DISCRIMINATIVE ABILITY OF CHC FACTOR SCORES FROM THE WJ III TESTS OF COGNITIVE ABILITIES IN CHILDREN WITH ADHD

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
July, 2013

DISCRIMINATIVE ABILITY OF CHC FACTOR

SCORES FROM THE WJ III TESTS OF COGNITIVE ABILITIES

IN CHILDREN WITH ADHD

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Date of Degree: JULY, 2013

Title of Study: DISCRIMINATIVE ABILITY OF CHC FACTOR SCORES FROM THE WJ III TESTS OF COGNITIVE ABILITIES IN CHILDREN WITH ADHD

Major Field: EDUCATIONAL PSYCHOLOGY, SPECIALIZATION IN SCHOOL PSYCHOLOGY

ABSTRACT: Students with attention-deficit/hyperactivity disorder (ADHD) make up approximately 5% of the school-aged population and they often experience significant difficulties in school, particularly in the areas of academics, disruptive behavior, and social relationships. A diagnosis of ADHD does not provide guidance for creating interventions to address the impairments. Effective diagnostic assessments should go beyond traditional symptom-based categorization and allow for more accurate and precise problem identification. The current study compared the cognitive abilities of children with ADHD to typically developing children using the CHC factors from the WJ III COG. Results confirmed that the children with ADHD in this study had significant weaknesses in long-term storage and retrieval (Glr) and processing speed (Gs) as compared to children with no disabilities. Research-driven, empirically-validated academic interventions should be implemented in the educational setting to address these cognitive weaknesses in students with ADHD.

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CHAPTER I

INTRODUCTION

Schooling is designed to foster and measure the cognitive, affective, social, and physical development of students (Deno, 2002; Merrell, Ervin, & Gimpel, 2006). Some students have difficulty in one or more of these areas and need assistance from school psychologists. One of the responsibilities of school psychologists includes conducting comprehensive psychoeducational evaluations of students to provide information for the diagnosis of disabilities. Assessment types range from informal curriculum-based assessment to a full battery of cognitive, achievement, behavioral, and emotional measurements (Shapiro, 2004; Smith, Barkley, & Shaprio, 2007).

Best Practices indicate that the most effective approach to assessments is for school psychologists to follow a data-driven, problem-solving model, where measures are taken to facilitate the problem-assessment process (Flanagan, Ortiz, Alfonso, & Dynda, 2006). Within the problem-solving approach, assessment information is collected to guide decision making and to identify the discrepancies between a student's current academic or behavioral performance, and the desired performance (Merrell et al., 2006). The goal of a psychoeducational evaluation, within this model, is to identify conditions that will impact a student's learning (Merrell et al., 2006). Assessment is necessary to ensure that a profile of difficulties is adequately identified and that services are appropriate for the problems a student is experiencing. Effective diagnostic assessments should go beyond traditional symptom-based categorization and allow for more precision and accuracy in problem identification (Decker, 2008).

Attention-Deficit/Hyperactivity Disorder (ADHD)

ADHD is one of the most commonly diagnosed childhood psychiatric disorders. Experts estimate that approximately 5% of the school-aged children in the U.S. have ADHD, and this disorder is found across every socioeconomic status and ethnicity (American Psychiatric Association, 2000; Barkley, 2003; Polanczyk, de Lima, Horta, Biederman, & Rohde, 2007; Söderlund, Sikström, & Smart, 2007). ADHD persists into adolescence in 50-80% of the cases diagnosed in childhood, and into adulthood in 30-50% of these cases (Barkley, 1997; Barkley, Fischer, Edelbrock, & Smallish, 1990; Klein & Mannuzza, 1991). This is a disorder that is pervasive across socially relevant groups and persists throughout one's lifespan. Symptoms of ADHD, such as inattention, hyperactivity, and impulsivity, create pervasive difficulties for those with the disorder. These difficulties span from academic failure to poor maintenance of social relationships.

As children begin schooling, inattention and disinhibited behaviors become troublesome. These are often seen as difficulties in organizing activities, following directions, and poor sustained attention to tasks, which results in poor work completion (Trout, Lienemann, Reid, & Epstein, 2007). A common characteristic of children with ADHD is persistent academic underachievement comparative to their intellectual abilities (Barkley, 1998). Research has found that 80% of children with ADHD exhibit low academic performance or learning problems, more than 50% require academic tutoring, and between 40-50% will receive services in special education programs (Trout et al., 2007). It has been shown that children with ADHD utilize inadequate problems solving strategies, exhibit fine and gross motor problems, and have expressive language difficulties (Tobin, Schneider, Reck, & Landau, 2008). Compared to their classmates, children with ADHD are observed as having trouble with note-taking, finishing long-term assignments, desk organization, implementing study skills, staying on task during instruction and independent work, participating in class discussions, and turning in assignments (Tobin et al., 2008).

Achievement test scores of children with ADHD frequently fall below those of their non-ADHD peers on academic subjects, including measures of reading, spelling, and math (Barkley, DuPaul, & McMurray, 1990; Brock & Knapp, 1996; Jensen & Cooper, 2002; Trout et al., 2007). The learning problems that co-occur with ADHD are recognized as clinically significant because they cause more disturbances for the student with ADHD and suggest poorer academic outcomes beyond what is expected from ADHD behavioral features alone (Jakobson & Kikas, 2007). Symptoms of the disorder can interfere with learning and classroom activities for students with ADHD and may predict concurrent and future academic difficulties (DuPaul, 2007).

Traditional methods of diagnosing attention-deficit/hyperactivity disorder are imprecise and fail to provide explicit information for relevant services (Barkley, 1998; Hechtman, 2000; Jensen, Martin, & Cantwell, 1997; Lahey & Willcut, 2002; McCann & Roy-Byrne, 2000; Shasky, 2007). This may be detrimental to student success because determining whether a student's academic underachievement is primarily due to a psychological disorder or specific educational context has direct implications for intensity of services. The specific interventions employed may differ as a function of assessment data used to make decisions. Failure to appropriately assess a student with ADHD may result in a waste of money, time, and energy on ineffective treatment approaches (Shasky, 2007). The focus of professional practice for school psychologists is shifting from special education eligibility determination to assessing cognitive and psychological processes in order to guide appropriate instruction (Schrank & Wendling, 2009). This shift presents a need to provide a link between cognitive assessment and evidence-based educational interventions (Schrank & Wendling, 2009). Research has presented strong support for the Cattell-Horn-Carroll (CHC) broad and narrow abilities predicting performance on multiple academic tasks (Evans et al., 2002; Floyd et al., 2003; Floyd et al., 2008).

Cattell-Horn-Carroll (CHC) Theory of Cognitive Abilities and ADHD

The most comprehensive and empirically supported theory of cognitive abilities is the Cattell-Horn-Carroll (CHC) theory (Alfonso, Flanagan, & Radwan, 2005). The CHC theory combines two complementary theories of intelligence: (1) Horn-Cattell (Gf-Gc) theory, which posits multiple domains of cognitive abilities (Horn, 1994; Horn & Noll, 1997) and (2) the Carroll (1993) three-stratum theory of cognitive abilities. The CHC theory uses a hierarchical framework with three strata to conceptualize cognitive abilities. Stratum III is considered general intelligence, stratum II consists of broad cognitive abilities, and stratum I consists of narrow cognitive abilities (Penny, Waschbusch, Carrey, & Drabman, 2005). The stratum II abilities associated with common behavioral deficits in ADHD include: (1) short-term memory (Gsm), (2) visual processing (Gv), (3) long-term storage and retrieval (Glr), and (4) processing speed (Gs).

Few studies provide analyses of the cognitive profile of children with ADHD (Ek, Fernell, Westerlund, Holmber, Olsson, & Gillberg, 2007). Furthermore, the leading theory of human intelligence, CHC theory, has been underutilized in examining individuals with ADHD. The aim of this study is to compare the cognitive abilities of children with ADHD to typically developing children. The study seeks to answer the following questions: (1) Do children with ADHD significantly differ from children without ADHD on the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs)? and (2) If significant differences are present between the two groups, can the factor be used to discriminate between the two groups? Specifically, it is hypothesized that the CHC stratum II abilities of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs) will differentiate children with and without ADHD.

CHAPTER II

REVIEW OF LITERATURE

Symptoms of Attention-Deficit/Hyperactivity Disorder

Students diagnosed with attention-deficit/hyperactivity disorder (ADHD) present developmentally inappropriate levels of inattention and/or impulsivity/hyperactivity (American Psychiatric Association, 2013). The *Diagnostic and Statistical Manual of Mental Disorders 5* (DSM-5; American Psychiatric Association, 2013) is the current standard for diagnosing attention-deficit/hyperactivity disorder (ADHD) in the United States. The DSM-5 (2013) diagnostic criteria for ADHD can be found in Appendix A. Symptoms of ADHD are divided into two dimensions: inattention symptoms (i.e., easily distracted, difficulty with sustained attention, and focused attention) and hyperactivity-impulsivity symptoms (i.e., excessive physical activity and deficiency in inhibiting behavior; Smith, Barkley, & Shapiro, 2007). There are three types of ADHD: (a) ADHD, Combined Type (ADHD-C) is when a child demonstrates at least six of the nine inattentive symptoms and six of the nine hyperactivity-impulsivity symptoms; (b) ADHD, Predominantly Inattentive Type (ADHD-PI) is when child presents with at least six of the nine inattentive symptoms; and (c) ADHD, Predominately Hyperactive-Impulsive Type (ADHD-HI) is when child exhibits six of the nine hyperactivity-impulsivity symptoms (Smith, Barkley, & Shapiro, 2007). In addition to the behavioral characteristics, symptoms must be observed in more than one setting (i.e., home and school), several of the inattentive or hyperactive-impulsive symptoms must be present before age twelve, do not occur exclusively during the course of a pervasive developmental disorder (with the exception of Autism), schizophrenia, or other psychotic disorder, and are not better accounted for by another mental disorder (American Psychiatric Association, 2013). A few of the associated signs of the disorder are poor motor coordination and sequencing, difficulty with planning and organizing strategies, verbal and nonverbal working memory, mental computation, poor verbal fluency and confrontational communication, impaired academic functioning, reduced intelligence, delays in adaptive functioning and self-regulation of emotion, and social problems (Barkley, 2003; Smith, Barkley, & Shapiro, 2007).

No medical tests exist to diagnose ADHD; however, in order to assess for the presence of ADHD symptomology, practitioners need to look at three broad areas: (a) behavioral inhibition, which is inhibiting an initial response, stopping an ongoing response, and thwarting competing events/responses from disrupting the process; (b) response control/self control, which are self-directed actions that serve to modify one's subsequent behavior so as to change the probability of future outcomes; and (c) executive functioning, which is the neuropsychological process that permit or assist with self-regulation (Barkley, 1997; 2003). These areas should be measured using multiple assessment procedures such as (a) structured observations, e.g., momentary interval recording, (b) behavior rating scales, e.g., Behavioral Assessment System for Children, Second Edition (BASC-2; Reynolds & Kamphaus, 2004), (c) clinical interviews, (d) continuous performance tests, e.g., Integrated Visual and Auditory Continuous Performance Test (Sanford & Turner, 1994), and (e) cognitive ability tests, e.g., Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG; Woodcock, McGrew, & Mather, 2001).

Etiology of ADHD

Research supports that ADHD has a neurobiological etiology (Barkley, 1990; Chelune, Ferguson, Koon, & Dickey, 1986; Kempton et al., 1999; Tannock, 1998). Biological etiology accounts for 55-85% of the variability in the appearance of ADHD symptoms and heritability increases the probability of an offspring of a parent with ADHD to have the disorder by 57% (Biederman et al., 1995). Environment etiological factors account for 15-45% of the variability in symptoms (Biederman et al., 1995).

Separating attention and executive functions into subcomponents matches the mapping of attentional functions onto various brain regions support the hypothesis that ADHD will be associated with structural and functional brain abnormalities in specific regions (Kane & Engle, 2002). Clinical observations and experimental research suggests that prefrontal cortex injury and disease creates deficits which include problems of attention, motor control, spatial orientation, short-term memory, temporal and source memory, metamemory, associative learning, perseveration, and reasoning (Kane & Engle, 2002). Executive functions are self-regulatory functions incorporating the ability to inhibit, plan, organize, use working memory, problem solve, and maintain focus for future goals (Seidman, 2006). Neural circuits centered in and passing through the prefrontal cortex operate the executive-attention functions (Hale, Myerson, Emery, Lawrence, & DuFault, 2007). Meta-analysis of existing literature shows that executive functions involve a distributed network of regions including frontal, parietal, and midline structures (Hale et al., 2007). During executive functions, the frontal brain regions organize, whereas posterior regions support the processing, storage, and manipulation of information (Hale et al., 2007). Impairments on neuropsychological measures of executive dysfunction are associated with abnormal brain structures seen in individuals with ADHD (Hale et al., 2007).

Neuropsychological Studies of ADHD

Behavioral characteristics similar to those of neuropsychological disorders of executive dysfunction are used to define ADHD. The similarities between symptoms observed in ADHD and those of patients with neurological disorders led to hypotheses that ADHD is a brain disorder affecting the prefrontal cortex (Seidman, 2006). Researchers indicated that lesions in the frontal lobe in animals and human neurological patients were often associated with impulsivity, distractibility, and hyperactivity (Seidman, 2006). Further, neuroimaging studies offer evidence for these hypotheses by showing brain structure variations in individuals with ADHD (Seidman, 2006). Clinical presentations match theories emphasizing the central role of attentional and executive dysfunctions, such as disinhibition, which suggests that ADHD is a neuropsychological disorder (Barkley, 1997).

The pattern of neuropsychological impairments associated with ADHD corresponds with findings of subtle anomalies in brain anatomy, functioning, and neurochemistry in individuals with ADHD (Tannock, 1998). Studies using various neuroimaging methods have shown the link between the central psychological deficits in ADHD to specific brain regions, primarily the frontal lobe and its connections to the basal ganglia and anterior temporal cortices, and their relationship to the central aspects of the cerebellum (Dige, Maahr, & Backenroth-Ohsako, 2008).

Studies of children with ADHD have illustrated executive dysfunctions associated with ADHD are correlated with differences in brain volume (Semrud-Clikeman, Steingard, Filipek, Biederman, Bekken, & Renshaw, 2000). In individuals with ADHD, studies have shown significant correlations of their full scale IQ score with total brain volume, left and right prefrontal regions, and cerebellar volumes (Berquin et al., 1998; Castellanos, Kurland, & Goldberg, 1996). Imaging studies have illustrated less white matter in the right hemisphere which is theorized to be related to poor performance on sustained attention tasks (Semrud-Clikeman et al., 2000). In a review of functional neuroimaging, Bush and colleagues (2005) discovered dysfunction in fronto-striatal structures (lateral prefrontal cortex, dorsal anterior cingulate cortex, caudate, and putamen) as possible contributors to the pathophysiology of ADHD. Due to the striatum's close associations with the prefrontal lobe, there is extensive evidence that a disturbance in frontal-striatal circuitry is present in individuals with ADHD (Diamond, 2005).

