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Integrity of Neuropsychological Processes in Children with Attention-deficit/hyperactivity Disorder and Comorbid Conditions

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INTEGRITY OF NEUROPSYCHOLOGICAL PROCESSES IN CHILDREN WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER AND COMORBID CONDITIONS

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Dissertation Approval

This is to certify that the thesis presented to us by Julie Henzel on the 1 day of June, 2010, in partial fulfillment of the requirements for the degree of Doctor of Psychology, has been examined and is acceptable in both scholarship and literary quality.

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Abstract

This study investigated the neuropsychological and behavioral profiles seen in children diagnosed with ADHD inattentive type (IA), inattentive type plus an internalizing disorder (IA + INT), combined type (CT), and combined type plus an externalizing disorder (CT + EXT). Subjects were 63 unmedicated children aged 6 to 16 who had been assessed with the Wechsler Intelligence Scale for Children–Fourth Edition (WISC–IV), Conners' Continuous Performance Test-Second Edition (CPT–II), and the Child Behavior Checklist (CBCL). Group differences were found for the WISC–IV Digits Backward subtest (IA + INT <IA), various CPT–II consistency measures (CT + EXT>IA and IA + INT), and externalizing behavior scales on the CBCL and TRF (IA + INT>IA, CT + EXT > CT). Forced-entry discriminant analyses were used to investigate whether the neuropsychological and behavioral measures could accurately predict group membership and to more generally evaluate the utility of a combined neuropsychological/behavioral approach in ADHD assessment. Combined methods resulted in correct classification rates of 88.9% and even 100% when the Teacher Report Form (TRF) was included, as compared to 68.3% to 71.4% for separate approaches. Results support meaningful distinctions among ADHD IA, IA + INT, CT, and CT + EXT groups, and the utility of the WISC–IV, CPT–II, CBCL, and TRF in differentiating these groups. Results further illustrate the

heterogeneous nature of ADHD and the value of using a combined neuropsychological/behavioral approach in ADHD assessment.

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Chapter 1

Introduction

Attention-deficit hyperactivity disorder (ADHD) is a common referral concern encountered by psychologists in both clinical and school practice. It is estimated that 8.7% of U.S. children ages 8 to 15, or 2.4 million children meet diagnostic criteria for ADHD (Froehlich et al. 2007), with similar prevalence rates found across other developed countries (Faraone, Sergeant, Gillberg, & Biederman, 2003). ADHD is primarily a genetic disorder, with twin studies suggesting a heritability rate of 76% (Faraone et al. 2005). Risk factors include maternal smoking during pregnancy (Mich, Biederman, Faraone, Sayer, & Kleinman, 2002), low birth weight (Nigg & Breslau, 2007), and pregnancy/delivery complications (Sprich-Buckminster, Biederman, & Milberger, 1993).

Characterized by a significant impairment in inattention and/or hyperactivity-impulsivity that is present in at least two settings such as home and school, ADHD can have negative implications for various aspects of a child's life (Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision; *DSM–IV–TR*; American Psychiatric Association; APA, 2000). Individuals with ADHD demonstrate self-regulatory difficulties in everyday life that include *activation* (organizing tasks, estimating time, starting tasks, and prioritizing), *focusing* (sustaining focus and shifting focus among tasks), *effort* (sustaining effort, processing speed, and regulating alertness), *emotion* (handling frustration and regulating emotions), *memory* (accessing previously learned information and working memory), and *action* (monitoring/regulating actions) (Brown, 2009). Furthermore, these difficulties often extend to cognitive functioning, academic achievement, (DuPaul, McGoey, Eckert, & VanBrakle, 2001), peer relationships (Hoza, 2007), self-esteem, and psychological well-being (Edbom, Granlund, Lichtenstein, & Larsson, 2008).

For the majority of children diagnosed with ADHD, this condition will persist into adulthood and may continue to have negative consequences on their lives if not managed appropriately (Barkley, 2005; Barkley, Murphy, & Fischer, 2008; Spencer, Biederman, & Mick, 2007). Long-term outcome studies suggest that individuals with ADHD are more likely to drop out of high school (32% to 40%), fail to complete college (5% to 10%), engage in antisocial activities (40% to 50%), and to underperform at work (70% to 80%) (Barkley et al., 2002). This population is also more prone to engage in unhealthy or unsafe activities, such as excessive speeding while driving and tobacco/illicit drug use (Barkley et al., 2002). Approximately 18% to 25% will go on to receive a personality disorder diagnosis as adults (Barkley et al., 2002).

