/HD, especially those who perform psychoeducational assessments. Otherwise, children may be labeled as below average or be overlooked to receive educational opportunities such as advanced learner placement.

Finally, the design of the study resembled that of the community comparison group of the MTA study making the findings useful to "real-world" clinicians and families. In particular, all children had been evaluated at a community clinic and most of the children were receiving stimulant medication treatment from their primary care physician. Thus, the findings have important implications for primary care physicians regarding the need for assessing the efficacy of a child's medication and titrating the dose accordingly. Without attention to such details, children with AD/HD will continue to be labeled as having lower IQs and possibly placed in classes that do not help them achieve up to their potential.

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APPENDIX A

TABLES

Table 1

Definitions of the Second Stratum Abilities as Proposed by CHC Theory

Broad Ability	**Definition**
Fluid Intelligence/Reasoning (*Gf*)	The use of deliberate and controlled mental operations to solve novel problems (i.e. tasks that cannot be performed automatically). It includes mental operations such as drawing inferences, concept formation, generating and testing hypotheses, identifying relations, problem-solving, and transforming information. Inductive and deductive reasoning are hallmark indicators of *Gf*.
Crystallized Intelligence/Knowledge (*Gc*)	The intelligence of the culture; it represents the acquired knowledge of the language, information and concepts of a specific culture, and/or the application of this knowledge. It is acquired during formal and informal education and general life experiences.
Visual-Spatial Abilities (*Gv*)	The ability to generate, retain, retrieve, and transform well-structured visual images. This domain represents a collection of abilities that emphasize a different process involved in the generation, storage, retrieval, and transformation of visual images.
Auditory Processing (*ga*)	Abilities that depend on sound as input and on the functioning of an individuals hearing apparatus (i.e. the ear)
Short-term Memory (*gsm*)	The ability to apprehend and maintain awareness of elements of information in the immediate situation. A limited capacity system that loses information quickly through the decay of memory traces, unless an individual activates other cognitive resources to maintain the information in immediate awareness.
Long-term Storage and Retrieval (*glr*)	The ability to store and consolidate new information in long-term memory and later retrieve it through association.
Cognitive Processing speed (*gs*)	The ability to automatically and fluently perform relatively easy or over-learned cognitive tasks, especially when high mental efficiency such as attention and concentration is required.
Quantitative knowledge (*gq*)	Acquired store of declarative and procedural quantitative knowledge. It represents an individual's store of acquired mathematical knowledge, which does not include reasoning with this knowledge. It is largely acquired through formal education.
Reading/Writing (*grw*)	A person's breadth and depth of acquired store of declarative and procedural reading and writing skills. It includes basic reading skills and ability to read and write complex discourse.

Table 2

WISC-IV Subtest Descriptions and CHC Classifications

Subtest	Broad Ability	Narrow Ability	Description of the Task
Block Design	*Gv*	Spatial Relations	Replicate a set of modeled or printed two-dimensional geometric patterns using red and white blocks within a specified time limit
Similarities	*Gc*	Language Development Lexical Knowledge	Describe how 2 words that represent common objects or concepts are similar
Digit Span	*Gsm*	Memory Span Working Memory	Repeat numbers either verbatim as stated by the examiner or in reverse order
Picture Concepts	*Gf* *Gc*	Induction General Information	Choose one picture from among 2 to 3 rows of pictures presented to form a common characteristic
Coding	*Gs*	Rate of Test Taking	Copy symbols that are paired with either geometric shapes or numbers using a key within a time limit
Vocabulary	*Gc*	Lexical Knowledge	Name pictures or provide definitions for words
Letter-Number Sequencing	*Gsm*	Working Memory	Recall a letter and number sequence read by the examiner with numbers recalled in ascending order and letters in alphabetical order
Matrix Reasoning	*Gf* *Gv*	Induction General Sequential Reasoning	Complete the missing portion of a picture matrix by selecting 1 of 5 response options
Comprehension	*Gc*	General Information	Answer a series of questions based on one's understanding of general principles and social situations
Symbol Search	*Gs*	Perceptual Speed Rate of Test taking	Scan a search group and indicate the presence or absence of a target symbol within a time limit
Picture Completion	*Gv*	Flexibility of Closure	View a picture and name the essential missing part within a time limit
Cancellation	*Gs*	Perceptual Speed Rate of Test taking	Scan both a random and a nonrandom arrangement of pictures and mark target pictures within a time limit
Information	*Gc*	General Information	Answer questions that address a wide range of general-knowledge topics
Arithmetic	*Gq* *Gf*	Math Achievement Quantitative Reasoning	Mentally solve a variety of orally presented arithmetic problems within a time limit
Word Reasoning	*Gc* *Gf*	Lexical Knowledge Induction	Identify a common concept being described by a series of clues