Further studies, using functional magnetic resonance imaging (fMRI), looked at the activation of brain regions during psychological testing. Results showed when compared to controls, children with ADHD had abnormal patterns of activation during attention and inhibition tasks (Rubia et al., 1999; Teicher et al., 2000; Vaidya et al., 1998). The differences are pronounced in the right prefrontal region, basal ganglia (striatum and putaman), and the cerebellum (Rubia et al., 1999; Techer et al., 2000; Vaidya et al., 1998). Additionally, research has provided support for neurotransmitter deficiencies in individuals with ADHD (Barkley, 2003). The data implicated deficiencies are in the availability of dopamine and norepinephrine (Barkley, 2003).

The extensive research on the neurological functioning of individuals with ADHD compared to average individuals showcase strong evidence for differentiation. These differences are observed in brain volume, neurochemistry make-up, the activation of brain regions during certain tasks, and circulatory functioning between the brain regions (Berquin et al., 1998; Bush,Valera, & Seidman, 2005; Castellanos et al., 1996; Diamond, 2005; Dige, Maahr, & Backenroth-Ohsako, 2008; Hale et al., 2007; Seidman, 2006; Semrud-Clikeman et al., 2000; Tannock, 1998). It is imperative to further explore these neurological differences, the cognitive impact, and the resultant effects on individuals with ADHD. The findings can assist researchers, medical doctors, mental health professionals, educational personnel, families, and individuals with this disorder.

Cognitive Processes Associated with ADHD

Barkley (1997) proposed that ADHD is a neurological disorder of response inhibition, and emphasized the need to not only focus on the behavioral, but also the cognitive outcomes for students with ADHD. Evidence continues to support that deficits in executive functioning may be the cognitive domain that best differentiates children with and without attention deficits (Barkley, 2001; Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001). Compared to controls, children with ADHD have shown significantly lower performance on cognitive tasks involving working memory (Barkley, Grodzinsky, & DuPaul, 1992), planning (Pennington, Grossier, & Welsch, 1993), cognitive flexibility (Chelune, Ferguson, Koon, & Dickey, 1986; Tripp, Ryan, & Peace, 2002), time perception (Rubia et al.,1999), motor inhibition (Trommer, Hoeppner, Lorber, & Armstrong, 1988), and phonemic fluency (Barkley, 1997; Boonstra, Oosterlaan, Sergeant, & Buitelaar, 2005; Grodzinsky & Barkley, 1999; Oosterlaan, Logan, & Sergeant, 1998; Oosterlaan & Sergeant, 1998; Pennington & Ozonoff, 1996; Sergeant, Geurts, Huijbregts, Scheres, & Oosterlaan, 2003; Willcutt et al., 2005). These deficiencies appear stable and are frequently observed in adolescents and adults with ADHD (Barkley, 2003).

A multitude of research supports children with ADHD have neurological variations and differential performance on cognitive and neuropsychological tests. It may prove advantageous if school psychologists applied this valuable information in the educational setting. Specifically, how do we measure these differences; how do they affect students with ADHD; and how can interventions address the deficits? The psychoeducational perspective provides an avenue to answer these questions.

Psychoeducational Perspective

The psychoeducational perspective developed from the education literature emphasizes the function of cognition (Horn, 1989) and complements the information processing and neurological conceptualizations of ADHD (Penny, Waschbusch, Carrey, & Drabman, 2005; Horn, 1989). According to Penny and colleagues (2005), the psychoeducational perspective is useful to further our understanding of the cognitive deficits underlying ADHD. Researchers have applied psychoeducational perspectives to ADHD when examining whether the disorder is associated with low cognitive ability (Penny et al., 2005). Results have been mixed, some studies showed lower intellectual abilities in children with ADHD compared to non-ADHD peers (Faraone, Biederman, Lehman, & Spencer, 1993) whereas, other studies failed to support the relationship between ADHD and cognitive abilities (Kaplan, Crawford, Dewey, & Fisher, 2000; Ward, 1994). The varied results may be due to the use of a subjective, one-dimensional and over-simplified definition of cognition (Penny et al., 2005), using one narrow-band test to measure a cognitive construct, and not utilizing detailed analyses of cognitive profiles (Ek et al., 2007). Using a multi-dimensional, theory-driven, and comprehensive cognitive measure would increase validity of the findings reporting cognitive abilities.

Cattell-Horn-Carroll (CHC) Theory of Cognitive Abilities

The innovative leading theory of intelligence, the Catell-Horn-Carroll (CHC) theory, is touted to be the most comprehensive and empirically supported psychometric theory of the complexity of cognitive abilities (Alfonso, Flanagan, & Radwan, 2005). The CHC theory was formulated when Kevin McGrew (1997) synthesized two complementary theories of intelligence: Horn-Cattell (Gf-Gc) theory (Horn, 1994; Horn & Noll, 1997) and the Carroll (1993) three-stratum theory of cognitive abilities. The Horn-Cattell (Gf-Gc) theory posits multiple domains of cognitive abilities (Horn, 1994; Horn & Noll, 1997). Carroll's (1993) three-stratum theory of cognitive abilities posits a structure of human intelligence that includes three hierarchical levels (strata) of abilities, differing by breath, and generality (McGrew, 2005). The resultant theory, CHC theory, uses a hierarchical framework with three levels (strata) to illustrate cognitive abilities. The highest level (Stratum III) is general intelligence, the second level consists of broad cognitive abilities (Stratum II), and the third level consists of the abilities of the narrow band measures (Stratum I; McGrew, 1997). The current version of the theory proposes 13 major cognitive ability factors: fluid reasoning (Gf), comprehension-knowledge (Gc), short-term memory (Gsm), long-term storage and retrieval (Glr), visual processing (Gv), auditory processing (Ga), processing speed (Gs), reaction and decision speed (Gt), psychomotor speed (Gps), domain-specific knowledge (Gkn), reading and writing (Grw), quantitative knowledge (Gq), oldfactory abilities (Go), tactile abilities (Gh), kinesthetic abilities (Gk), and psychomotor abilities (Gp; Schneider & McGrew, 2012). There is extensive empirical support for the CHC theory (Waschbusch, Daleiden, & Drabman, 2000). Carroll (1993; 1997) established substantial support for the factor structure of intelligence hypothesized by CHC theory in a reanalysis of 460 data sets. Validity and reliability have been provided for the CHC theory by multiple studies encompassing large- and small-sample studies, many using comparative cross-battery data sets, developmental, outcome criterion prediction, heritability, and neurocognitive studies (Buckhalt, McGhee, & Ehrler, 2001; Flanagan & McGrew, 1998; Horn & Noll, 1997; McGhee & Liberman, 1994; McGrew, 2005; Reed & McCallum, 1995; Roberts, Pallier, & Stankov, 1996; Stankov, 2000).

Stratum I consist of narrow cognitive abilities. Each subtest of the WJ III COG measures one or more of the narrow cognitive abilities defined by CHC theory. Please refer to Appendix B for a full description of the selected narrow abilities. Stratum II consists of broad cognitive abilities (CHC factor clusters; McGrew, 2005). The CHC factor clusters include two or more narrow-ability subtests from stratum I to form a cluster representing a higher level construct. The clusters representing these broad abilities provide information for analysis of within-individual variability and valuable interpretative information for examining patterns of educational and psychological strengths and weaknesses (McGrew, 2005). Stratum III consists of the single general intellectual ability composite score (GIA; McGrew, 2005).

Description of the Selected CHC Stratum II Factors

The stratum II abilities associated with common behavioral deficits in ADHD include: short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs). Short-term memory (Gsm) involves the ability to maintain information and use it within a few seconds, also affiliated to working memory capacity (Schrank, 2005; Schneider & McGrew, 2012). Visual processing (Gv) is spatial orientation, the ability to analyze and synthesize visual stimuli, and the ability to hold and manipulate visual images (Schrank, 2005). Long-term storage and retrieval (Glr) involves the cognitive processes of encoding and storing information and later retrieving the information via association (Schacter & Tulving, 1994; Schneider & McGrew, 2012; Tulving, 2000). Processing speed (Gs) is the ability to perform routine cognitive tasks quickly and fluently over a period of time. This factor is also referred to as cognitive fluency (Mather & Wendling, 2003). These factors are related to mentally manipulating information, visual-spatial processing, recalling previously learned information, and acquiring automaticity, respectively (Alloway, Gathercole, Holmes, Place, Elliott, & Hilton, 2009; Flory et al., 2006; Mahone, 2011; McInnes et al., 2003; Penny et.al., 2005).

CHC and ADHD

The Cattell-Horn-Carroll (CHC) domains have proven useful in understanding normal cognitive development in children (Horn, 1985) and adults (Schaie, 1994). Because CHC theory has been shown to be useful in conceptualizing normal cognitive development, it may also show helpful in conceptualizing abnormal cognitive development. Therefore, CHC theory may be useful in understanding ADHD areas of relative strengths and weaknesses associated with the disorder. The identification of factors that account for significant variance in achievement outcomes is important for both assessment and treatment of this disorder. In particular, variables found to be the main predictors of achievement problems should be addressed preceding treatment and therefore serve as possible targets for school-based interventions (DuPaul, Volpe, Jitendra, Lutz, & Gruber, 2004). Results of previous research has suggested several areas are impacted in individuals with ADHD which include problems of attention, motor control (important in processing speed tasks), spatial orientation (important in visual processing tasks), short-term memory, temporal and source memory, metamemory, associative learning (important in long-term storage and retrieval tasks), perseveration, and reasoning (Kane & Engle, 2002). These areas are important in academic achievement in children and appear to have a role in predicting academic achievement among children with ADHD, including task engagement, severity of ADHD symptoms, and cognitive factors (e.g., skill level; DuPaul, Volpe, Jitendra, Lutz, Lorah, & Gruber, 2004). These deficits seen in children with ADHD are tied to factors that are important in academic achievement and may include short-term memory, long-term storage and retrieval, processing speed, and visual processing.

Short-term memory (Gsm). Researchers have documented the importance of short-term memory, memory span, and working memory in all academic areas (Evans, Floyd, McGrew, & Leforgee, 2002; Floyd, Shaver, & McGrew, 2003; McGrew, Barry, Rafael, & Rogers, 2009). The CHC factor short-term memory (Gsm) shares most of its variance with working memory capacity (Schrank, 2005). Working memory capacity refers to a system for both temporary storage and manipulation of information. Working memory capacity plays an important role in current inclusive models of cognition (Anderson & Lebiere, 1998), and is involved in a wide range of multifaceted behaviors, such as comprehension, reasoning, social skills, and problem solving (Engle, 2002). The factor has been found to directly correlate with academic performance, thereby could be considered to be the most important factor in determining general intelligence (Gatherhole, Lamont, & Alloway, 2006). An individual's performance on working memory span tasks depend on various factors, with domain-specific skills such as chunking and rehearsal, facilitating storage and a domain-general capability allowing for cognitive control and executive attention (Gatherhole, Lamont, & Alloway, 2006). Working memory capacity can forecast an individual's cognitive behavior across domains, such as reading comprehension, problem solving, and reasoning because of the general executive attention demands of the tasks, rather than the domain-specific demands of tasks (Conway & Engle, 1996; Conway, Kane, & Engle, 2003; Engle, Cantor, & Carullo, 1992; Engle, Kane, & Tuholski, 1999; Turner & Engle, 1989).

The concept of working memory is part of a wider understanding of learning, seen in terms of the way the individual processes incoming information and relates the information to what is already held in long-term memory (Reid, 2009). Working memory is a psychological space where incoming information is temporarily held, into which information may be drawn from long-term memory, and where information can be manipulated (Reid, 2009). In educational terms, it's where the learner thinks, understands, and makes sense of information in order to solve problems. Information can be transferred from the working memory and stored in long-term memory, leaving the working memory space free for further tasks (Reid, 2009).

Behavioral and neuroimaging studies have shown that the same neural systems that are important for working memory are also important for selective attention and individual differences in working memory correspond to individual differences in selective attention (Diamond, 2006). In other words, the prefrontal system that helps us selectively attend to stimuli in our environment and ignore irrelevant stimuli is the same system that helps us selectively keep our attention focused on the information we want to hold in working memory (Diamond, 2006). More specifically, the dorsolateral prefrontal cortex is responsible for maintaining information in an active, easily accessible state for working memory (Kane & Engle, 2002). Studies support that working memory capacity is an individual-differences variable and accounts for a significant portion of variance in general intellectual ability (Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Conway, Kane, & Engle, 2003; Engle, Kane, & Tuholski, 1999; Kane, Hambrick, Tuholski, Wilhelm, Payne, & Engle, 2004; Kyllonen, 1996; Kyllonen & Christal, 1990; Süβ, Oberauer, Wittmann, Wilhelm, & Schulze, 2002).

Kane and Engle (2002) proposed the average differences in working memory capacity are mediated by differences in the individual's dorsolateral prefrontal cortex functioning. The findings were based on the observation that working memory capacity/executive-attention functions appeared to map onto dorsolateral prefrontal cortex (and networked) structures (Kane & Engle, 2002). Even simple cognitive tasks involve multiple processes and the dorsolateral prefrontal cortex is a necessary structure in executive attention processes (Kane & Engle, 2002).

The dorsolateral prefrontal cortex sustains the activation of memory representations even when attentional focus is drawn elsewhere due to distractions (Kane & Engle, 2002). Results indicate that working memory is the aspect of executive attention that is critical to predicting success across higher order cognitive domains and particularly dependant on the dorsolateral prefrontal cortex (Kane & Engle, 2002).

Working memory can be broken into two different types: (1) verbal and (2) nonverbal. Verbal working memory is also referred to as “internalized self-directed speech” (Barkley, 2003). Verbal working memory derives from a developmental process seen in childhood, the progressive internalization or privatization of speech. By five to seven years of age, self-directed speech progresses from being public to subvocal to ultimately being private, in so doing giving rise to verbal thought (Barkley, 2003). Self-directed speech provides a greater capacity for self-control, the ability to plan, and adhere to goal-directed behavior, and is aided by executive functions (self-directed imagery and hearing; Smith, Barkley, & Shapiro, 2006). Barkley believed this internalization of speech represents a larger progression, in that various other forms of behavior may be internalized as well (sensory-motor, action, emotion, and play; Barkley, 2003). For those with ADHD, the privatization of speech is expected to be delayed which results in greater public speech (excessive talking), less organized and rule-oriented-speech, and increased difficulty following instructions (Barkely, 2003). Furthermore there appears to be a reduced influence of self-directed speech in controlling one’s own behavior, and less verbal reflection before acting (Barkley, 2003). Given this private self-directed speech is a key basis for verbal working memory, this cognitive activity is predicted to be impaired in individuals with ADHD. Research supports this theory as evidenced by children with ADHD exhibiting difficulties with tasks such as backward digit span, mental arithmetic, paced auditory serial addition, paired-associate learning, and other tasks believed to reflect verbal working memory (Barkley, 1997b; Chang et al., 1999; Grodzinsky & Diamond, 1992; Kuntsi, Oosterlaan, & Stevenson, 2001).