Three main subtypes of ADHD are currently recognized in the *DSM–IV–TR* (APA, 2000). These include predominantly inattentive type (ADHD-IA), predominantly hyperactive-impulsive Type (ADHD-HI), and combined type

(ADHD-CT). The *DSM–IV–TR* also allows for the diagnosis of ADHD Not Otherwise Specified (ADHD NOS) when an individual's symptoms do not completely meet criteria. Twenty percent to 30% of children with ADHD have predominately inattentive subtype (Spencer et al., 2007), which is characterized by behavioral symptoms such as failing to give close attention to details or making careless errors in work, difficulty sustaining attention in tasks or activities, and becoming easily distracted by extraneous stimuli (APA, 2000). Fewer than 15% of children with ADHD are within the predominantly hyperactive-impulsive category (Spencer, 2007), which is represented by behavioral symptoms such as difficulty awaiting one's turn, sitting still, and staying seated at appropriate times. The majority of children are in the ADHD-CT category (50% to 75%; Spencer et al., 2007), which is associated with symptoms from both the inattentive and hyperactive-impulsive categories (see APA, 2000). A child must demonstrate at least six of nine behavioral symptoms from the inattentive and/or hyperactive-impulsive categories in two or more settings in order to qualify for an ADHD diagnosis (APA, 2002). Additionally, some symptoms must have been present prior to the age of 7.

In 77% of cases, ADHD is comorbid with at least one other condition (Biederman, Faraone, & Lapey, 1992), thus making comorbidity the rule rather than the exception (Ollendick, Jarrett, Grills-Taquechel, Hovey, & Wolff, 2008). Rates range from 3% to 51% for concurrent internalizing disorders and 43% to

93% for externalizing disorders (Ollendick et al., 2008). Common comorbid psychiatric conditions seen in ADHD include other disruptive behavior disorders (25% to 40%), anxiety disorders (30%), mood disorders (10% to 30%), and tic disorders (6%) (National Resource Center on ADHD, 2003). Learning disabilities also co-occur in children with ADHD at a rate of 31% (DuPaul & Stoner, 2003), with reading (8% to 39%), math (12% to 30%), and spelling (12% to 27%) problems frequently reported (Barkley, 2005). Internalizing disorders, such as depression or anxiety, occur at similar rates across ADHD subtypes, while externalizing disorders tend to be more common in ADHD-HI or ADHD-CT (Elia, Ambrosini, & Berrettini, 2008; Jensen, Martin, & Cantwell, 1997; Power, Costigan, Eiraldi, & Leff, 2004). Girls with ADHD tend to manifest comorbid internalizing disorders, whereas boys are more prone to externalizing disorders, such as oppositional defiant disorder (ODD) and conduct disorder (CD) (Gershon & Gershon, 2002). Comorbid learning disabilities tend to be more common in children with ADHD-IA (Marshall, Hynd, Handwerk, & Hall, 1997). A high degree of similarity between the behavioral expressions of conditions such as anxiety or ODD with ADHD further complicates the diagnostic picture when assessing a child for suspected ADHD.

Assessment of ADHD.

Traditional assessment of ADHD is largely behaviorally-based and relies heavily on teacher and parental reports of behavior (see Barkley, 1997a). ADHD assessments typically include a parent interview, teacher interview, observations of behavior, and standardized child behavior checklists. Demographic information, information on presenting concerns, and developmental, medical, school, and family histories are gathered during the course of the parent interview. The clinician also typically inquires about the presence of symptoms of other major childhood developmental and psychiatric conditions. This can be accomplished through semistructured or unstructured formats, but comparisons should be made to DSM behavioral criteria for ADHD (American Academy of Pediatrics; AAP, 2000; Barkley, 1997a). Standardized child behavior checklists designed to assess ADHD provide a means of quantifying the degree to which a child's behavior deviates from typical same-aged peers and can provide a means of gathering information from observers of the child's behavior who can not be directly interviewed. In addition to narrow-band rating scales that are primarily designed to measure ADHD, clinicians also frequently use broad-band rating scales to assess for the presence of comorbid conditions (AAP, 2000).

Limitations of behaviorally based ADHD assessment.

Important limitations exist in a behavioral approach to ADHD assessment that complicate the differential diagnosis process. The techniques of gathering information from multiple informants in the form of interviews or psychosocial rating scales are considered best practice for ADHD assessment (e.g. American Academy of Pediatrics; AAP, 2000; Barkley, 1997). However, discordance among informants of a child's behavior is common (Angtrop, Roeyers, Oosterlaan, & Van Oost, 2002; Bird, Gould, & Staghezza, 1992; Grills & Ollendick, 2002), with correlations only reaching .27 between parents and teachers, .25 between parent and child self-report, and .20 between teacher and child self-report (Achenbach, McConaughy, & Howell, 1987). Additionally, psychosocial rating scales have shown limited utility for discriminating among disorders with similar symptom patterns (Hale, How, DeWitt, & Coury, 2001; Mahone et al., 2002; Sullivan & Riccio, 2007). Factors such as altered environmental demands and differences in behavioral expectations/tolerances of a child's behavior may account for discordance between parents and teachers (Burns, Walsh, & Gomez, 2003; Konold, Walthall, & Pianta, 2004). Discrepancies between child and adult ratings often arise when an internalizing disorder is present. While adults are generally regarded as more valid reporters for externalizing disorders with overt symptoms such as ADHD and oppositional defiant disorder (ODD) (Bird et al., 1992), a child's ratings may be more relevant for internalizing disorders that hinge on subjective distress such as generalized anxiety disorder (GAD) or depression (Masi, Mucci, Favilla, Romano, & Poli, 1999).