Table 3
Sample Characteristics

Sample Size	N = 35
Age	10.9 (SD = 1.6)
Gender	
Male	25 (71.4%)
Female	10 (28.6%)
Race	
Caucasian	31 (88.6%)
African American	4 (11.4%)
AD/HD Diagnosis	
Combined Type	20 (57.1%)
Inattentive Type	12 (34.3%)
Hyperactive-Impulsive Type	3 (8.6%)
Other Diagnoses	
Learning Disability	8 (22.9%)
Oppositional Defiant Disorder	2 (5.7%)
Conduct Disorder	1 (2.9%)
Medication Type	
Adderall XR	9 (25.7%)
Concerta	13 (37.1%)
Ritalin LA	4 (11.4%)
Metadate	3 (8.6%)
Focalin XR	2 (5.7%)
Daytrana	2 (5.7%)
Vyvanse	2 (5.7%)
	M (SD)
ADHD Rating Scale Scores	
Inattention symptoms	7.3 (2.3)
Hyperactive-Impulsive symptoms	5.2 (3.0)
Inattention severity	20.3 (5.7)
Hyperactive-Impulsive severity	15.1 (6.9)
BASC-2 T-scores	
Inattention	66.5 (7.5)
Hyperactivity	64.7 (12.5)
Time on Stimulant (in months)	30 (23.8)
Time between Testing Sessions (in days)	25 (34.2)

Note. BASC-2 = Behavior Assessment System for Children – Second Edition.

Table 4

Correlations For IQ and CPT Variables When ON Medication

	FSIQ	VCI	PRI	WMI	PSI	CPTCI	OMIS	COMIS	HITRT	HRTSTD	VAR
FSIQ	--										
VCI	.80***	--									
PRI	.78***	.51**	--								
WMI	.50**	.10	.22	--							
PSI	.55***	.35*	.10	.39*	--						
CPTCI	-.25	-.15	-.08	-.22	-.34*	--					
OMIS	-.38*	-.35*	-.30	-.15	-.22	.81***	--				
COMIS	-.02	.14	.12	-.24	-.21	.02	-.05	--			
HITRT	-.34*	-.44**	-.28	.09	-.16	.58***	.56***	-.42*	--		
HRTSTD	-.38*	-.27	-.22	-.19	-.42*	.88***	.71***	.11	.69***	--	
VAR	-.38*	-.22	-.20	-.27	-.50*	.83***	.66***	.14	.54***	.96***	--

Note. FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; CPTCI = CPT Clinical Confidence Index; OMIS = Omissions; COMIS = Commissions; HITRT = Hit Reaction Time; HRTSTD = Hit Reaction Time Standard Error; VAR = Variability; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 5

Correlations For IQ and CPT Variables When OFF Medication

	FSIQ	VCI	PRI	WMI	PSI	CPTCI	OMIS	COMIS	HITRT	HRTSTD	VAR
FSIQ	--										
VCI	.71***	--									
PRI	.76***	.45**	--								
WMI	.63**	.19	.30	--							
PSI	.52***	.06	.17	.28	--						
CPTCI	.04	.21	.18	-.15	-.21	--					
OMIS	.08	.15	.15	-.20	.04	.76***	--				
COMIS	-.07	.17	-.01	-.16	-.23	-.10	-.23	--			
HITRT	-.13	-.02	.02	-.17	-.18	.70***	.62***	-.26	--		
HRTSTD	-.10	.14	.03	-.23	-.28	.88***	.71***	-.05	.83***	--	
VAR	-.05	.17	.07	-.25	-.22	.85***	.69***	-.08	.64***	.94***	--

Note. FSIQ = Full Scale IQ; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; CPTCI = CPT Clinical Confidence Index; OMIS = Omissions; COMIS = Commissions; HITRT = Hit Reaction Time; HRTSTD = Hit Reaction Time Standard Error; VAR = Variability; * = $p < .05$, ** = $p < .01$, *** = $p < .001$.

Table 6

IQ Scores On and Off Medication

	On Meds		Off Meds		η_p^2
	M	(SD)	M	(SD)	
FSIQ	104.8	(13.5)	97.6	(12.0)***	.44
Index Scores					
VCI	104.5	(15.1)	99.0	(13.2)**	.26
PRI	106.3	(16.0)	103.7	(13.2)	.05
WMI	106.7	(14.2)	99.4	(14.7)*	.16
PSI	93.6	(12.6)	87.7	(14.5)**	.18
Subtest Scores					
BD	11.4	(3.7)	10.3	(3.4)*	.12
SIM	11.2	(3.3)	10.4	(2.9)	.06
DS	9.2	(2.7)	9.2	(3.1)	.00
PC	10.0	(4.0)	10.9	(3.1)	.07
CD	8.7	(3.0)	7.7	(3.1)*	.15
VOC	11.2	(2.9)	10.1	(2.8)***	.29
LNS	13.4	(3.7)	10.8	(3.9)**	.23
MR	11.5	(3.6)	10.6	(2.7)	.08
COMP	10.3	(3.0)	9.3	(3.0)*	.10
SS	9.1	(2.1)	7.9	(2.8)*	.14

Note. FSIQ = Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index; BD = Block Design; SIM = Similarities; DS = Digit Span; PC = Picture Completion; CD = Coding; VOC = Vocabulary; LNS = Letter-Number Sequencing; MR = Matrix Reasoning; COMP = Comprehension; SS = Symbol Search;
*p < .05, **p < .01, ***p < .001.

Table 7

Number of Children Showing Reliable Change on IQ Variables

	Total with RC	Total without RC
FSIQ	17 (49%)	18 (51%)
Index Scores		
VCI	11 (31%)	24 (69%)
PRI	7 (20%)	28 (80%)
WMI	16 (46%)	19 (54%)
PSI	10 (29%)	25 (71%)

Note. RC = Reliable Change; FSIQ = Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index.