Nonverbal working memory is also referred to as “covert self-directed sensing” (Smith, Barkley, & Shapiro, 2006). Nonverbal working memory refers to one’s ability to sustain information online so to use it later to control a motor response (Smith, Barkley, & Shapiro, 2006). Nonverbal working memory is mostly composed of visual imagery and private audition (Barkley, 2000). Our senses, mainly vision and hearing, contribute to one’s internalized “resensing” which involves two interrelated processes: (1) the retrospective function (resensing past information and holding it in mind thereby making it a sensory activity); and (2) the prospective function (preparation of motor action initiated by the resensing of past information; Barkely, 2000). Together these functions provide for the progressive development of autonoetic awareness, and sense of time (Barkley, 2000). Additionally, this allows for imitation and vicarious learning, self-awareness, and cross temporal organization of behavior (Barkley, 2000). Research has indicated individuals with ADHD exhibit substantial impairments on various tasks purported to measure nonverbal working memory such as memory for objects, memory for spatial relations, block span tasks, pointing task, block tapping test, and visual retention test (Jakobson & Kikas, 2007; Marusiak & Janzen 2005; Marzocchi et al., 2008).

The normative update of the Woodcock-Johnson III Tests of Cognitive Abilities (WJ III NU) included the performance of multiple clinical samples (Woodcock, McGrew, Schrank, & Mather, 2007). Disability classification was based on the *ICD-10: International Classification of Diseases and Related Health Problems* (World Health Organization, 1992). Children and adolescents making up the attention-deficit/hyperactivity disorder group consisted of a sample size of 896 participants (Woodcock, McGrew, & Schrank, 2007). The sample included ADHD-PI, ADHD-HI, and ADHD-C. Co-occurring psychological, learning, and mental disorders were not controlled for in the sample. The lowest overall subtest score for the ADHD children and adolescents was in auditory working memory (median *SS* = 86) indicating mild impairment (Woodcock, McGrew, & Schrank, 2007). The subtest auditory working memory required the examinee to maintain a string of verbalized stimuli in immediate awareness and then recode and verbalize the sequence with the numbers in sequential order and the names of the objects in sequential order (Gazzaniga, Ivry, & Mangun, 1998). Concluding remarks note recoding tasks that are manageable for same-age peers are difficult for children and adolescents with ADHD (Schrank, 2005).

Using the Wechsler Intelligence Scale for Children, third edition (WISC-III; Wechsler, 1991), Muir-Broaddus and colleagues (2002) reported findings that the ADHD group underperformed on measures examining working memory. The researchers used the arithmetic subtests, coding subtests, and freedom from distraction index (FDI) scores to assess working memory. The freedom from distraction index (FDI) included the subtests arithmetic and digit span. Muir-Broaddus et al. (2002) reported low average functioning across all areas assessed. Substantial limitations of the study present doubt to the validity of the results. The coding subtest is a measure of visual motor speed and dexterity (i.e., processing speed) and does not measure short-term memory or working memory (Schwean & Saklofsek, 1998; Wechsler, 1991). Furthermore, the digit span subtest of the freedom from distractibility index (FDI) is not a pure measure of working memory (Reynolds, 1997). The scores from forward and backward recall are combined and greatly reduce its validity as a measure of working memory (Reynolds, 1997). Barkley (1998) illustrated children with ADHD scored significantly lower than the normative data when measured on the mental arithmetic or backward digit span. Significant differences were not seen with the subtests of forward digit span and coding in the same sample (Barkley, 1998).

Marusiak and Janzen (2005) investigated the working memory of children with ADHD as measured on the Standford-Binet Intelligence Scales, Fifth Edition (SBV; Roid, 2003). In a retrospective causal-comparative design, the archival data of 46 children with ADHD were compared to 59 non diagnosed children ranging in ages from 5 to 17 years. The ADHD group was not controlled for co-occurring disorders in the study. The control group consisted of children referred for various emotional, behavioral, and educational challenges. The working memory scores consisted of a verbal working memory task (last word subtest) and a nonverbal working memory task (block span subtest) which produced a working memory total score. Independent samples *t* test analysis revealed the working memory factor scores for the ADHD group (*M* = 90.00, *SD* = 12.4) were significantly lower than the working memory scores for the control group (*M* = 100.20, *SD* = 12.6).

Furthermore, multiple *t* tests comparisons were performed and found only the working memory factor (no other factors) was significantly different in the ADHD group versus the control group. A paired-samples *t* test analysis was performed to compare the verbal and nonverbal working memory factors scores in the ADHD group. Results showed the nonverbal working memory factor scores were significantly lower than the verbal working memory scores. No significant differences were found in the control group. In this study and in others, children with ADHD scored significantly lower on nonverbal and verbal working memory (Marusiak & Janzen, 2005). As tasks in the working memory factor are theoretically based on Baddeley's working memory model (Baddeley & Hitch, 1974), it has been suggested that compared to the phonological loop (verbal working memory), the visuospatial sketchpad (nonverbal working memory) depends more strongly on the central executive. If both verbal and nonverbal are held constant, measures of nonverbal working memory may be more impaired than verbal working memory as a higher load is placed on the central executive in individuals, especially those with ADHD (Baddeley, Cocchini, Sala, Logie, & Spinnler, 1999; Vandierendonck, Kemps, Fastame, & Szmalec, 2004).

Visual processing (Gv). Visual processing (Glr) is regulated by the central executive system in the frontal lobe and exists as part of nonverbal working memory (McGrew, 2005). This cognitive ability involves visual perception of patterns, spatial relations, and attention to visual details (Mather & Woodcock, 2001). Research has illustrated visual processing significantly predicts math achievement above and beyond an individual's IQ (Clifford, 2008).

Visual processing (Gv) relies on a set of functions largely moderated by a right-hemisphere network of distributed brain regions (Possin, 2010). The distributed network includes multiple brain regions such as the parietal lobe, lateral prefrontal cortex, medial temporal lobes, inferior temporal cortex, occipital cortex, basal ganglia, and white matter tracts (Possin, 2010). Functions of visual processing (Gv) include screening visual information for processing, arranging visual information, orienting attention, filtering extraneous information, and planning how to use visual information to attain behavioral goals (Possin, 2010). This multi-faceted domain of cognition takes part in the perception, selection, organization, and utilization of location and object-based information (Possin, 2010).

Multiple studies have reported working memory tasks discriminate between ADHD and controls without ADHD (Alloway, Gathercole, Holmes, Place, Elliott, & Hilton, 2009; Bedard & Tannock, 2008; Jakobson & Kikas, 2007). Impairments in visual-spatial and auditory-verbal working memory tasks in ADHD have remained robust even after controlling for co-occurring psychiatric disorders and general intellectual function (Bedard & Tannock, 2008). Although working memory shares a neuroanatomical association with the frontal lobes, it is distinct from other executive functions such as inhibition. Individuals with ADHD exhibit substantial working memory deficits, particularly in visual-spatial tasks (Alloway et al., 2009).

Researchers Jakobson and Kikas (2007) looked at the cognitive profiles of 152 children with ADHD-Combined type, ADHD-Combined type plus a learning disability, and controls. Visual spatial abilities, verbal and visual-spatial working memory, fine motor skills, and verbal abilities were assessed. Tasks demanding sophisticated cognitive integration (e.g. block construction and mental rotation), visual-spatial and verbal working memory (e.g., memory for objects, memory for spatial relations, and memory for sentences), word memory (e.g., memory for words), and verbal reasoning were significantly worse in ADHD groups relative to the control group (Jakobson & Kikas, 2007).

Executive and non-executive functioning was explored by Marzocchi and colleagues (2008). The researchers investigated children with ADHD and children with a reading disability. To assess working memory, the Self Ordered Pointing Task (SoP)-abstract designs (Petrides & Milner, 1982) was employed. Participants were shown a series of cards containing six to twelve abstract items and were instructed to point to a different item on each card. The two dependent variables were (a) the number of errors, and (b) the number of perseverative errors (Marzocchi et al., 2008). Results indicated that children with ADHD had a visual spatial working memory deficit. The deficit is hypothesized to be due to a deficit in the active control of the retention of the visual spatial information (Marzocchi et al., 2008). The reading disability group and ADHD group were equally impaired in visual working memory, suggesting that a common process deficit is present in both disabilities. On the non-executive functioning tasks, the ADHD group scored significantly lower than the controls on spatial short-term memory (Corsi Block Tapping Test; Schellig, 1997), visual short-term memory (Benton Visual Retention Test; Sivan, 1992), and non-perseverative errors (Marzocchi et al., 2008).

Similarly, Westerberg, Hirvikoski, Forsberg, & Klingberg (2004) investigated whether boys with ADHD showed significant deficits in visual spatial working memory compared to controls using two computerized tests: a choice reaction time test (CRT) and a test of visual-spatial working memory. Both tests involved motor responses from the participants (pressing a key on the keyboard and pointing to a circle on a computer screen). Results reported the boys with ADHD performed significantly worse on both the choice reaction time test and the visual-spatial working memory test compared to the control group (Westerberg et al., 2004). The magnitude of the difference between groups was more than twice as large for the visual spatial working memory task versus the choice reaction time test (Westerberg et al., 2004). Furthermore, the magnitude of the differences grew as the boys became older. It is implied from the study that visual-spatial working memory is an aspect of cognitive functioning that is significantly weaker in boys with ADHD as compared to their average peers. These results are consistent with the idea that working memory deficits are a central cognitive mechanism underlying the symptoms of ADHD (Westerberg et al., 2004). The findings could be confounded by the motor response requirement of the participants. Thus, it may reflect lack of behavioral inhibition (e.g., impulsivity) or slow and variable performance due to a processing speed deficit.

Long-term storage and retrieval (Glr). Deficits in long-term storage and retrieval can affect the way an individual stores new information as well as how they retrieve acquired information. Tasks measuring long-term storage and retrieval can be negatively affected by inattention and the inability to inhibit recalling related, but unnecessary information which can impede efficiencies in retrieval (Mather & Wendling, 2003; Schrank, 2005). Long-term storage and retrieval (Glr) is an important cognitive ability because it is a route to automaticity (Gazzaniga, Ivry, & Mangun, 1998). Long-term storage and retrieval (Glr) is related to reading, mathematics, and writing achievement during elementary school years (Evans, Floyd, McGrew, & Leforgee, 2002).

Long-term storage and retrieval (Glr) involves locating information in long-term memory and bringing it to working memory (Mather & Woodcock, 2001). There are two main types of long-term memories: (1) explicit (semantic and episodic), and (2) implicit (procedural and conditioning; Carlson, 2010). The WJ III COG long-term storage and retrieval (Glr) subtests require semantic (general knowledge) explicit long-term memory (Mather & Woodcock, 2001). To create a long-term memory, the to-be-learned information is gathered via sensory systems (e.g., eyes, ears) and relayed to the neocortex (Carlson, 2010). Pathways from the sensory system cortical areas join on the medial temporal lobe and in areas surrounding/adjacent to the hippocampus (Carlson, 2010). These areas synthesize the information from the different modalities to create a global memory. This information is sent to the entorhinal cortex and then to the hippocampus where the information is integrated (Carlson, 2010). Synaptic changes in the hippocampus maintain the memory (Carlson, 2010). Long-term storage and retrieval deficits can be due to encoding, storage, or retrieval problems (Fiorella, Hale, & Snyder, 2006). Pinpointing the cause of the dysfunction may assist in developing appropriate interventions (Fiorella, Hale, & Snyder, 2006).

Long-term episodic memory and working memory in children with ADHD was examined by Skowronek, Leichtman, and Pillemer (2008). Twenty-nine, 4th-8th grade males (12 with ADHD) were administered two working memory tasks (digit span and the Simon game) and three long-term episodic memory tasks (a personal event memory task, story memory task, and picture recognition task). Results illustrated children with ADHD performed worst than controls on the working memory tasks, but as well as or better than peers in long-term episodic tasks, demonstrating particularly detailed memory for personally experienced past events. The parents of the children completed questionnaires about their child's memories in daily life. Parents rated children with ADHD lower than children without ADHD on working memory and long-term semantic memory (e.g., remembering names, spelling, and math), but rated them as high or higher on memory for events. Skowronek and colleagues (2008) deduced that the performance difference seen in the study participants may reflect a relative weakness among children with ADHD in long-term semantic memory and working memory, coupled with a relative strength in long-term episodic memory.

As compared with their non-ADHD peers, children with ADHD consistently perform poorer on tasks that involve recall of verbal information with time delay (long-term storage and retrieval) and auditory interference and with tasks that require delay for the purposes of ordering and updating information (working memory; Heyer, 1995). A number of studies have demonstrated that children with ADHD have profound difficulty keeping their thoughts in logical order, organizing and categorizing linguistic information and performing on tasks involving working memory (Barkley, 1997; Heyer, 1995; McInnes, Humphries, Hogg-Johnson, & Tannock, 2003).

Cutting and colleagues (2003) examined both processes and product scores from the California Verbal Learning Test for Children (CVLT-C: Delis, Kramer, Kaplan, & Ober, 1994) in a group of 38 children ages 6 to16 years with ADHD (without a reading disorder). Both groups (ADHD and controls) learned the same amount of material and used similar strategies to memorize the list of words, such as semantically clustering the words (Cutting, Koth, Mahone, & Denckla, 2003). However, the ADHD group showed weaknesses in recalling what they learned after delays (even when provided with cues) and difficulty when asked to recognize (not recall) the words on the list (Cutting et al., 2003). The weaker than expected recognition of the words on the CVLT-C list for the ADHD group compared to their initial learning of the words was observed due to perseveration rather than storage (Cutting et al., 2003). Children with ADHD adequately learn new information, but have difficulty with recall and using the information after a delay (Cutting et al., 2003). Overall, the findings suggest that children with ADHD even without the most common type of learning disability in the verbal domain (reading disability) showed unexpected weaknesses in their ability to retain verbal material (Cutting et al., 2003). These weaknesses do not appear during the initial learning phase, but instead they appear only after a delay period (Cutting et al., 2003). The source of this retention weakness could be inefficient recall or inefficient strategies during the encoding stage, hindering the recall of newly learned verbal material.

Muse (2007) examined the affect of co-occurring reading disability on the performance of cognitive functions in children. Participants included children ranging in age of 7 to 13 years whom met the criteria for one of the following groups: ADHD (n = 16), reading disability (n = 6), ADHD plus reading disability (n = 8), and control group (n = 26). Muse employed various measures to assess cognitive abilities, reading levels, executive functioning, and memory. The

ADHD group and ADHD plus reading disability group illustrated deficits on various executive functioning measures and memory tasks (Muse, 2007). On the executive functioning tasks, results showcased that children with ADHD were more impulsive, inattentive, and had slower and more inconsistent response times compared to children without ADHD. On the memory tasks, significant differences were seen in the ADHD group on the delayed recall memory task from the Wide Range Assessment of Memory and Learning, Second Edition (WRAML-2; Sheslow & Adams, 2003; Muse, 2007). The ADHD group had significantly lower scores on the delayed recall subtest compared to the control group (M = 9.43 and M = 11.96, respectively; Muse, 2007).

Muir-Broaddus and colleagues (2002) utilized archival data of neuropsychological tests performance relative to published norms and parent ratings to examine 78 children with ADHD. Notwithstanding average to low average IQs and academic achievement, the children performed poorly comparative to test norms on most measures responsive to fronto-executive functioning (span of attention, sustained attention, response inhibition, and working memory; Muir-Broaddus, Rosenstein, Medina, & Soderberg, 2002). Poor performance was also noted on most memory tests requiring free recall/retrieval, a skill dependent in part on intact frontal/subcortical functioning which is important for long-term retrieval (Muir-Broaddus et al., 2002). Results indicate statistically significant weaknesses in the ADHD sample on most measures tapping span of attention, sustained attention, and working memory and some of the measures of response inhibition (Muir-Broaddus et al., 2002). The findings emphasize the negative effects of poor behavioral inhibition on working memory and other fronto-executive functions.