Table 8

CPT Scores On and Off Medication

	On Meds		Off Meds				
	Mean	SD	Mean	SD	*F*	*p*	η_p^2
Omissions	53.6	17.1	59.6	20.2	3.18	.08	.09
Commissions	49.9	9.1	51.9	9.2	1.39	.25	.04
Variability	51.5	11.9	58.0	11.3	14.92	.001***	.31
Hit Reaction Time	45.1	10.6	54.1	14.2	35.03	.001***	.52
HRT Standard Error	50.8	11.8	58.9	12.1	24.39	.001***	.43
Confidence Index	49.7	24.1	66.0	24.5	21.51	.001***	.39

Note. CPT= Conners Continuous Performance Task; HRT = Hit Reaction Time; *p < .05, ** p < .01, ***p < .001.

Table 9

Number of Children Showing Reliable Change on CPT Variables

	Total with RC	Total without RC
Omissions	13 (37%)	22 (63%)
Commissions	1 (3%)	34 (97%)
Variability	25 (71%)	10 (29%)
Hit Reaction Time	1 (3%)	34 (97%)
HRT Standard Error	13 (37%)	22 (63%)
Confidence Index	16 (46%)	19 (54%)

Note. CPT = Conners Continuous Performance Task; RC = Reliable Change; HRT = Hit Reaction Time.

Table 10

Rates of Reliable Change in IQ Scores Based on Medication Response

		FSIQ Response	
		Reliable Change	No Change
CPT Medication Response	Responder	16 (59%)	11 (41%)
	Non-Responder	1 (12%)	7 (88%)

		VCI Response	
		Reliable Change	No Change
CPT Medication Response	Responder	10 (37%)	17 (71%)
	Non-Responder	1 (12%)	7 (88%)

		PRI Response	
		Reliable Change	No Change
CPT Medication Response	Responder	7 (26%)	20 (74%)
	Non-Responder	0	8 (100%)

		WMI Response	
		Reliable Change	No Change
CPT Medication Response	Responder	13 (48%)	14 (52%)
	Non-Responder	3 (38%)	5 (62%)

		PSI Response	
		Reliable Change	No Change
CPT Medication Response	Responder	6 (22%)	21 (78%)
	Non-Responder	4 (50%)	4 (50%)

Note. CPT = Continuous Performance Test; FSIQ = Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PRI = Perceptual Reasoning Index; WMI = Working Memory Index; PSI = Processing Speed Index.

APPENDIX B

FIGURES

Figure 1. Model of Barkley's Theory of AD/HD

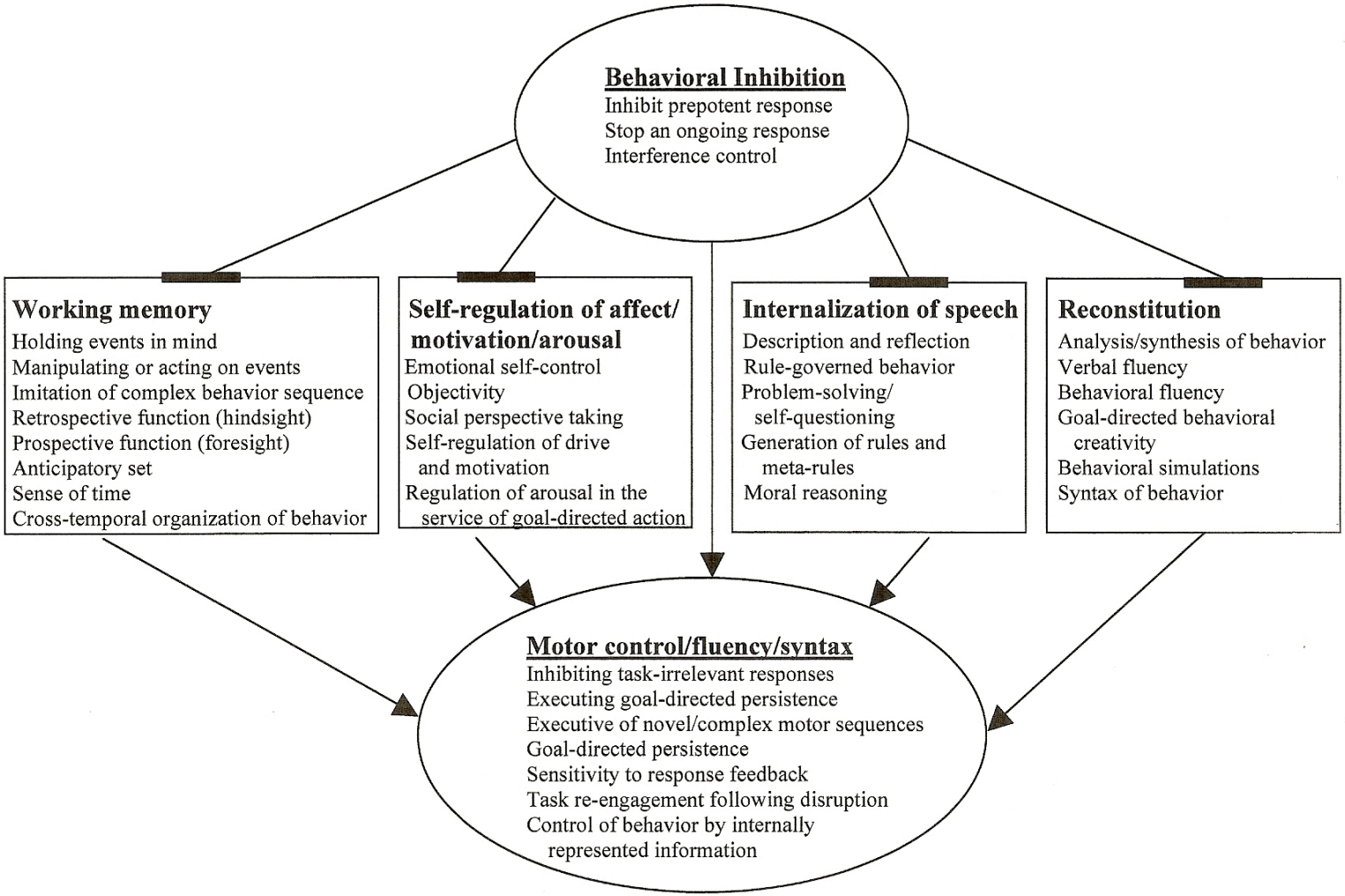


Figure 2. Model of Cattell-Horn-Carroll's