Similarly, Solanto and colleagues (2007) looked at neurocognitive functioning among ADHD subtypes. Specifically, the researchers explored attention, inhibitory control, working memory, learning, and executive functioning in children ranging in ages from 7 to 12 years. Eighty children were divided accordingly to one of the three groups; ADHD-Combined type ADHD-C), ADHD-Predominantly Inattentive type (ADHD-PI), or the control group. Co-occurring disorders were controlled for in the study. All neurocognitive data were analyzed both with and without an intellectual quotient (IQ) co-variate (Solanto et al., 2007). On the neurocognitive battery, prior to controlling for IQ, children with ADHD-C group performed poorly on motor impulsivity, cognitive inhibitory control, visual-spatial working memory and planning, and delayed recall compared to the ADHD-PI group and the control (Solanto et al., 2007). After controlling for IQ, significant differences remained in memory storage and retrieval in the ADHD-C group on the delayed recall task and slow and variable processing speed in the ADHD-PI group (Solanto et al., 2007).

Processing speed (Gs). Efficiency of cognitive processing is based partly on the speed of mental activity (McGrew, 2005). Mental quickness has been considered an important component of intelligence (Nettelbeck, 1994; Vernon, 1983). The more rapidly and efficiently an individual can automatize basic tasks, the more attention and working memory can be apportioned to higher level aspects of task performance (Fry & Hale, 2000). Performance on measures of processing speed can be affected by motivation and attention. Individuals who are impulsive may work quickly and carelessly (Schrank, 2005). On the other hand, children with ADHD have been shown to demonstrate slowed processing speed relative to typically developing peers (Mahone, 2011). Processing speed (Gs) is related to the academic areas of reading (Evans et al., 2002; Rucklidge & Tannock, 2002), mathematics (Floyd, Shaver, & McGrew, 2003), and writing achievement (Floyd, Clark, & Shadish, 2008; Mahone, 2011; McGrew & Knopik, 1993).

Processing speed (Gs) tasks measure the rate of processing or automaticity to perform simple visual-motor tasks, the maintenance of attention under timed conditions, and require both perceptual and semantic processing (Fiorello, Hale, & Snyder, 2006; Schrank & Flanagan, 2003). Processing speed (Gs) can vary based on developmental level (Kail & Hall, 1994; Salthouse, 1991) and individual differences (Shananhan et al., 2006). It is theorized that three component processing systems are involved in the cognitive process: (1) sustained attention or vigilance, also referred to as a state of readiness to respond (Corkum & Seigel, 1993; Losier, McGrath, & Klein, 1996; Sergeant & Van der Meere, 1990; Van der Meere, 1996), (2) selective attention or spatial distribution of attention (Nigg, Swanson, & Hinshaw, 1997; Pearson, Yaffee, Loveland, & Norton, 1995; Swanson et al., 1991; Tannock, Schachar, & Logan, 1993), and (3) response inhibition (Tannock, 1998). Research supports that individuals with ADHD display slow and inaccurate performance and faster than average decline in performance when the demand for effortful processing is increased (Sergeant & Van der Meere, 1990; Van der Meere, 1996). Similarly, research suggests the processing speed deficits exhibited by children with ADHD is not occurring at the level of orientation or perception of stimulus, which is related to functions of the posterior brain systems (Mahone, 2011). It is theorized that these processing speed deficits occur between sensation/perception and action and involve a state of preparedness to respond (Mostofsky & Simmonds, 2008). The process includes the selection of an appropriate response to a stimulus and is thought to be related to premotor and prefrontal circuits, and frontal-posterior connections involved in the area (Mostofsky & Simmonds, 2008; Posner & Raichle, 1994). These results indicate that the neural networks that are responsible for prediction and preparation of neural conditions needed for motor responses are impaired in individuals with ADHD (Courchesne & Allen, 1997).

The Woodcock-Johnson III Normative Update (WJ III NU; Woodcock, McGrew, & Schrank, 2007) illustrated in the performance of 874 individuals with ADHD, for both the children/adolescent and adult samples, processing speed (Gs) was a relatively low score. A negative correlation between inattention and processing speed was found by Chhabildas, Pennington, & Willcutt (2001) in the three subtypes of ADHD versus controls. Using the WISC-III, Solanto et al. (2007) illustrated children with ADHD-PI performed worse on the processing speed tasks compared to ADHD-C and the control group. Also utilizing the WISC III, Ek et al. (2007) and Riccio et al. (2006), found those with ADHD scored the lowest on the freedom from distractibility tasks and processing speed indices. In studying the effects of co-occurring reading disability in children with ADHD, Muse (2007) showed that children with ADHD have significant weaknesses in long-term retrieval and processing speed. Willcutt et al. (2005) illustrated that children with ADHD exhibited weaknesses primarily on the response-inhibition and processing speed tasks compared to children with a reading disability; whereas, Shanahan et al. (2006) reported general processing speed deficits in both the ADHD group and reading disability group compared to controls. Furthermore, the researchers implied that processing speed is the most promising candidate for neuropsychological deficit that is common in both children with ADHD and children with reading disability.

A wealth of research studies provides support for cognitive impairments in children with ADHD (e.g., Alloway et al., 2009; Bedard & Tannock, 2008; Cutting et al., 2003; Jakobson & Kikas, 2007; Marusiak & Janzen, 2005; Marzocchi et al., 2008; Muir-Broaddus et al., 2002; Muse, 2007; Sergeant & Van der Meere, 1990; Solanto et al., 2007; Van der Meere, 1996; Westerberg et al., 2004). Various assessment measures have been used to try to quantify these deficits. Unfortunately, not all assessment instrumentation is created equal. The poor performance seen in the ADHD groups could be due to the assessment measures used, measurement error (e.g., one test to represent a cognitive construct), and cofounding variables (e.g., gross motor movement requirement in assessing working memory). Based on the research-derived CHC theory of intelligence, the Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG) offers a theoretical, conceptual, and research-based foundation for comprehensively measuring cognitive abilities (Schrank, 2005).

Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG)

The Woodcock-Johnson III Tests of Cognitive Abilities is an individually administered battery of cognitive subtests designed for children, adolescents, and adults (McGrew, 2005). The WJ III was developed to have substantive validity with CHC theory. Construct representation was a driving force in the design and revision of the WJ III cognitive battery. The distinction between broad and narrow abilities is an important concept in CHC theory. Each subtests of the WJ III is intended to be a single measure of one of the narrow abilities (McGrew, Keith, Flanagan, & Vanderwood, 1997). The principle objective in item development was to sufficiently measure the narrow ability, or construct, identified in the specifications derivative from CHC theory. To ensure that all items in a test measured the same narrow ability or trait, the item-selection process utilized stringent fit-criteria based on the Rasch model (McGrew, 2005; Schrank, 2005). This process decreased the probability of selecting items that measured processes extraneous to the proposed construct. The narrow abilities identified for each test is supported by a description of the cognitive process(es) identified by research using the same or very similar tasks (McGrew, 2005; Schrank, 2005).

Although subtests are the basic administration components of the WJ III COG, clusters of subtests provide the primary basis for test interpretation. To increase construct representation the clusters were constructed to include two or more qualitatively different narrow abilities (Messick, 1995). Cluster interpretation minimizes the danger of generalizing from the score for a single, narrow ability to a broad, multifaceted ability. Cluster interpretation results in higher validity because more than one component of a broad ability comprises the score that serves as the basis for interpretation. The subject's performance on individual subtests is primarily used to understand the broader cluster score and broad area of competence. An individual's performance can be interpreted in terms of the individual's proficiency, on the narrow or broad ability measured (Schrank, 2006). Therefore test level interpretation may provide the most functional information for neuropsychological evaluations. The narrow abilities that are measured by each test closely correspond to intellectual functions, such as word knowledge, visual memory, or memory span. Each test was constructed to contain an operational definition of a cognitive ability to provide evidence of the intellectual function (Schrank, 2006).

The WJ III COG provides a measure of general intellectual ability (GIA). The GIA score represents the first principal component accounting for the most variance in overall performance on the tests that comprise the scale (McGrew, 2005). The GIA score will often be the best single-score predictor of various global criteria such as overall school achievement or other life outcomes that have some relationship to cognitive ability (McGrew, 2005).

Investigating ADHD with the Woodcock-Johnson

Few articles report studies of the use of the Woodcock-Johnson in assessing children with ADHD. Relevant research is sparse and most was found in unpublished dissertation manuscripts. Using the Woodcock Johnson Tests of Cognitive Ability-Revised (WJ-R COG), Carella (1997) investigated the cognitive profiles of children with ADHD, Predominantly Inattentive type (ADHD-PI) compared to children with ADHD, Predominantly Hyperactive-Impulsive type

(ADHD-HI). Participants ranged in age from six to eleven years and were separated into two groups: ADHD-PI group (*n* = 23) or ADHD-HI group (*n* = 26; Carella, 1997). To ensure the children's intelligence quotient (IQ) was between 80 and 119, the Wechsler Intelligence Scale for Children, 3rd Edition (WISC-III; Wechsler, 1991) was administered to the children. Subtests that formed the three CHC clusters of the WJ-R COG, i.e., auditory processing (Ga), visual processing (Gv), and fluid reasoning (Gf), were administered to the participants as well. No significant differences were found between the two groups on the three CHC factors. Both groups performed in the average range on all three clusters (range of *M* = 94 to 103). Carella attributed the limited findings to the small sample size, lack of a control group or ADHD-Combined group, or simply that the subtypes do not present cognitive differences.

Similarly, Penny, Waschbusch, Carrey, & Drabman (2005) were interested in exploring the relationship between the CHC factors and children with ADHD. Using the Woodcock Johnson III Tests of Cognitive Abilities (WJ III COG) Penny and colleagues examined whether the cognitive abilities as measured by the CHC factors are associated with symptoms of ADHD and if test behaviors mediated the association. Participants included 52 children between the ages of 6 to 12 years old with 33 (63%) participants in the ADHD group and 19 (37%) in the control group (Penny et al., 2005). The sample was obtained from a summer treatment camp for children with ADHD and related externalizing disorders. Many of the children with ADHD had co-occurring diagnoses of oppositional defiant disorder (52%) or conduct disorder (36%). The entire control group had reported externalizing behavior problems. The ADHD group consisted of 32 participants with ADHD, Predominantly Hyperactive-Impulsive type (ADHD-HI) and one with ADHD, Predominantly Inattentive type (ADHD-PI). Participants were administered the full extended battery of the WJ III COG, which included 20 subtests. To assess the participants' test session behavior, the *Guide to Assessment of Test Session Behavior* (GATSB; Glutting & Oakland, 1993) was used. Researchers hypothesized that the relationship between ADHD and CHC abilities would be explained by test session behavior. Results from the study illustrated inattentive symptoms of ADHD have a significant relationship with processing speed which was not mediated by test session behavior. Test session behavior did mediate the relationship between ADHD symptoms and visual spatial and auditory processing (Penny et al., 2005). This study is informative about the role of processing speed, but it had a negligible number of ADHD, Predominantly Inattentive type participants and did not include a control group.

The discriminative utility of the Woodcock-Johnson III clinical clusters in identifying children with ADHD was explored by Bray (2004). A sample of 52 children (26 diagnosed with ADHD and 26 controls) between the ages of 5 to 12 years were included in the study (Bray, 2004). Co-occurring disabilities were not controlled for. The participants were administered eleven subtests from the WJ III COG: auditory attention, auditory working memory, concept formation, decision speed, incomplete words, numbers reversed, pair cancellation, planning, retrieval fluency, rapid picture naming, and sound blending. These subtests made up the five clinical clusters: broad attention, executive processing, phonemic awareness, working memory, and cognitive fluency. Group differences were not present in the WJ III COG clinical clusters with mean scores for both groups in the average range (Bray, 2004). Significant differences were found on two subtests: (1) auditory attention (selective attention) and (2) rapid picture naming (accuracy of naming facility; Bray, 2004). The ADHD group scored significantly lower on both subtests; however, scores remained within the low average to average range. The WJ III COG clinical clusters provided accurate ADHD classification more than 70% of the time (Bray, 2004). The subtests auditory attention, auditory working memory, and rapid picture naming correctly classified the ADHD group more than 80% of the time (Bray, 2004). The ADHD group showed impairment on tasks requiring auditory discrimination and cognitive fluency or processing speed (Bray, 2004).

Lastly, the attention battery of the WJ III COG was explored by Poock (2005). Using archival clinic data, Poock attempted to validate the attention battery of the WJ III COG in children with ADHD. The archival clinic data sample consisted of 30 files, participants were placed in either the ADHD group (n = 14) or control group (n = 16; Poock, 2005). Participants ranged in age from 6 to 12 years. For each participant, the scores on the six subtests that create the three clinical scores for working memory, broad attention, and executive processes from the WJ III COG were collected. For the working memory composite, the ADHD group score (M = 89, SD = 12) was significantly lower than the control group (M =107, SD =14). On the broad attention composite, significantly lower scores were noted in the ADHD group (M = 87, SD = 10) compared to the control group (M = 103, SD = 12). Similarly, on the executive processes composite comparison illustrated significantly lower scores in the ADHD group (M = 87, SD =11) versus the control group (M = 102, SD = 11; Poock, 2005). Results indicated that the three factor scores of working memory, broad attention, and executive processes differentiated group membership of children with and without ADHD. Consistently lower performances were noted for children with ADHD on ability tests and higher scores on tests measuring deficits. Poock concluded the findings suggest children with ADHD present a different cognitive profile than children without ADHD on the WJ III COG. Concerns regards Poock's study include the small number of participants (N = 37), disproportion of gender representation in both groups (74% boys in ADHD group compared to 28% boys in control group), and not accounting for intellectual ability, or co-occurring disabilities.

As evidenced from the aforementioned studies, there has been some interest in utilizing the research-based, empirically-validated cognitive measure of the Woodcock-Johnson to better understand children with ADHD. The studies have examined the cognitive differences in the subtypes of ADHD, test session behavior, discriminative ability of clinical clusters, and the validity of the attention battery of the WJ COG in children with ADHD. Results have been promising; however, the studies were plagued by low sample size, construct under representation, lack of control groups, and possible misattribution due to co-occurring disorders. The current study aims to add to the research literature by exploring the cognitive abilities of children with ADHD using the WJ III COG.

Purpose and Hypotheses

ADHD is a pervasive disorder affecting individuals in every context, including school. Many of the symptoms have the ability to impact a student's educational attainment. A few associated signs of the disorder include poor motor coordination, difficulty planning and organizing strategies, poor verbal fluency, and impaired academic functioning (Barkley, 2003; Smith, Barkley, & Shapiro, 2007). Neuropsychological impairments associated with ADHD correspond with findings of subtle abnormalities in brain anatomy, functioning, and neurochemistry (Tannock, 1998). Examining children with ADHD through a psychoeducational perspective helps in understanding how these neuropsychological impairments affect children in school. Utilizing the Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG) and examining the factor-analytically supported CHC factors, provides for comprehensive measurement of the selected cognitive abilities in children with ADHD (Schrank, 2005).