Theory of Cognitive Abilities

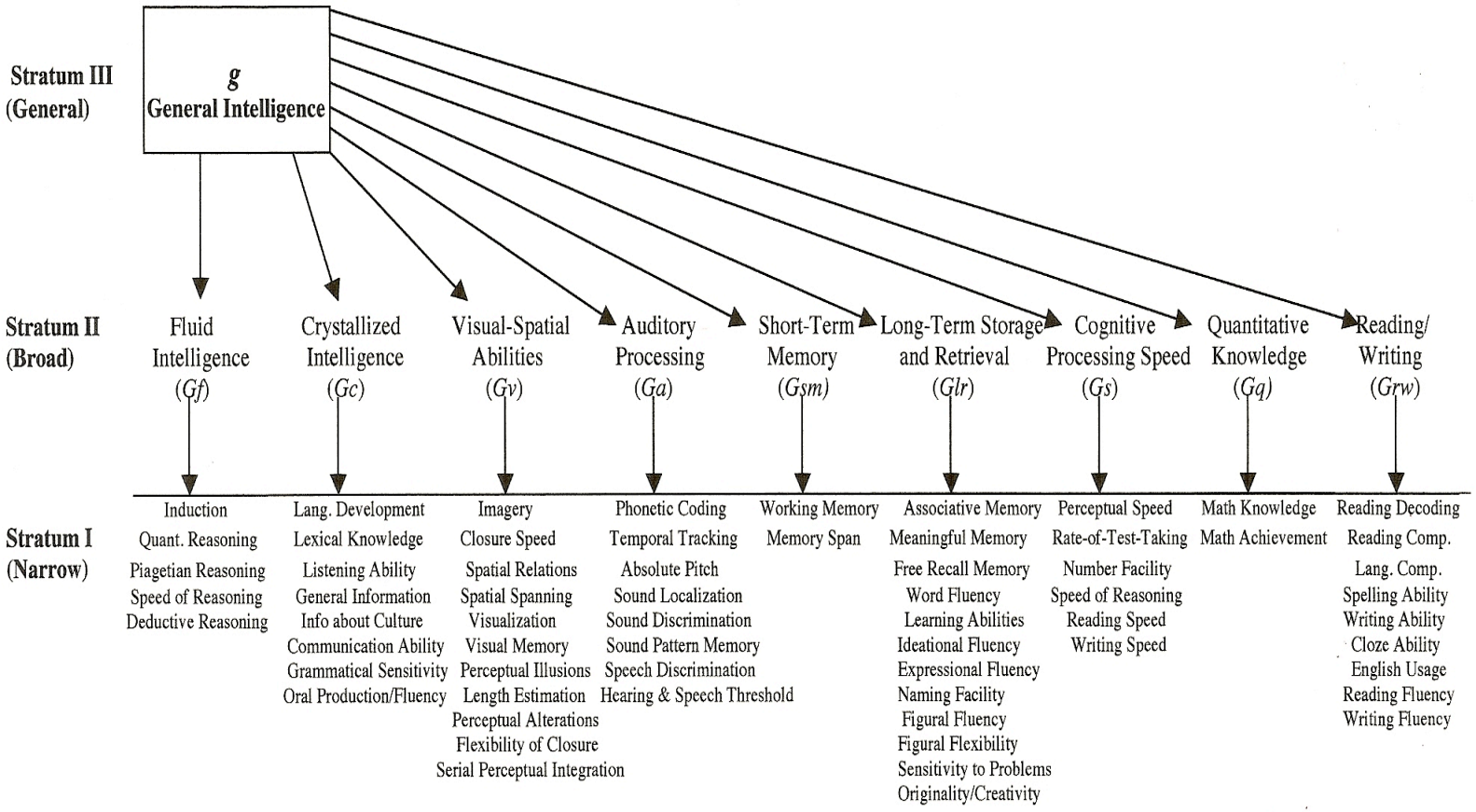
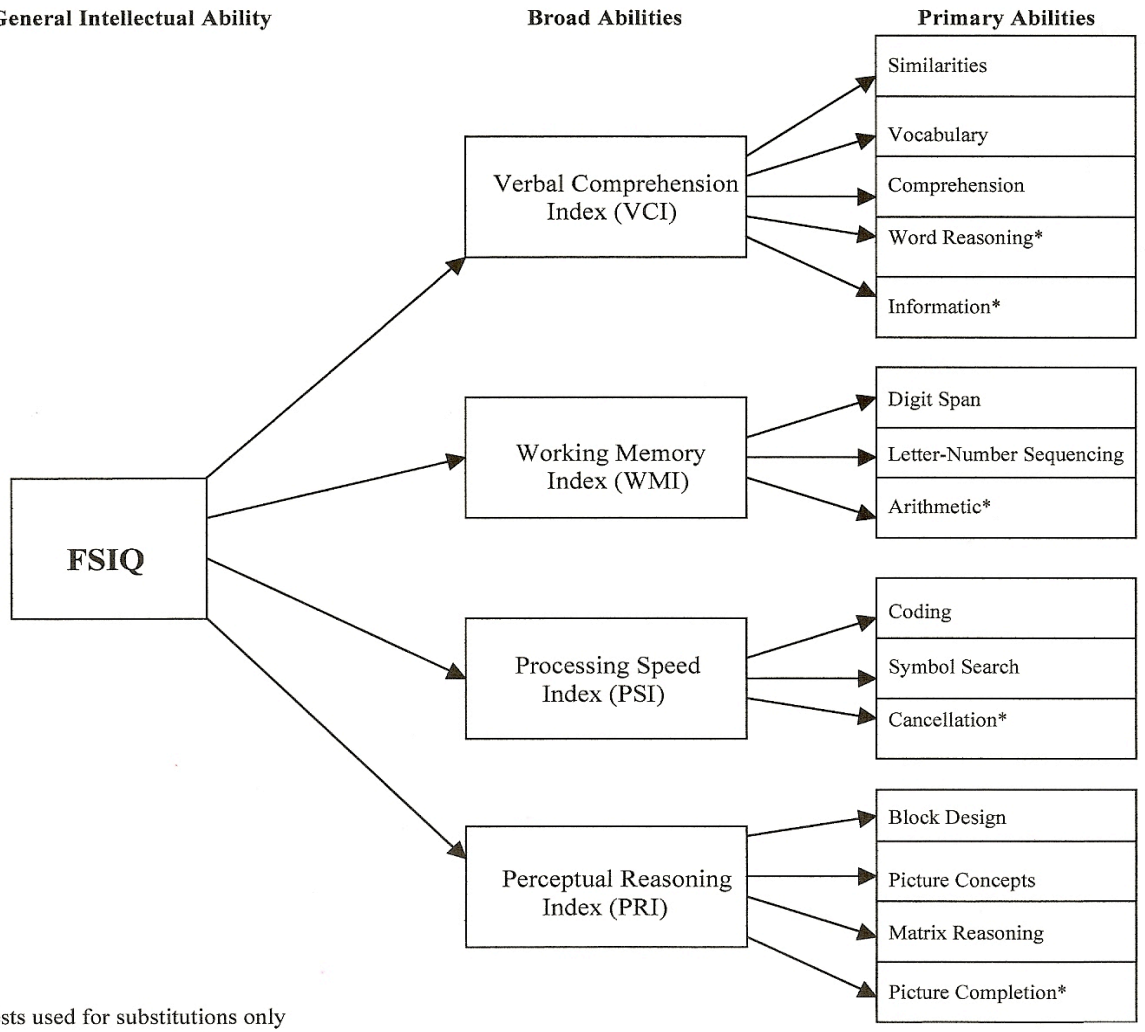
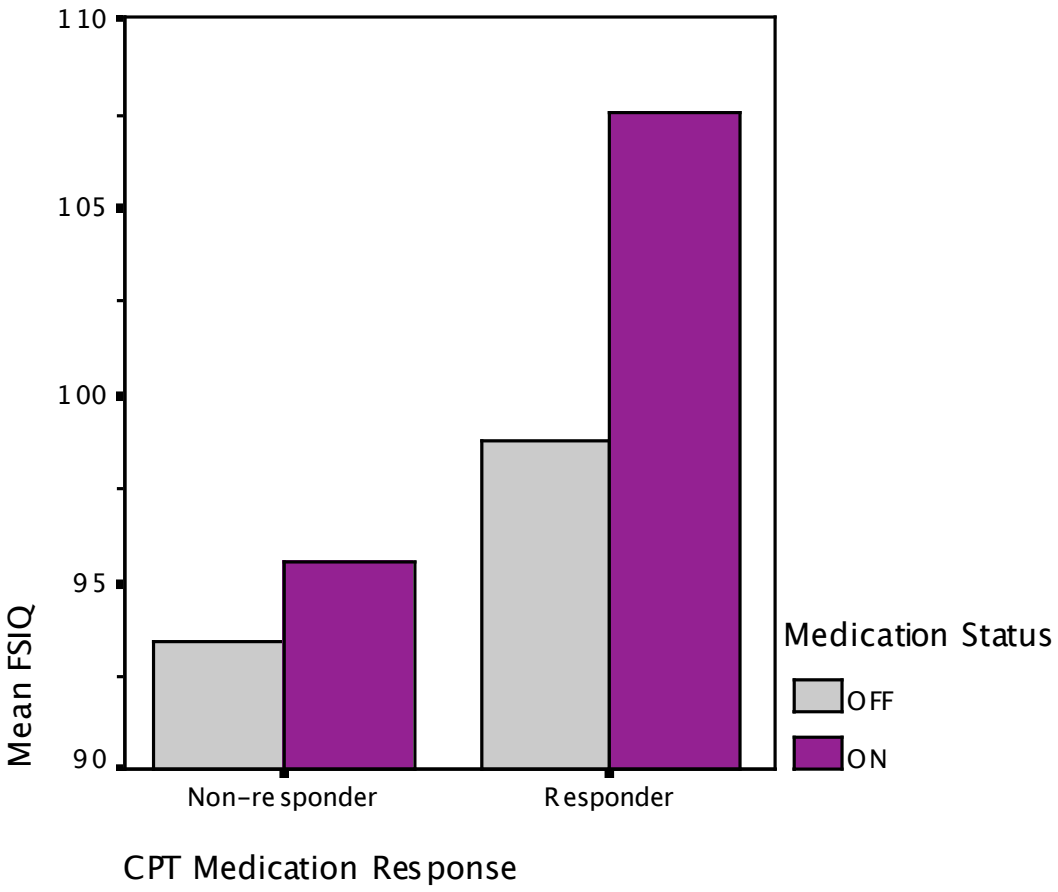


Figure 3. The structure of the WISC-IV



Note. * = Subtests used for substitutions only

Figure 4. Mean FSIQ Scores of CPT Medication Responders and Non-Responders When On and Off Medication



APPENDIX C

CONSENT AND ASSENT FORMS

THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

CONSENT TO ACT AS A HUMAN PARTICIPANT

Form for Parents/Guardians of Child Participants

Project Title: An Examination of the Effects of Stimulant Medication on the IQ Test Performance of Children with AD/HD

Project Directors: Jennifer Smith Adams, M.A. and Arthur D. Anastopoulos, Ph.D.

Parent/Guardian's Name: _____

Participant's Name: _____

DESCRIPTION AND EXPLANATION OF PROCEDURES:

You and your child are being asked to participate in a project that will examine how stimulant medication affects your child's performance on an intelligence test. Participation will involve having both you and your child complete various tasks that will take a total of approximately two to three hours of time.

Your child will be asked to complete an intelligence test and a computerized attention task during two separate testing sessions that will take place approximately two weeks apart. During one of the testing sessions your child will be required to be on his/her stimulant medication for testing whereas during the other session, your child will be required to be off his/her stimulant medication. Each testing session will be videotaped and should last about one hour. Your child will have the option to discontinue participation at any time.

This research project also requires you to complete an interview and several questionnaires about your child's AD/HD symptoms and level of functioning in various settings. These questionnaires and interview should take about an hour to complete. Participation also includes having your child's physician and teacher complete a few questionnaires. In particular, you will be asked to provide consent to speak with your child's physician in order to obtain medical clearance for your child to participate in the study. Your child's physician will also be asked questions regarding your child's prescription. To gain information about your child's academic functioning, one of your child's teachers will be requested to complete a few questionnaires.

RISKS AND DISCOMFORTS:

The risks involved in this study are minimal and are no more than those usually associated with psychological testing. For instance, your child may feel mildly uncomfortable during the testing session where he/she is required to be off his/her medication. However, any distress your child may feel is not likely to be any greater than that experienced at other times your child is off medication. Furthermore, in order to ensure that your child is less likely to experience an adverse reaction to being off his/her medication, your child's physician will be consulted to determine if your child can participate in the study.

Your participation in the project is entirely voluntary and, should you or your child become uncomfortable or distressed, you are free to refrain from answering any questions and withdraw from the study altogether at any point without penalty or prejudice. You and your child are also free to obtain information about this study from the researcher or researcher assistant running this study before, during or after your participation in this project.

All information provided by you and your child will be kept confidential. All data will be identified by research numbers only and no individual's name will be directly associated with the data. Data will be kept in a locked file cabinet in a locked office building and destroyed after 5 years.

The principal investigator and research assistants involved in the study are required to sign confidentiality agreements. Only the principal investigator and research assistants who have signed confidentiality agreements will handle completed materials. All the information that you provide and all the information that you answer during the course of this project will be kept in strict confidentiality.

BENEFITS:
For participation in this study, your child will be paid $40 and you will be mailed a letter describing the results from your child's testing sessions. You and your child will also benefit from a better understanding of issues related to psychological research and will have an opportunity to learn more about yourselves through responses to questionnaires and completion of an IQ test. Broader benefits will enable researchers and clinicians to better understand the effects of stimulant medication on children's intelligence test performance. This research can aid in determining whether children with AD/HD should be on or off their medication prior to taking tests.

CONSENT:
By signing this consent form, you agree that you understand the procedures and any risks and benefits involved in this research. You and your child are free to refuse to participate or to withdraw your consent to participate in this research at any time without penalty or prejudice; your participation is entirely voluntary. Your privacy will be protected because you will not be identified by name as a participant in this project.