The selected cognitive abilities purported to be impaired in individuals with ADHD have significant importance in academics. Short-term memory (Gsm) is important in all academic areas (Evans et al., 2002; Floyd, Clark, & Shadish, 2008; Floyd, Shaver, & McGrew, 2003). A subcomponent of short-term memory is long-term storage and retrieval (Glr) which is related to reading, math, and writing (Evans et al., 2002). Mental quickness, or processing speed (Gs), is an important component of intellectual ability, (Nettelbeck, 1994; Vernon, 1983) reading (Evans et al., 2002; Rucklidge & Tannock, 2002), mathematics (Floyd, Shaver, & McGrew, 2003), and writing achievement (Mahone, 2011). Regulated by the central executive system and part of working memory, visual processing (Gv), significantly predicts math achievement (Clifford, 2008).

The purpose of the current study is to compare the cognitive abilities of children with ADHD to typically developing children. The study seeks to answer the following questions: (1) Do children with ADHD significantly differ from children without ADHD on the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs)? and (2) If significant differences were present, could the factor be used to discriminate between the two groups? Specifically, it is hypothesized that the CHC stratum II abilities of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs) would differentiate children with and without ADHD.

CHAPTER III

METHODOLOGY

Participants

This study examined two groups of children aged 6 to 12 years old. The first group was 23 children diagnosed with ADHD (ADHD group). The second group was 49 children without ADHD (control group). Participants in the ADHD group included children with a diagnosis of ADHD from a licensed psychologist. Participants were identified through an archival database collected from a community mental health clinic in the South-Central United States. This fee-for-service clinic provides comprehensive mental health services to children, adolescents, and adults. Individuals were referred for evaluation and treatment by physicians, parents, educators, self or community mental health providers. Many individuals were referred for diagnostic evaluation with chief complaints of inattention, hyperactivity, learning, and/or behavior problems. All clinic clients signed a statement which included that test data might be used for research purposes. A copy of the testing permission form is in Appendix C. Each participant from the clinic included in the study received a comprehensive psychoeducational evaluation. The evaluation included assessments of intellectual ability, behavior, emotional functioning, learning, memory, and academic achievement. The psychoeducational evaluations were completed by senior school psychology doctoral candidates under the supervision of a licensed psychologist. The evaluations consisted of a comprehensive interview, usually conducted with one or both custodial parents or legal guardian. The interview gathered history of symptoms, complaints, impairments associated with these symptoms, and information about the participant's developmental history, social/behavioral functioning, and medical background.

Following the intake interview, participants in the ADHD group underwent a series of psychoeducational tests. The data collected during the evaluation were used to guide diagnostic impressions. ADHD symptomology was determined by: (1) parent and teacher forms of the Behavior Assessment System for Children, 2nd Edition (BASC-2; Reynolds & Kamphaus, 2004), and Conners 3 (Conners, 2008), (2) semi-structured interviews with the children, parents, and teachers (e.g., the BASC-2 Structured Developmental History), (3) medical, academic and developmental histories, (4) continuous performance test (e.g., Integrated Visual and Auditory Continuous Performance Test; Sandford & Turner, 1995), and (5) clinical observations. Diagnoses were made by the licensed psychologist using criteria from the DSM-IV-TR.

The control group consisted of 49 participants from the Woodcock-Johnson III normative update sample matched to the ADHD group on age, grade, gender, ethnicity, and GIA. The sample included the individual participants' scores on GIA, four CHC factors, and the subtests scores for each CHC factor.

Measures

Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG). The WJ III COG is a norm-referenced, individually administered battery of subtests that measures intellectual abilities. The tests are appropriate for individuals 2 to 90 years old (Woodcock, McGrew, & Mather, 2001). The WJ III COG consists of age-based standard scores with a mean of 100 and a standard deviation of 15 (McGrew, 2005). The WJ III COG measures general intellectual ability (GIA), intra-cognitive discrepancies, cognitive categories, CHC factors, clinical clusters, and predicts achievement (McGrew, 2005). The WJ III COG contains 20 subtests, each measuring a different aspect of cognitive ability. The WJ III COG is divided into two batteries: the Standard Battery (tests 1 through 10) and the Extended Battery (tests 11 through 20). An examiner can use the Standard Battery alone or in conjunction with the Extended Battery depending on the purpose of the assessment (Mather & Woodcock, 2001). The age range and breadth of cognitive abilities assessed allow the WJ III COG to be used for educational, clinical, or research purposes with preschool to geriatric aged individuals.

Administration and Scoring. The subtests are administered using an easel format. The trained examiner reads the directions printed on one side of the flip-book, while the examinee observes the corresponding test items presented on the flip-book facing them. The examiner uses the easel to direct all the subtests; however, a few subtests are presented from an automated recording (e.g., numbers reversed, auditory working memory, memory for words). Additionally, some tests require the examinee to use a response booklet to circle objects (e.g., decision speed, pair cancellation, visual matching). Scoring is objective and straightforward for the examiner. The test record booklet and administration easel provide basal and ceiling criteria for each subtest. Subtests raw scores from the examinee's test record and response booklet are typed into the computer scoring software *Compuscore and Profiles Program* (Shrank & Woodcock, 2001). The scoring program calculates the standardized scores and presents them in a table of scores. Additionally, a brief summary narrative report of the examinee is provided.

Norming. The WJ III COG battery was normed from 1996 to 1999 using a sample of 8,818 participants from across the United States. School-aged children made up more than half the sample with 4,782 student participants. Students with disabilities were included in the normative sample based on the disability classification from the *ICD-10: International Classification of Diseases and Related Health Problems* (World Health Organization, 1992).

Reliability and Validity. Reviewers of the WJ III strongly support the WJ III testing battery as reliable and valid. Reviewers have described the cognitive assessment as "state of the art" (Sandoval, 2003, p.14), and "clearly a superior instrument" (Cizek, 2003, p. 9). Reliability for the tests and clusters were calculated with the split-half procedure or the Rasch method (Schrank, 2005). Majority of the reliability estimates are .81 or higher (Schrank, 2005). The WJ III COG is based on empirically validity evidence, including CHC theory (Schrank, McGrew, & Woodcock, 2001). Each subtests was designed to measure a narrow ability (stratum I ability; Schrank, McGrew, & Woodcock, 2001). Stringent fit criteria based on the Rasch model were used to ensure that all test items of a subtest measured the same narrow ability (Schrank, McGrew, & Woodcock, 2001). A confirmatory factor-analysis (CFA) showed almost all the subtests from the WJ III COG load only on one factor indicating the subtests are not confounded by construct-irrelevant variance (Schrank, McGrew, & Woodcock, 2001). The cognitive cluster intercorrelations are low to moderate (.20 to .60) meaning the broad cognitive abilities are related to, but distinct from, one another (Schrank, McGrew, & Woodcock, 2001).

CHC Factors (Stratum II constructs)

The WJ III COG CHC factors were used as cognitive variables in the current study for several reasons. First, the WJ III COG provides a practical way to measure and interpret CHC theory (Flanagan et al., 1997). Second, CHC factors combine two or more subtests thus reducing the chances of over-interpretation using single subtests scores (Schrank, McGrew, & Woodcock, 2001). Third, the CHC factors provide a comprehensive profile that helps determine educational and psychological strengths and weaknesses (Schrank, 2005). Four CHC factors were chosen as variables for this study based on their concordance with theory and research regarding underlying cognitive factors purported to be related to ADHD. The CHC factors include short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs). Short-term memory (Gsm) demonstrates good reliability (r = .88). The subtests and reliabilities for short-term memory (Gsm) are numbers reversed (r = .87), memory for words (r = .80), and auditory working memory (r = .87; Schrank, 2005). Visual processing (Gv) shows good reliability (r = .81). The subtests and reliabilities for visual processing (Gv) are spatial relations (r = .81), picture recognition (r = .76), and planning (r = .74; Schrank, 2005). Long-term storage and retrieval (Glr) has good reliability (r = .88). The subtests and reliabilities for long-term retrieval (Glr) are visual-auditory learning (r = .86), retrieval fluency (r = .85), and visual-auditory learning-delayed (r = .88; Schrank, 2005). Processing speed (Gs) has excellent reliability (r = .92). The subtests and reliabilities for processing speed (Gs) are visual matching (r = .91), decision speed (r = .87), rapid picture naming (r = .97), and pair cancellation (r = .81; Schrank, 2005).

Independent and Dependent Variables

The independent variable for this study was diagnostic categorization; i.e., ADHD or no ADHD diagnosis, which was the control group. The four dependent variables were the CHC factor scores measured in standard scores for short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs).

Procedure

Four hundred and thirty-five client files were initially reviewed to determine eligibility for this study. A list of potential participants was generated from a master database of all clinic clients. The master database included client identification number, age, assessments given, and diagnosis. Two primary criteria were used to develop a list of potential participants: (1) age within 6 years 0 months to 12 years 11 months at time of assessment, and (2) a diagnosis of

ADHD. Using the list of potential participants, the primary investigator pulled the 97 client files and stored them in a secure location in the school psychology clinic. The primary investigator went through each file and removed those that had co-occurring diagnosis, a GIA score below 70, and/or missing scores for the CHC factors of interest. Please refer to the participant inclusion criteria in Appendix D.

Diagnostic reliability. To ensure diagnostic reliability a second independent licensed psychologist employed by the clinic received the diagnostic reports and assessment data from a progressive random sample of 18% (*n* = 9) of the cases. A progressive random sample involved the primary investigator randomly selecting nine files from the total of 49. The second independent licensed psychologist read the files and determined, based on the information provided, to agree or disagree with the diagnosis of ADHD. If the second psychologist disagreed with the initial diagnosis, then the file(s) was omitted from the study and additional files would haven be chosen for the diagnostic reliability until 100% agreement was achieved. One hundred percent agreement was achieved with the initial nine files, therefore diagnostic reliability was achieved.

Database Creation. The data for the ADHD group were collected using a systematic approach to ensure accurate data collection. The primary investigator used a spread sheet with columns for participant identification number, date of birth, age, grade, gender, ethnicity, GIA score, short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), processing speed (Gs), and each subtests for the selected CHC factors. The names of all the variables and their respective codes were developed for data entry and collection. Participants included in the study were identified only by the clinic assigned client identification number for confidentiality.

For the control group, data from the participants used to norm the WJ III COG were requested from the Woodcock-Muñoz Foundation (WMF). A formal proposal was required and consisted of the study rationale, research questions, study data analyses, data requested, and proposed dissemination plan. The WMF proposal is presented in Appendix E. The WMF advisory board approved the use of the data. A copy of the approval letter is located in Appendix F. The research director from WMF sent 1158 individual subjects' data from children ages 6 years 0 months to 12 years 11 months used to norm the WJ III COG in a PASW Statistics 18 file along with the corresponding data codebook. The first matching criteria used to create the control group for the study was chronological age by months (CAMOS). The clinic participants' ages were in years and months; therefore, the primary investigator calculated the clinic participants' CAMOS by using their date of birth. A column for CAMOS was added to the spreadsheet. The ages ranged from 73 months (6 years 1 month) to 155 months (12 years 9 months). The additional matching criteria, listed in order, were (a) grade, (b) gender, and (c) ethnicity. If there were still multiple matches, the final matching criteria for a control participant was a GIA at or near *SS* = 100.

Data Analyses

The aim of this study was to compare the cognitive abilities of children with ADHD to typically developing children. To ensure the two groups were comparably matched on the demographic information, chi-square analysis and a one-way analysis of variance (ANOVA) were conducted. The study sought to answer: Do children with ADHD significantly differ from children without ADHD on the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs)? A one-way between-group multivariate analysis of variance (MANOVA) was used to examine the differences between the two groups on the cognitive factors. A MANOVA was selected because it is appropriate for comparing groups on multiple intercorrelated dependent variables, has greater sensitivity for detecting differences between groups, allows control over Type I error rate (the probability of detecting a significant effect when there is no real effect), and has more power than univariate statistical analyses (Stevens, 2002). The second question the study sought to answer: If significant differences are present, can the factor be used to discriminate between the two groups? A discriminate function analysis (DFA) was chosen because it can detect which of the CHC variables discriminate between the two naturally occurring groups and evaluates the usefulness of a synthesized function for differentiating between groups by classifying participants (Stevens, 2002).

CHAPTER IV

RESULTS

The study sought to answer the following questions: (1) Do children with ADHD significantly differ from children without ADHD on the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs)? and (2) If significant differences were present, could the factor be used to discriminate between the two groups?

Demographic Analysis

Demographic analyses were conducted between the original ADHD group (*n* = 49) and control group (*n* = 49) and no significant differences were found. Not every participant had scores for all four CHC factors. After running the MANOVA, only the participants that had scores for all four CHC factors were used, thereby reducing the ADHD group to 23. Due to the excluded participants during the MANOVA, demographic analysis was re-analyzed.

The participants ranged in age from 6 to 12 years old, with a mean age of 9.52 years (114.13 months; *SD* = 21.16). Of the 72 participants, 48 (67%) were male, and 24 (33%) were female. They consisted of three racial/ethnic groups: Caucasian (83%), African American (11%), and other (Bi-racial or Native American; 6%). The ADHD group consisted of twelve participants with ADHD, Combined type; nine participants with ADHD, Predominantly Inattentive type; and two participants with ADHD, Hyperactive/Impulsive type. The subtypes were combined to form the ADHD group. Analyses were conducted to determine if the ADHD and control groups were equivalent on demographic variables. Chi-square analyses indicate insignificant differences between the ADHD and control groups for gender, χ^2 (1, 72) = 0.32 and race, χ^2 (1, 72) = 2.04. A one-way analyses of variance (ANOVA) found insignificant differences between the ADHD and control groups for age, F (1, 70) = 0.03, grade level, F (1, 70) = 0.61, and general intellectual ability (GIA), F (1, 70) = 2.89. Demographic data are summarized in Table 1. Intercorrelations were examined for the selected CHC factor scores in the normative sample and study participants, see Tables 2 and 3, respectively.

Wilks' MANOVA

The MANOVA was used to determine if the ADHD group and the control group performed differently on the four selected CHC stratum II factors. The MANOVA showed a statistically significant difference between the ADHD group and the control group on the factors, Wilks' λ = 0.79, F (4, 67) = 4.40, p = .003. The ADHD group and control group had statistically significant differences for long-term storage and retrieval (Glr), F (1, 70) = 11.81; p =.001; η_p^2 = 0.14 and processing speed (Gs), F (1, 70) = 4.29; p = .042; η_p^2 = 0.06. The control group scored significantly higher than the ADHD group on long-term storage and retrieval (Glr) ($M(Glr)_{control}$ = 103.14, SD = 12.54; $M(Glr)_{ADHD}$ = 91.39, SD = 15.4; Cohen's d = 0.83) and processing speed (Gs) ($M(Gs)_{control}$ = 99.37, SD = 15.00; $M(Gs)_{ADHD}$ = 91.83, SD = 13.01; Cohen's d = 0.54). Nonsignificant differences were found between the control group and ADHD group on short-term memory (Gsm), F (1, 70) = 3.76; p =.056; η_p^2 = 0.05 and visual processing (Gv), F (1, 70) = 1.93; p =.169; η_p^2 = 0.03. Mean scores, standard deviations, and cohen's d for the CHC stratum II factors standard scores by group are presented in Table 4.