The research and this consent form have been approved by the University of North Carolina at Greensboro Institutional Review Board, which ensures that research involving people follows federal regulations. Questions regarding your rights as a participant in this project can be answered by calling Mr. Eric Allen at (336) 256-1482. Questions regarding the research itself will be answered by calling Jennifer Smith Adams at (336) 256-0061 or Arthur D. Anastopoulos at (336) 346-3196 extension 303. Any new information that develops during the project will be provided to you if the information might affect your willingness to continue participation in the project.

By signing this form, you are agreeing to participate and to allow your child to participate in the project described to you by Jennifer Smith Adams.

_____ _____

Participant's Signature* Date

*If the participant is a minor or for some other reason unable to provide Informed Consent, complete the following:

Participant is years old or unable to sign because .

_____ _____

Custodial Parent(s)/Guardian Signature(s) Date

THE UNIVERSITY OF NORTH CAROLINA

GREENSBORO

CHILDREN'S ASSENT FORM

Many children with AD/HD take medication because it helps them pay attention and sit still in class. However, one thing we do not know very much about is whether medication helps children with AD/HD make better grades on tests. We are asking you to help us find out how the medication you take affects how well you do on different kinds of tests.

If you agree to be in our study, we are going to ask you to complete a few tests. One of these tests is completed on a computer and measures how well you pay attention to things. The other test measures things like how many words you know and how fast you can memorize a code.

If at any time you decide not to finish, you may stop whenever you want. You can ask questions at any time that you might have about this study. Also, your participation in this study is completely voluntary.

Signing this paper means that you have read this or had it read to you and that you want to be in the study. If you don't want to be in the study, don't sign the paper. Remember, being in the study is up to you, and no one will be mad if you don't sign this paper or even if you change your mind later.

Signature of Participant _____ Date _____

Signature of Investigator _____ Date _____

APPENDIX D

MEASURES

Participant Information Questionnaire

I. CLIENT DATA

Child's Full Name: _____ Parent's Name: _____

Age: _____ Date of Birth: _____

Gender: _____ Ethnicity: _____

II. SCHOOL HISTORY

Preschool Experience

Has your child ever attended:	**No**	**Yes**
Early Intervention Program		
Developmental Preschool		
Special Education Preschool		

School Performance and Behavior

Has your child ever:	**No**	**Yes**
Undergone testing		
Had an IEP or SPED		
Been labeled LD (Learning Disabled)		
Failed a subject		
Repeated a grade		
Been suspended		
Been expelled		

C. Special Services at School

Has your child ever received:	**No**	**Yes**
Resource room (part time)		
Self-contained LD room (full time)		
Behavior Disorders classroom (BED)		
Speech/Language Therapy		
Physical/Occupational Therapy		
School counseling		
Advanced Learner (AL)		
Classroom accommodations		

Current Grade Level: _____ Has IEP or receiving Special Education services: Y N

III. CHILD'S PSYCHIATRIC STATUS

Has your child ever been diagnosed with:	**No**	**Yes**
AD/HD		
Oppositional Defiant Disorder		
Conduct Disorder		
Antisocial Behavior		
Learning Disability		
Mental Retardation		
Schizophrenia/Psychosis		
Bipolar/Manic Depression		
Depression/Suicide		
Anxiety Disorders		
Phobias		
Tics/Tourettes		
Seizures/Epilepsy		

Has your child ever exhibited:	**No**	**Yes**
Loose thinking		
Delusions		
Hallucinations		
Diminished interest in peers		
Self-injurious behavior		
Self-stimulation		
Alcohol use		
Cigarette use		
Substance use		
Physical abuse		
Sexual abuse		

Has your child ever been:	**No**	**Yes**
Physically abused		
Sexually abused		

IV. CHILD'S EVALUATION AND TREATMENT HISTORY

A. Prior Evaluations

Has your child ever undergone:	No	Yes (Date of evaluation)
Psychological or Psychiatric Evaluation		
Pediatric evaluation for AD/HD		
Neurological Evaluation		
Intelligence Testing		
Academic Achievement Testing		
Speech/Language/Hearing Evaluation		

Results/Scores:

Previous Diagnosis(es):

Current Diagnosis(es):

B. Psychological/Psychiatric Treatment

Has your child ever received:	No	Yes (Date of Treatment)
Counseling/Therapy		
Inpatient Treatment		
Residential Treatment (i.e. group home)		
Social Skills Training		

C. Pharmacotherapy

Has your child ever taken:	NO	Yes
Ritalin		
Ritalin LA or SR		
Focalin		
Concerta		
Metadate ER or CD		
Adderall		
Adderall XR		
Dexedrine		
Dexedrine Spansules		
Cylert		
Clonidine/Tenex		
Wellbutrin		
Straterra		

D. Current medication

Name of your child's physician: _____

Prescribed Stimulant Medication: _____ Dosage: _____

Physician's orders regarding this medication (i.e. take one pill 1 time each day in the morning):
_____

Who administers this medication to your child: _____

Time(s) medicine is taken: _____ # of days a week medicine is taken: _____

Is medication taken on the weekends? Y N Is medication taken during the summer? Y N

How long has your child been taking this medication? _____

Does this child take any other medications? If so, please complete the following information.