Discriminant Function Analysis Post Omnibus

A discriminant function analysis was conducted to predict whether a participant fit in the ADHD diagnostic group or not. The variables that made the function were the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr) and processing speed (Gs). The resulting discriminant function significantly differentiated the groups, Wilks' $\lambda = .79$, χ^2 (2) = 15.87, $p = .003$. According to the structure matrix, the retrieval of previously learned information (long-term storage and retrieval) and automaticity (processing speed) have the greatest predictive ability to differentiate the two groups. The group centroids suggest the ADHD group (-0.74) has a lower average score for the function than the control group (0.35). The control group recalled more previously learned information and had greater automaticity than the ADHD group. The relationships of factors to the discriminant function are presented in Table 5.

Significant mean differences were observed for the ADHD and control groups from the function. The canonical correlation of .46 indicated that this discrminant function accounted for 21% of the variance between the groups. The discriminant function revealed a significant association between groups and two predictors. The two factors that significantly contributed to the function were long-term storage and retrieval (Glr) and processing speed (Gs). Long-term storage and retrieval (Glr) (.80) more strongly predicting group membership than processing speed (Gs) (.48). Specificity of predicted group membership, for the control group was 74%. Sensitivity of predicted group membership for the ADHD group was 74%. Overall, the percent correctly classified was 74%. The function increased the accuracy rate of correctly classified participants by 24%, from 50%, or chance level. Classification results are presented in Table 6.

CHAPTER V

DISCUSSION

The aim of this study was to compare the cognitive abilities of children with ADHD to typically developing children. The study sought to answer the following questions: (1) Do children with ADHD significantly differ from children without ADHD on the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs)? (2) If significant differences are present, can the factor be used to discriminate between the two groups? It was hypothesized that the CHC stratum II abilities of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs) would differentiate children with and without ADHD.

A MANOVA was used to determine if the ADHD group and the control group performed differently on the four selected CHC stratum II factors. The MANOVA showed a significant difference between the ADHD group and the control group on the cognitive factors of long-term storage and retrieval (Glr) and processing speed (Gs). The control group scored significantly higher than the ADHD group on the two factors. A DFA was conducted to predict whether participants would be identified in the ADHD diagnostic group or not. The variables that significantly contributed to the function were long-term storage and retrieval (Glr) and processing speed (Gs). Significant mean differences were observed for the ADHD and control groups from the function. The DFA revealed a significant association between groups and two predictors; however, long-term storage and retrieval (Glr) was the strongest predictor of group membership. The function primarily represents "quick recall," which is the ability to retrieve previously learned information with automaticity. Specificity of predicted group membership, not having ADHD and being predicted to be in the control group, was 74%. Sensitivity of predicted group membership, having ADHD and being predicted to be in the ADHD group, was 74%. The function increased the accuracy rate of correctly classified participants, from 50%, or chance level, by approximately 24%. The findings support the use of these two CHC factors to promote incremental diagnostic validity, possibly when used in conjunction with other measures of cognitive functioning, such as continuous performance tests.

CHC Factor Results

Short-term memory (Gsm). In previous studies, ADHD and control groups performed differently on various cognitive abilities. For example, two studies (Marusiak et al., 2005; Skowronke, Leichtman, & Pillemer, 2008) found children with ADHD to perform lower on working memory tasks than children in the control group. Muir-Broaddus and colleagues (2002) showed the ADHD group underperformed on measures examining span of attention, sustained attention, and working memory. Poock (2005) indicated working memory differentiated group membership of children with and without ADHD. Bray (2003) found that the ADHD group had impairments on tasks requiring selective attention, or concentration, and holding information while processing another task.

Results from the current study did not produce a significant difference between the two groups on the cognitive ability short-term memory (Gsm) with both groups scoring in the average range. Similarly, Alloway, Gathercole, Holmes, Place, Elliott, & Hilton (2009) found that it was more attributable to chance that children with ADHD either performed at or below average (51%) on measures of verbal working memory. Possible explanations for the incongruent findings include tasks demands, or secondary effects of ADHD. The WJ III COG short-term memory (Gsm) relies mainly on verbal working memory; however, impairments may be more related to nonverbal working memory (Marusiak & Janzen, 2005). Furthermore, the data may indicate that the deficits seen in children with ADHD on short-term memory (Gsm), as well as other tests of working memory, may be due to a secondary deficit, driven by core deficits in motor or behavior (Alloway et al., 2009). This might indicate that measures of working memory may not be appropriate for ADHD/non-ADHD differentiation and may be poor predictors of ADHD. Nonetheless, further research is needed to explore this cognitive ability.

Visual processing (Gv). Similar to findings in verbal working memory, Alloway et al. (2009) found 61% of children with ADHD either performed at or below average on measures of visual-spatial working memory. Marzocchi and colleagues (2008), using Self Ordering Pointing Tasks (SoP), found children with ADHD have a visual-spatial working memory deficit due to a deficit in the active control of the retention of visual-spatial information. Westerberg et al. (2004) showed boys with ADHD performed worse on visual-spatial working memory tasks compared to boys in the control group. The previous studies (e.g., Alloway et al., 2009; Marzocchi et al., 2008; Westerberg et al., 2004) relied on single measures to represent a cognitive ability. Their findings are questionable because using a single measure to assess a cognitive ability greatly increases the probability of influences of measurement error. The WJ III COG CHC factors are clinical clusters, or stratum II constructs, which include at least two subtests which decrease error variance (McGrew, 2005). Using the CHC factors of the WJ-R COG, Carella (1997) compared ADHD, Predominantly Inattentive type and ADHD, Predominantly Hyperactive-Impulsive type. The findings showed that both groups performed in the average range on the visual processing cluster (M = 95 and M = 103, respectively). Penny and colleagues (2005) used the WJ III COG, and showed test session behavior mediated the relationship between ADHD and visual-spatial thinking. In the current study, the ADHD group and control group scored similarly and in the average range on visual processing (Gv). The results indicate that children with ADHD have typical abilities in the area of visual processing (Gv) and poor performance found in other studies may be due to a behavioral component of ADHD.

Long-term storage and retrieval (Glr). Cutting and colleagues (2003) suggested individuals with ADHD may adequately acquire new information; however, they have difficulty with recall after delays. Using the California Verbal Learning Test for Children (CVLT-C), the researchers found children with ADHD initially learned an adequate amount of words but after delays had difficulty recalling what they had learned when compared to controls. Furthermore, the ADHD group recognized fewer words than the control group. However, both groups scored within the average range on all subtests (Cuttings et al., 2003). Similarly, Muir-Broaddas and colleagues (2002) also found using the CVLT-C the ADHD group and control group were consistently within normal limits on the tests tapping retention of information already learned. Solanto et al. (2007) results showed the ADHD, Combined group performed significantly worse on delayed recall tasks compared to the control group. Muse (2007) showed the ADHD group had significantly lower scores on the WRAML-2 story memory delayed recall subtest compared to the control group (M = 9 and M = 12, respectively). These studies used verbal learning measures to assess children's memory.

The findings in this study appear similar to previous studies of long-term storage and retrieval (Glr), but there are differences in how the construct was measured. The previous studies utilized long-term retrieval assessment methods that relied on narrow abilities of visual or auditory memory. This study investigated the CHC factor long-term storage and retrieval (Glr) which presents the information from the subtests visually and verbally, and requires the ability to store information (e.g., concepts, ideas, names, items) in long-term memory and to fluently retrieve it later through association (Mather & Woodcock, 2001). The CHC factor long-term storage and retrieval (Glr) measures associative memory, ideational fluency, and naming facility (Mather & Woodcock, 2001). Associative memory joins information from two types of properties (e.g., seeing an object and hearing the name of the object) and compares the information with stored representations (Schrank, 2006). Ideational fluency is the ability to rapidly verbalize a series of words, or phrases related to a specific condition or object (Mather & Woockcock, 2005). Naming facility is the ability to rapidly verbalize names for concepts or things when shown a picture (Mather & Woodcock, 2005). Hervey, Epstein, and Curry (2004) noted in their meta-analytic review, adults with ADHD do not show difficulties with memory when information is presented with visual stimuli in the form of a figure. These findings are consistent with executive functioning data on verbal fluency in adults with ADHD (Hervey, Epstein, & Curry, 2004). Research of adults with ADHD has shown poor performance in response to verbal cues; however, these differences dissipate if pictures are used as cues to prompt verbal responses (Benton et al., 1983; Halstead & Wepman, 1959; Lezak, 1995). Hervey, Epstein, and Curry (2004) theorized that verbally based memory tasks are negatively affected by a disruption in recoding ensuing poor performance either directly or through poor memory strategy selection. In the current study, the ADHD group scored significantly lower than the control group on long-term storage and retrieval (Glr). The present study adds to the research because it suggests long-term storage and retrieval (Glr) measures that require verbal ability may demonstrate life-long deficits in long-term storage and retrieval (Glr) for those with ADHD.

Processing speed (Gs). The Woodcock-Johnson III Normative Update (WJ III NU; Woodcock, McGrew, & Schrank, 2007) illustrated in the performance of 874 individuals with ADHD, for both the children/adolescent and adult samples, processing speed (Gs) was a relatively low score. Chhabildas and colleagues (2001) found a negative correlation between inattention and processing speed in the three subtypes of ADHD versus controls. Solanto et al. (2007) used the WISC-III to show children with ADHD, Predominately Inattentive type performed worse on the processing speed tasks compared to ADHD, Combined type and the control group. Ek et al. (2007), using the WISC-III, found those with ADHD scored the lowest on tasks of freedom from distractibility and processing speed indices. The results reflected impairments in working memory and cognitive speed. In studying children with ADHD, ADHD plus reading disorder, reading disorder, or controls, Muse (2007) illustrated that children with ADHD have processing speed deficits. Similarly, Shanahan et al. (2006) demonstrated general processing speed deficits in both clinical groups (ADHD and reading disability) compared to controls. Willcutt et al. (2005) examined children with ADHD versus children with a reading disability. Results showed that children with ADHD exhibited weaknesses in processing speed tasks and that processing speed is the most promising candidate for a neuropsychological deficit that is common in both children with ADHD and children with a reading disability. Similar to previous studies, the current study also found significant deficits in processing speed (Gs) for children with ADHD. Within the educational realm, deficits in processing speed can have a pronounced impact on reading fluency and the impairments can manifest in automaticity, sustained effort, consistency of response preparation, and retrieval fluency (Mahone, 2011). Interventions to address these areas may be beneficial for students with ADHD throughout their educational endeavors.

Contribution

Properly assessing ADHD as related to academic underachievement is to aide in providing effective interventions. Treatment for ADHD usually includes educating parents and teachers about the disorder, training them in effective interventions, providing information about educational resources and psychotropic medication (Barkley, 1999). There are promising strategies to correct academic and behavioral deficits (DuPaul, 2007); however, if students are incorrectly diagnosed educational staff may not appropriately match these strategies to the needs of children with ADHD. There are a variety of interventions that show promise, such as computer-assisted instruction (Clarfield & Stoner, 2005; DuPaul, 2007; Mautone, DuPaul, & Jitendra, 2005), class-wide peer tutoring (DuPaul, Ervin, Hook, & McGoey, 1998), home-based parent tutoring (Hook & DuPaul, 1999) or homework support (Power, Karustis, & Habboushe, 2001), self-regulated strategies for written expression (Reid & Lienemann, 2006), and directed note taking (Evans, Pelham, & Grudberg, 1995).

Long-term storage and retrieval (Glr) Interventions. The current study illustrated children with ADHD performed significantly lower on tasks measuring long-term storage and retrieval (Glr) and interventions should address this weakness. Interventions to address limitations due to poor long-term storage and retrieval (Glr) include active learning (Marzano et al., 2001), rehearsal (Simsek & Balaban, 2010), elaboration (Squire & Schacter, 2003), mnemonics (Wolfe, 2001), visual representation (Greenleaf & Wells-Papanek, 2005), and organizational strategies (Simsek & Balaban, 2010).

Active learning involves providing a variety of learning tasks, incorporating emotions and novelty, promoting creativity, and teaching children to picture the information during listening and reading to develop and improve comprehension and recall (Marzano et al., 2001;

McInnes et al., 2003). Rehearsal strategies include activities that involve identifying and repeating important groups of new material. Flash cards, verbal rehearsing, listing concepts, highlighting, underlining, using mnemonics, and summarizing the information are some examples of rehearsal strategies (Simsek & Balaban, 2010). Elaboration strategies involve connecting new information and familiar information (Simsek & Balaban, 2010). It is also recommended that educators employ visual supports (e.g., diagrams, illustrations, and graphic organizers) when presenting novel or complex information in order for the lesson to capitalize on both verbal and visual-spatial abilities in students with ADHD (McInnes et al., 2003). Organization strategies include reviewing and restructuring the presented material by creating outlines and tables, categorizing, re-grouping, and concept maps (Simsek & Balaban, 2010). Classroom accommodations for students with deficits in long-term storage and retrieval (Glr) might include: (a) keeping oral directions short and simple, (b) asking the student to paraphrase directions to ensure understanding, (c) providing visual cues for the directions or steps to be followed, and (d) encourage the student to spend time studying and rehearsing the new information (Wendling & Mather, 2009).

Processing speed (Gs) Interventions. The current study also supported that children with ADHD performed significantly lower on tasks measuring processing speed (Gs) and interventions should be employed to help compensate for this weakness. Behaviors related to processing speed (Gs) are positively influenced by repeated practice, speed drills, and use of computer games that require an individual to quickly make decisions (Mahncke, Bronstone, & Merzenich, 2006; Tallal et al., 1996). Additionally, accommodations that aide students with limited processing speed (Gs) include extended time, providing outlines of lecture materials, emphasizing accuracy over speed, providing immediate feedback, limit copying activities, and increasing wait times both after questions are asked and after responses are given (Mahone, 2011; Schrank & Wendling, 2009).

Strengths

One strength of the current study is it excluded participants with co-occurring disorders, such as learning disabilities, other behavioral, or emotional disorders. The decision to not include these children was based on previous findings that indicate the presence of coexisting disorders may have a significant influence on cognition and behavior in children with ADHD (Crawford, Kaplan, & Dewey, 2006). Research has demonstrated an inverse relationship between the number of coexisting disorders in children with ADHD and performance on tests of memory and visual-motor skills (Crawford, Kaplan, & Dewey, 2006). Additionally, an increased prevalence of behavioral problems and impairment in everyday functioning are noted in children with ADHD plus coexisting disorders (Crawford, Kaplan, & Dewey, 2006).

This study restricted the age range of participants from six to twelve years-old, which may allow for it to exclude the impact of cognitive development specific to adolescence. There are differences in cognition and behavior in children as compared to adolescents (Barkley, Grodzinsky, & DuPaul, 1992). A meta-analysis demonstrated that both children with ADHD and control groups showed age-related improvements on neurological assessments, but the deficit between groups remains significant (Seidman et al., 2006). Age-related improvements in speed of processing during childhood and adolescence are highly correlated with developmental improvements on complex-span tasks (Case, Kurland, & Goldberg, 1982; Hitch, Towse, & Hutton, 2001; Kail, 1992). Behaviorally, children diagnosed with hyperactivity/impulsivity display less impulsivity and more inattentive symptoms as they become older (Goldstein & Goldstein, 1998). Symptoms of disinhibition appear to arise earliest in children with ADHD and decline earlier than the other symptoms of ADHD (Hart, Lahey, Loeber, Applegate, & Frick, 1995). By adolescents, inattention and hyperactive-impulsive behaviors declines; however, symptoms remain above average in individuals with ADHD (Fisher, Barkley, Fletcher, & Smallish, 1993). The DSM-IV-TR acknowledges that in adolescents and adults, symptoms of hyperactivity become less conspicuous as the individual learns to compensate for the weakness and control behavior (American Psychiatric Association, 2000). Future studies investigating the CHC factors using younger and older populations would be of interest. Investigations across age range could examine the cognitive abilities associated with maturation. Additionally, how the ability deficits are related to further areas of academic success could be explored (Willcutt et al., 2001).

The current study eliminated children with a general intellectual ability (GIA) score below 70. There is a debate among researchers as to whether intellectual ability should be controlled for in studies of the cognitive abilities of children with ADHD (Brigett & Walker, 2006). Several studies that have controlled for group differences in intellectual ability, have noted the loss of statistical significance between groups (Grskovic, Zentall, & Stormont-Spurgin, 1995; Murphy, Barkley, & Bush, 2001; Werry, Elkind, & Reeves, 1987). For example, Werry, Elkind, & Reeves (1987) observed a loss of statistical significance from their initial findings in a study of children with ADHD and deduced that perhaps cognitive deficits found in this population reflect low intellectual abilities. A study by Scheres et al. (2004), showed boys with ADHD had deficits in executive functioning tasks compared to controls. After controlling for the individual's intellectual ability, the significant differences dissipated (Scheres et al., 2004). It has been postulated that if lower intellectual ability were an attribute of ADHD, then controlling for it would take out a portion of the variance that is associated with ADHD (Nigg, 2001; Werry, Elkind, & Reeves, 1987). Therefore, many studies do not assess the important covariate of GIA, leaving open the possibility that many of the deficits often attributed to ADHD could be attributable to differences in IQ (Willcutt et al., 2001). The current study elected to not include individuals with a GIA score below 70 to remove the possibility of co-occurring mental retardation. The ADHD and control group were matched on GIA scores and the scores were not included in the statistical analyses. Taking into account the child's GIA helps to examine the cognitive difficulties that may be directly attributed to ADHD versus those difficulties attributed to overall cognitive deficits.

Limitations and Future Directions

Limitations to this study include: (a) small, non-diverse sample, (b) combining the ADHD subtypes, and (c) not accounting for ADHD symptom severity. The participants come completely from a town in South-Central United States and were predominantly Caucasian, which may limit the generalizability of the results to more diverse communities or populations. Increasing the number of participants and broadening the ADHD group to include a more diverse sample would help to generalize the results to a national population. Additionally, a larger number of participants might detect further differences between the two groups.

It is established that inattention and hyperactivity/impulsivity are relatively distinct aspects of ADHD (American Psychiatric Association, 2000), which suggests that there may be different cognitive abilities associated with these aspects of ADHD. Diamond (2005) noted differences between the inattentive and combined subtypes in the areas of cognitive and behavioral profiles, reactions to medication, and underlying neurobiological functioning. In contrast, using the WJ CHC factors, Carella (1997) found no significant differences between the two subtypes of ADHD and Penny et al. (2005) showed visual-spatial deficits are common between all types of ADHD. Still, the potential differences were not explored in the current study due to the small sample size. This should be further investigated to determine what, if any, subtype differences exist on CHC factor performance.

ADHD symptoms vary in presentation and range from mild to severe. The database utilized in the study did not quantify the severity of the symptomology in the ADHD sample. Barry, Lyman, & Klinger (2002) underscored that a good predictor of academic underachievement in individuals with ADHD is not only a categorical diagnosis of ADHD, but also the severity and pervasiveness of the ADHD symptoms**.** Future studies including the severity of the ADHD symptomology and the relationship with CHC factors should be explored.

The American Academy of School Psychology (2003) highlighted the utility of assessing cognitive strengths and weaknesses in so to provide required documentation for legal protection and/or the provision of special services or accommodations. The National Association of School Psychology (2002) suggested that cognitive assessment should be used for discovering strengths and weaknesses on variables (e.g., verbal short-term memory) known to be linked to reading and other academic areas. Research has illustrated that the CHC broad and narrow abilities can predict performance on academic tasks (Evans, Floyd, McGrew, & Leforgee, 2002; Floyd, Clark, & Shadish, 2008). Future research utilizing the CHC broad and narrow abilities in children with ADHD may provide important information in identifying and educating this population.

Best Practices in school psychology indicate that the most effective approach to assessment is for school psychologists to follow a data-driven, problem-solving model, where measures are taken to facilitate the problem-assessment process (Flanagan, Ortiz, Alfonso, & Dynda, 2008). Within the problem-solving approach, assessment information is collected to guide decision making and to identify the discrepancies between a student’s current academic or behavioral performance, and the desired performance (Merrell et al., 2006). Effective diagnostic assessments should go beyond traditional symptom-based categorization and allow for more accurate and precise problem identification (Decker, 2008). One of the major purposes of a comprehensive assessment is to create hypotheses from a student's cognitive profile that provide guidance for creating innovative techniques that produce effective instruction (Reynolds & Shaywitz, 2009).

ADHD consists of many interrelated symptoms, each of which may differently contribute to academic difficulties for these children. Links between specific symptoms of ADHD and the particular aspects of academic performance they affect have not received a great deal of attention (Berthiaume, 2006). It is important that we identify how the behaviors of children with ADHD contribute to academic problems so we can create interventions that specifically address those areas of difficulty. Moreover, knowledge of the contributions of behavioral difficulties as they interact with cognitive processes is critical for understanding the academic performance and potential of these children. Research in this area may provide important insights in constructing appropriate educational interventions for children with ADHD.

Conclusion

The purpose of the current study was to compare the cognitive abilities of children with ADHD to typically developing children. The study sought to answer the following questions: (1) Do children with ADHD significantly differ from children without ADHD on the four CHC factors of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs)? and (2) If significant differences were present, could the factor be used to discriminate between the two groups? Specifically, it was hypothesized that the CHC stratum II abilities of short-term memory (Gsm), visual processing (Gv), long-term storage and retrieval (Glr), and processing speed (Gs) would differentiate children with and without ADHD. A MANOVA showed a significant difference between the ADHD group and the control group on the cognitive factors long-term storage and retrieval (Glr) and processing speed (Gs). The control group scored significantly higher than the ADHD group on the two factors. A DFA was conducted to predict whether participants would be identified in the ADHD diagnostic group or not. The variables that made the function were long-term storage and retrieval (Glr) and processing speed (Gs). Significant mean differences were observed for the ADHD and control groups from the function. The DFA revealed a significant association between groups and both predictors; however, long-term storage and retrieval (Glr) was the strongest predictor of group membership. The findings from the current study illustrated significant weaknesses in long-term storage and retrieval (Glr) and processing speed (Gs) in children with ADHD. Research-driven, empirically-validated academic interventions should be implemented in the educational setting to address these cognitive weaknesses in students with ADHD.

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APPENDICES

Table 1. Demographic Variables of Participants

	ADHD Group	Control Group	Total
	N = 23	*N* = 49	*N* = 72
	M (SD)	*M (SD)*	*M (SD)*
Age in months	113.52 (20.45)	114.41 (21.69)	114.13 (21.16)
Grade	3.30 (1.55)	3.63 (1.70)	3.53 (1.65)
GIA[a]	96.57 (11.46)	101.76 (12.36)	100.10 (12.24)
	N (%)	*N* (%)	*N* (%)
Gender			
Boys	15 (65%)	33 (67%)	48 (67%)
Girls	8 (35%)	16 (33%)	24 (33%)
Race/Ethnicity			
Caucasian	20 (87%)	40 (82%)	60 (83%)
African American	1 (4%)	7 (14%)	8 (11%)
Other	2 (9%)	2 (4%)	4 (6%)

Note. [a]GIA = General Intellectual Ability

Table 2. Correlations of the selected CHC factors from the WJ III NU COG normative participants, Age 6 to 12 years (*n* = 1158).

	Gsm	Gv	Glr	Gs
Gsm[a]	1.00	0.22	0.36	0.27
Gv[b]		1.00	0.29	0.21
Glr[c]			1.00	0.34
Gs[d]				1.00

Note. [a]Gsm = Short-term memory; [b]Gv = Visual processing ; [c]Glr = Long-term storage and retrieval; [d]Gs = Processing speed

Table 3. Correlations of the selected CHC factors from study participants (*n* = 72).

	Gsm	Gv	Glr	Gs
Gsm[a]	1.00	0.17	0.40	0.25
Gv[b]		1.00	0.07	-0.01
Glr[c]			1.00	0.26
Gs[d]				1.00

Note. [a]Gsm = Short-term memory; [b]Gv = Visual processing ; [c]Glr = Long-term storage and retrieval; [d]Gs = Processing speed

Table 4. Mean Scores, Standard Deviations, and Cohen's *d* for the Selected CHC Stratum II Factors Standard Scores by Group

	ADHD Group		Control Group		
	M	*SD*	*M*	*SD*	Cohen's *d*
Gsm[a]	94.70	13.37	101.65	14.53	0.50
Gv[b]	103.91	7.78	100.06	12.16	-0.38
Glr[c]	91.39	15.48	103.14	12.54	0.83
Gs[d]	91.83	13.00	99.37	15.00	0.54

Note. [a]Gsm = Short-term memory; [b]Gv = Visual processing ; [c]Glr = Long-term storage and retrieval; [d]Gs = Processing speed

Table 5. Relationships of Factors to the Discriminant Function

CHC Factor	*F*	*p*	Structure Coefficient	SDFC
Gsm[a]	3.77	.056	.453	.239
Gv[b]	1.93	.169	-.324	-.489
Glr[c]	11.81	.001	.801	.727
Gs[d]	4.29	.042	.483	.313

Note. [a]Gsm = Short-term memory; [b]Gv = Visual processing; [c]Glr= Long-term storage and retrieval; [d]Gs = Processing speed; SDFC = Standardized Discriminant Function Coefficient

Table 6. Classification Results

			Predicted Group Membership		
		Classification	Control	ADHD	Total
Original	Count	Control	36	13	49
		ADHD	6	17	23
	Percentage	Control	73.5%	26.5%	100%
		ADHD	26.1%	73.9%	100%

73.6% of Original Grouped Cases Correctly Classified.

Appendix A

Attention-Deficit/Hyperactivity Disorder Diagnostic Criteria as stated in the DSM-5

A. Either (1) or (2):

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

Inattention

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

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

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

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

(e) often has difficulty organizing tasks and activities

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

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

(h) is often easily distracted by extraneous stimuli

(i) is often forgetful in daily activities

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

Hyperactivity

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

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

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

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

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

(f) often talks excessively

Impulsivity

(g) often blurts out answers before questions have been completed

(h) often has difficulty awaiting turn

(i) often interrupts or intrudes on others (e.g., butts into conversations or games)

B. Some hyperactive-impulsive or inattentive symptoms that caused impairment were present before the age of twelve years.

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

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

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

Code based on type:

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

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

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

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

(American Psychiatric Association, 2013).

Appendix B

Description of Selected Stratum I Narrow Abilities per CHC factor

Short-term memory (Gsm)

Test 7, Numbers Reversed: Repeating increasingly long series of dictated digits in reversed order; measures working memory.

Test 9, Auditory Working Memory: After hearing a sequence of numbers and objects, examinee has to first repeat back the objects in sequential order and then the numbers in sequential order; measures working memory.

Test 17, Memory for Words: Examinee must repeat a list of unrelated words in the correct sequence; measures auditory memory span.

Visual processing (Gv)

Test 3, Spatial Relations: Examinee has to identify two or three pieces that form a target shape; measures visualization and spatial relations.

Test 13, Picture Recognition: Examinee must recognize a subset of previously presented pictures within a field of distracting pictures; measures visual memory.

Test 19, Planning: Examinee has to trace a pattern without lifting the pencil, retracing any part of the path, or skipping any part; measures spatial scanning and general sequential reasoning.

Long-term storage and retrieval (Glr)

Test 2, Visual-Auditory Learning: Examinee has to associate new visual symbols with familiar words in oral language and translate a series of symbols presented as a passage; measures associative memory.

Test 10, Visual-Auditory Learning-Delayed: Examinee tries to “read” sentences written with the rebuses learning in Visual-Auditory Learning; measures associative memory.

Test 12, Retrieval Fluency: Examinee must name as many examples from a given category within a one-minute time frame; measures ideational fluency and naming facility.

Processing speed (Gs)

Test 6, Visual Matching: Must locate and circle the two identical numbers in a row of six numbers; measures perceptual speed.

Test 16, Decision Speed: Examinee must quickly locate in each row the two pictures that are most similar conceptually; measures semantic processing speed.

Test 18, Rapid Picture Naming: Examinee tries to name simple pictures as quickly as possible for two minutes; measures naming facility.

Test 20, Pair Cancellation: Examinee must scan rows as quickly as possible to locate and circle each instance which a certain picture is followed by a certain other picture; measures attention and concentration.

(Mather & Woodcock, 2001; Schneider & McGraw, 2012; Schrank & Wendling, 2009)

Appendix C

OKLAHOMA STATE UNIVERSITY

College of Education

School Psychology Center
Phone: (405) 744-5474
Fax: (405) 744-6756

Permission Form

Name: ___________________________ ***Date:***________________________
(Please Print)

I hereby voluntarily consent to utilize the school and/or counseling psychology services provided through the Oklahoma State University School Psychology Center. Possible services include individual, group, martial, or family therapy, consultation, educational intervention, and individual psychological testing. As a client utilizing the service of a psychological associate, I understand that I have a right to ask any question I may have about the process, methods, duration, and goals of the services that are rendered to me and the right to discuss any concerns I may have. I have the right to terminate those services at any time.

I have read and hereby certify that I understand the following:

- The School Psychology Center provides training and research for Oklahoma State University School Psychology program. The program requires that all student therapists or interviewers be under the supervision of faculty psychologists.
- There is a possibility that my psychological associate and/or supervising psychologists may change during the course of the therapy or services.
- For training or research purposes sessions may be audio or video taped, and/or observed by supervisors or other psychological associated of the Oklahoma State University School Psychology Center.
- Tapes, tests, and other information obtained during my contacts with the clinic may be used for research and/or training purposes. I give consent for my individual data to be presented anonymously at professional meetings and/or published in a scientific journal.
- I understand that one of my rights involves confidentiality. Within certain limits, information revealed by me or my child during counseling/testing will be kept strictly confidential, and will not be revealed to any other person or agency without my permission. If I give my written permission to release information to my health insurance company, employee assistance program, or other health benefits program, I understand that psychological associates may disclose the nature of services provided, the diagnosis, the dates of services, the fees charged, and other relevant information specifically requested by the insurance company or program.
- I understand that there are certain limits to confidentiality, in which it is required by law and/or professional ethics that psychological associates reveal information to other persons or agencies, without my permission. These limits to confidentiality are as follows:
  A. If I or my child threaten grave bodily harm or death to a reasonably identified person, a psychological associate may be required (1) to inform appropriate

legal authorities and the intended victims; (2) to arrange for voluntarily hospitalization; or (3) to take appropriate steps to initiate proceedings for involuntary hospitalization pursuant to law.