Medication: _____ Dosage: _____ Reason: _____

Medication: _____ Dosage: _____ Reason: _____

Medication: _____ Dosage: _____ Reason: _____

Please circle the number that best describes your perceptions regarding the efficacy of your child's stimulant medication in managing his/her symptoms of AD/HD.

1	**2**	**3**	**4**	**5**
Not Effective		Somewhat Effective		Extremely Effective

THE UNIVERSITY OF NORTH CAROLINA
GREENSBORO

AD/HD Clinic

Dear Doctor:

Your patient _____ wishes to take part in a research study assessing the effects of stimulant medication on IQ test performance. I am conducting this study to fulfill the requirements for the doctoral degree in clinical psychology at UNCG. My faculty sponsor for the project is Dr. Arthur Anastopoulos of the UNCG AD/HD Clinic. The study will involve having children aged 8-12 who have been diagnosed with AD/HD take an IQ test and a computerized measure of attention during two separate testing sessions. For one of these testing sessions the child will be required to be off his/her medication during testing whereas for the other session the child will take his/her medication approximately 90-120 minutes before testing. The testing sessions will be held approximately 2 weeks apart. Statistical analyses will be conducted to determine whether participants' stimulant medication affected their IQ test performance.

Included with this letter you will find a consent form authorizing us to request and disclose information about this patient. The parent/legal guardian of your patient has signed this form because they would like me to request your approval for their child to participate in the aforementioned study. Basically, I need to make sure that it will be okay for your patient to be off his/her stimulant medication for one of the testing sessions.

Attached you will find a form requesting your approval for your patient to participate in this study. Please complete part 1 of the form by indicating your recommendations regarding your patient's request to participate in this study. If you feel that your patient can participate in this study please complete part 2 of the form. Once the form is complete, please return it in the postage-paid envelope included in this packet or feel free to the fax the form addressed to my attention to 346-3197.

Thank you for your time regarding this matter. If you have any questions about the study please feel free to contact me at 256-0061 or my faculty sponsor, Arthur D. Anastopoulos, at 346-3196, extension 303.

Sincerely,

Jennifer Smith Adams, M.A.
Principal Investigator

Arthur D. Anastopoulos, Ph.D.
Faculty Sponsor

Child's name: _____ Birth date: _____

PART ONE: Physician's Recommendations
Please check the box that reflects your decision regarding whether you patient should be allowed to participate in the aforementioned study.

☐ I approve my patient's participation in this study.

☐ I recommend that my patient **NOT** participate in this study.

_____ _____
Physician's signature Date

_____ _____
Physician's name (print) Phone

_____
Address

_____
City, State & Zip

PART TWO: Medication Information
Please answer each question as it pertains to your patient.

Patient's Diagnosis(es):

Prescribed Stimulant Medication: _____ Dosage: _____

Time(s) medicine is taken: _____ # of days a week medicine is taken: _____

Is medication taken on the weekends? Y N Is medication taken during the summer? Y N

Does this child take any other medications? If so, please complete the following information.

Medication: _____ Dosage: _____ Reason: _____

Medication: _____ Dosage: _____ Reason: _____

Medication: _____ Dosage: _____ Reason: _____

Please circle the number that best describes your perceptions regarding the efficacy of your patient's stimulant medication in managing his/her symptoms of AD/HD.

1	**2**	**3**	**4**	**5**
Not Effective		Somewhat Effective		Extremely Effective

APPENDIX E

PARENT FEEDBACK LETTER

SUMMARY OF CHILD IQ ASSESSMENT RESULTS

Child's Name:
Examiner: **Jennifer Smith Adams, M.A.**
Dates of Testing: **OFF Medication: _____; ON Medication: _____**
Test Administered: **Wechsler Intelligence Scale for Children-Fourth Edition (WISC-IV)**

	Standard Score	
	OFF Medication	**ON Medication**
Similarities	12	11
Vocabulary	10	12
Comprehension	11	15
Verbal Comprehension Index	**104**	**114**
Block Design	12	12
Picture Concepts	13	17
Matrix Reasoning	14	15
Perceptual Reasoning Index	**119**	**129**
Digit Span	11	13
Letter-Number Sequencing	10	16
Working Memory Index	**102**	**126**
Coding	12	13
Symbol Search	12	15
Processing Speed Index	**112**	**123**
FULL SCALE IQ (FSIQ)	**113**	**130**

Testing results obtained using a non-standardized format of an IQ test may not be an accurate estimate of your child's true ability or intellectual functioning. Moreover, your child's performance in a research setting may not be a strong indicator of his performance in other settings such as the classroom. Therefore, these results should not be used for clinical management or educational placement purposes.

Keeping these limitations in mind, parents and teachers may want to consider the implications of the results. Based on your child's performance, his scores significantly improved when he was on medication, especially in relation to his working memory and ability to process new information quickly. As seen in the above table, his scores on 8 of 10 subtests were better when he was on medication, which resulted in a 17-point increase in his Full Scale IQ score. In addition, your child's behavior improved when he was on medication as evidenced by his increased concentration and attention span, his ability to sit still, and his completion of more items with fewer mistakes. Overall, your child appears to perform better when on medication in a testing situation such as taking an IQ test.