B. If I or my child express a serious intent to grievously harm myself (himself or herself), it may be necessary for a psychological associate (1) to reveal information to family members and/or persons authorized to respond to such emergencies, in order to protect me from harm; (2) to arrange for voluntary hospitalization; or, (3) to take appropriate steps to initiate proceedings for involuntary hospitalization pursuant to law.

C. If a court of law issues a legitimate subpoena, a psychological associate may be required to provide information that is specifically described in the subpoena.

D. If I or my child are being evaluated or treated by order of a court of law, the results of the evaluation or treatment ordered may be revealed to the court.

E. If a psychological associate has good reason to suspect that a child is a victim of physical abuse, sexual abuse, or neglect, he/she is required to report the abuse or neglect to the Department of Human Services and/or law enforcement authorities.

F. If I or my child use psychological treatment and/or records in my behalf in a legal, the records must be available to both parties.

- I understand these limitations to confidentiality as outlined above.
- I also understand (a) that the fee for psychological services is $______ per session, (b) that the sessions are 50 minutes in duration, and (c) that I must give twenty-fours notice if I wish to cancel an appointment, or the full per session fee will be charged. Information and assistance regarding scheduling of appointments, payment for fees, and insurance coverage for psychological services are provided by the front desk staff.
- I am expected to pay for services at the time they are provided unless other arrangements have been made in advance.

______________________________ Signature of Client

______________________________ Authorizing Signature of Parent/Legal Guardian (if client is under 18 years of age)

______________________________ Psychological Associate

Appendix D

Participant Inclusion Criteria

The ADHD group comprised of children's files from an archival database from the university school psychology clinic. To be included in the study, the participants must have the following:

1. primary diagnosis of ADHD
2. no concomitant learning or emotional disabilities
3. between the ages of 6 years, 0 months to 12 years, 11 months at the time of assessment
4. have scores on at least one of the four CHC factors (Gsm, Gv, Glr, Gs)
5. GIA score of 70 or above

The control group comprised of children from the normative data from Woodcock-Munoz Foundation. To be included in the study, participants must have the following:

1. no diagnosis of learning, behavioral, emotional or mental disability
2. between the ages of 6 years, 0 months to 12 years, 11 months at the time of assessment
3. have scores on all four CHC factors (Gsm, Gv, Glr, Gs)
4. GIA score of 70 or above.

For each of the included control participants, the following descriptive information was requested: gender, ethnicity, grade, age, and general intellectual ability (GIA) score. Individual participants' data was requested (versus group means) for the purposes of individually matching the ADHD participants to the control participants and preliminary analyses to determine if the ADHD and control groups were equivalent on demographic variables.

Appendix E

Proposal to: Woodcock-Munoz Foundation
By: Julie Rowland, M.S.
Faculty Advisor: Terry Stinnett, Ph.D.

Proposed study-rationale and research questions:
Schooling is designed to foster and measure the cognitive, affective, social, and physical development of students (Deno, 2002; Merrell, Ervin, & Gimpel, 2006). Unfortunately, some students have difficulty in one or more of these areas and need assistance. The main objective of the school psychologist is to help students who are having trouble academically and/or behaviorally within the school. The main methods of helping fall into two categories: assessment and intervention. Based on the problem-solving model, assessments should provide a direct link to intervention. Therefore, assessments should ensure that a student's difficulties are adequately identified and interventions are appropriate.

Best Practices indicate the most efficient and effective approach to assessment is for the school psychologist to follow a data-driven problem-solving model. Within this model, assessment information is collected to guide decision making throughout the steps in order to identify any discrepancies between the student's current academic and/or behavioral performance and the desired performance (Merrell, Erin, & Gimpel, 2006). The eventual goal of an evaluation is to recognize conditions that will enable the student to learn (Tilly, 2002). To reduce interference and increase confidence in the effectiveness of the intervention, the assessment should be directly linked to interventions. This advancement is unlike the conventional approaches of the past that merely involved testing to categorize students.

The traditional method of diagnosis of disabilities such as Attention-Deficit/Hyperactivity Disorder (ADHD) has chiefly been based on phenomenology, or the presence of disorder-related symptoms. This method often is not precise, nor does it provide explicit information relevant to intervention (Barkley, 1998; Hechtman, 2000; Jensen, Martin, & Cantwell, 1997; Lahey & Willcut, 2002; McCann & Roy-Byrne, 2000; Newcorn et al., 2001). As a result, this disconnect can be detrimental to the success of the student. The determination of whether a student's academic underachievement is due to a disorder and/or idiographic context needs to be adequately evaluated because of the direct implications it has in the formulation of the interventions. For example, the behaviors targeted for change and the specific interventions employed differ as a function of assessment decisions. Thus, failure to make the correct diagnosis may result in the waste of money, time, and energy on inappropriate treatment approaches (Shasky, 2007). Assessment is necessary to ensure that the student's difficulties are identified and that interventions are developed that are appropriate for the problem the student is experiencing.

A majority of students with ADHD have difficulties with school performance. When a student with ADHD enters school, symptoms of inattention and disinhibition may become more troublesome. Their problems are often manifested by difficulties in organizing activities, following directions, reduced comprehension of material, unsuccessful study skills, poor preparation for class, inability to sustain attention to tasks or to complete schoolwork on time, disruptive behavior, peer conflict, and conflict with teachers (Cherkes-Julkowski, Sharp, & Stolzenberg, 1997; Hinshaw, 1992; Trout, Lienemann, Reid, & Epstein, 2007; Zentall, 1993). As a result, one of the most common characteristics exhibited by students with ADHD is underachievement relative to their intellectual abilities (Barkley, 1998). Various studies posit that 80% of children with ADHD exhibit academic performance or learning problems (Cantwell & Baker, 1991), more than 50% require academic tutoring (Barkley, 1998), and between 40% to 50% will receive services in special education programs (Reid, Maag, Vasa, & Wright, 1994). Furthermore, overall achievement test scores of children with ADHD frequently fall below those of their non-ADHD peers in all academic subjects (Barkley, DuPaul, & McMurray, 1990; Brock & Knapp, 1996; Jensen & Cooper, 2002; Semrud-Clikeman et al., 1992). The symptoms of the disorder can interfere with learning and classroom activities for students with ADHD and have been found to be significant predictors of concurrent and future academic difficulties (DuPaul, 2007). As a student progresses in school, the academic materials become more multifaceted and require higher-order cognitive abilities (i.e., executive functions). Some of the higher-order cognitive abilities believed to be disrupted by ADHD are also likely to be involved in academic achievement (e.g., working memory in mental arithmetic or spelling; internalized speech in reading comprehension; verbal fluency in oral narratives and written reports, etc). Little is known about the clinical implications of these multiple cognitive deficits in children with ADHD.

The leading theory of intelligence, Cattell-Horn-Carroll (CHC), provides a theoretical nomenclature to identify and understand the ability constructs measured by intelligence batteries. Woodcock-Johnson III COG tests utilize the CHC theory as the theoretical template. A major advantage of applying the CHC theory to ADHD is that it could provide areas of relative strengths and weaknesses associated with the disorder. Identification of factors that account for significant variance in academic outcomes is important for both assessment and treatment of this disorder. In particular, variables that are found to be the main predictors of academic achievement problems need to be addressed preceding treatment and serve as targets for school-based interventions (DuPaul, Volpe, Jitendra, Lutz, & Gruber, 2004).

The overall aim of this study is to assist school psychologists in using the Woodcock-Johnson III Tests of Cognitive Abilities (WJ III COG) to aid in the assessment of ADHD. In turn, this information will guide school psychologists in choosing the most appropriate interventions to meet the needs of the student. Implications for this research will add to and clarify ADHD diagnosis that is not based on overt behavior; note the relative strengths of the student (versus only the weaknesses); and provide explicit, relevant information to guide interventions.

Research Questions

- Do significant differences exist between the ADHD groups and non-ADHD control group on the WJ III CHC factors (stratum II constructs)?
- If so, could a function to discriminate the two groups be made of the stratum II constructs?

Hypothesis

It is hypothesized that there will be a difference between the ADHD group and Control group on the CHC factors.

Proposed study data analyses:
The ADHD group will comprise of archival data from the university school psychology clinic. To be included in the study, the participants have a primary diagnosis of ADHD (no concomitant learning or emotional disabilities), between the ages of 6 years, 0 months to 12 years, 11 months at the time of assessment, have scores on at least one of the four CHC factors (Gsm, Gv, Glr, Gs) and GIA of 70 or above.

The control group will comprise of normative data from Woodcock-Munoz Foundation. To be included in the study, participants should be without a diagnosis, between the ages of 6 years, 0 months to 12 years, 11 months at the time of assessment; have scores on the CHC factors (Gsm, Gv, Glr, Gs) and a GIA of 70 or above.

This study is interested in the performance on each CHC factor based on group membership. To determine whether there are any differences between the independent groups on the continuous dependent variables a one-way MANOVA will be utilized to compare the independent variable -group status (ADHD and control) with the dependent variable-four of the CHC factors (Gsm, Gv, Glr, Gs). The vector of means for each of the four CHC factors will be compared between the two groups. Main effects and significant interactions will be examined.

If statistical significance is found with the one-way MANOVA, we will proceed to see which of the variables have significantly different means across the groups. A discriminant function analysis will be used to examine this and evaluate the usefulness of the CHC factor clusters creating a function to discriminate the two groups.

Data requested:
Completion of this proposed study would involve collection of data from individual participants in the WJ III norming sample for age groups 6 years, 0 months through 12 years, 11 months with no diagnosis of learning, behavioral, emotional or mental disabilities. To match the archival data, a total of 30 participants will be needed from the norming sample.

For each of the included participants, the following descriptive information is requested: gender, ethnicity, and age. Individual participants' data is requested (versus group means) for the purposes of post hoc procedures to look at the influence of gender, ethnicity and age on factors. Furthermore, GIA, Gsm, Glr, Gv, Gs and the subtests scores that make up each of the factors is requested.

Proposed dissemination plan:

- Preparation of dissertation, to be presented to Oklahoma State community at large and to be published and held in the University library.
- Presentation at state and national conferences, including American Psychological Association conference, National Association of School Psychologists conference, and Oklahoma Psychological Association state conference.
- Submission for publication in a research journal, such as the Journal of Attention Disorder or the School Psychology Review.

Appendix F

The *Woodcock-Muñoz* **Foundation**

Kevin S. McGrew, PhD
Research Director
1313 Pondview Lane E.
St. Joseph, MN 56374

09-20-11

Dr. Terry Stinnett &
Julie Rowland
School of Applied Health & Educ. Psych.
445 Willard Hall
Stillwater, OK 74078

RE: Investigation of the ADHD and non-ADHD subjects on select WJ III cognitive ability measures

Dear Dr. Stinnett & Ms. Rowland

I am pleased to inform you that your request to perform analyses on a portion of the *WJ III NU standardization data files* has been approved by the WMF advisory board. It is important to note that the standard score file you will receive is based on the latest WJ III NU norms and not the original WJ III 2001 norms.

In accepting these data, you agree to, and recognize, the following general conditions:

- The data are the property of the *Woodcock-Muñoz Foundation*. You may not release the data to a third party and you should limit your current activities to those outlined in your approved request.
- At an appropriate time in your analyses, you will provide the foundation a synopsis of your research findings.
- If you should present your results at a conference and/or have a manuscript accepted for publication, we would appreciate a copy of the final paper(s). When and if a manuscript is published, we would appreciate either an offprint or e-copy (pdf file) of the final article.
- If your research results in formal publications, we expect that WMF be acknowledged (either in the body of the text or in a footnote).

All correspondence regarding your study should be sent directly to me ([illegible]; mail address above). If you need technical assistance and/or consultation during any stage of your project, including help with the preparation of presentation materials and/or manuscripts, please don't hesitate to contact me.

Finally, WMF anticipates receiving other requests that may use the same data file(s) to investigate research questions that are similar to yours. We must evaluate all requests on their own merits--independent of other prior, pending, or approved data requests. The granting of access to a WJ-related data file does *not* guarantee that you are the only researcher who may be analyzing a WJ dataset with regard to a particular set of research questions. To facilitate professional communication and potential collaboration among different research teams, we ask your permission to provide your name (and contact information) to other researchers that may be pursuing similar research with a WJ data file. Similarly, we will ask other researchers to do reciprocate. It is not appropriate for WMF to monitor potentially competing research teams. We only ask permission to share names and contact information—we cannot guarantee that all parties will grant this permission. It is the responsibility of potentially competing research teams to initiate these professional courtesy communications. *Do you wish to have your name and contact information shared with regard to the above issue?*

I look forward to working with you on this interesting and important research project.

Sincerely,

Kevin S. McGrew

Kevin S. McGrew, PhD.
Research Director

Voice (320) 260-1309

Appendix G

Oklahoma State University Institutional Review Board

Date:	Friday, February 04, 2011
IRB Application No	ED119
Proposal Title:	Discriminative Ability of Cattell Horn Carrol Factor Scores of the Woodcock-Johnson III Cognitive Abilities and Achievement Tests in Children with Attention Deficit Hyperactivity Disorder
Reviewed and Processed as:	Exempt

Status Recommended by Reviewer(s): Approved Protocol Expires: 2/3/2012

Principal Investigator(s):

Julie E. Rowland
1013 E. Camden Lane
Stillwater, OK 74075

Terry Stinnett
445 Willard
Stillwater, OK 74078

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46.

☐ The final versions of any printed recruitment, consent and assent documents bearing the IRB approval stamp are attached to this letter. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be submitted with the appropriate signatures for IRB approval.
2. Submit a request for continuation if the study extends beyond the approval period of one calendar year. This continuation must receive IRB review and approval before the research can continue.
3. Report any adverse events to the IRB Chair promptly. Adverse events are those which are unanticipated and impact the subjects during the course of this research; and
4. Notify the IRB office in writing when your research project is complete.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact Beth McTernan in 219 Cordell North (phone: 405-744-5700, beth.mcternan@okstate.edu).

Sincerely,

Shelia M. Kennison

Shelia Kennison, Chair
Institutional Review Board

VITA

Julie Elizabeth Rowland

Candidate for the Degree of

Doctor of Philosophy

Dissertation: DISCRIMINATIVE ABILITY OF CHC FACTOR SCORES FROM THE WJ III TESTS OF COGNITIVE ABILITIES IN CHILDREN WITH ADHD

Major Field: EDUCATIONAL PSYCHOLOGY, SPECIALIZATION IN SCHOOL PSYCHOLOGY

Biographical:

Education:

Completed the requirements for the Doctor of Philosophy in Educational Psychology, Specialization in School Psychology at Oklahoma State University, Stillwater, Oklahoma by July, 2013.

Completed the requirements for the Master of Science in Clinical and Counseling Psychology at Augusta State University, Augusta, Georgia in 2004.

Completed the requirements for the Bachelor of Science in Research Psychology at University of Georgia, Athens, Georgia in 2002.

Experience:

Tulsa Public School District. Tulsa, Oklahoma. Pre-Doctoral Psychology Intern.

Shawnee Public School District. Shawnee, Oklahoma. Consultant.

Transitions of Augusta, P.C. Augusta, Georgia. Psychometrist and Group Therapist.

Professional Memberships:

American Psychological Association – Student Affiliate

National Association of School Psychologists – Student Member