Because there is much overlap between the symptoms of ADHD and other psychiatric conditions, accurately diagnosing ADHD requires an understanding of the behavioral patterns of numerous disorders (Reddy & Hale, 2007). Inattention, a hallmark behavioral symptom of ADHD (see APA, 2002), can be attributed to at least 38 different conditions (Goodman & Poillion, 1992). Disorders where a disruption of attention is commonly seen include learning disabilities, pervasive developmental disorders, auditory processing disorders, anxiety disorders, and mood disorders (Reddy & Hale, 2007).

In a behavioral approach, there is a tendency to view the symptom of inattention as a unitary concept (i.e. whether or not the child has difficulty sustaining attention). However, neuropsychology suggests that inattention is indeed multifaceted (Baron, 2004; Miller, 2007; Miller & Hale, 2007, Mirsky, Bruno, Duncan, Ahearn, & Kellam, 1991). Forms of attention important to consider include *shifting* (reallocating attention from one thing to another; Mirsky et al., 1991), *divided* (multitasking or attending to multiple things at once; Baron, 2004), *selective/focused* (maintaining focus in the presence of background distractions; Baron, 2004), *sustained* (staying on task over longer periods of time; Mirsky et al., 1991), and *attentional capacity* (the use of attention for memory purposes; Miller, 2007). An additional model of attention includes *orienting* (attending to location of sensory information), *detecting* (reporting the presence of a target for conscious processing), and *alerting* (preparing for the processing of a priority event) (Posner & Petersen, 1990).

Practitioners should also consider whether a child's distraction or inattention is internal (i.e., caused by his or her thoughts, worries, or ruminations) or external (i.e., caused by stimuli in the external environment) (Miller, 2007; Reddy & Hale, 2007). For example, a child with an anxiety disorder may become distracted due to replaying a recent fight with a friend or worrying about an upcoming test. In contrast, a child with ADHD might be distracted by materials in his desk or noise outside the classroom.

The clinical criteria as outlined in the *DSM–IV–TR* have also been a source of debate in terms of gender equity and threshold level. ADHD is diagnosed in boys 3 times more often than in girls (Barkley, 2005; Elia, Ambrosini, & Berretini, 2008), and boys are 5 to 9 times more likely to present to clinics with ADHD symptoms than girls (Barkley, 2005). However, the *DSM–IV–TR* does not currently account for differences in male/female symptom expression patterns, which may partially explain why males are disproportionally diagnosed with this condition. It has been shown that parents and teachers typically report lower levels of ADHD symptoms in females than males (DuPaul, 1991; Gershon & Gershon, 2002), and as Barkley (2005) points out, the *DSM–IV* ADHD threshold level was set through studies that primarily investigated this condition in boys (also see Lahey et al., 1994). Barkley (2005) suggests that the ADHD clinical criteria may be unfairly high to females, for females must essentially demonstrate a higher degree of impairment in order to qualify for a diagnosis.

It has also been questioned whether the current threshold level is appropriate for identifying children who truly require treatment for ADHD symptomatology as well as specifying subtype (Barkley, 2005; Hale & Fiorello, 2004). Children who fall below the 6-symptom criteria (APA, 2000) are less likely to receive treatment, yet they may still show significant impairment (Elk, Fernell, Westerlund, Holmberg, Olsson, & Gillberg, 2007; Scahill et al., 1999). Additionally, ADHD subtypes, as currently defined by symptom counts are not always clear and may not be stable constructs throughout a child's life. In the case of children initially diagnosed with ADHD-HI, many may later meet criteria for inattentive or combined types, given that hyperactive symptoms have been shown to decrease as a child ages (Barkley, 2005; Lahey, Pelham, Loney, Lee, & Willcutt, 2005). Rather than actually shifting subtypes, it has been proposed that children initially diagnosed with ADHD-HI may have an earlier developmental stage of ADHD-CT or have a milder version of CT (Barkley, 2005). Though children initially diagnosed as ADHD-HI may also meet criteria for IA later in life, they tend to retain their inhibitory deficits, which are not present in children with true ADHD-IA (Barkley, 2005).

Research has suggested that two additional distinct subtypes of ADHD may also exist, which are not currently recognized by the *DSM–IV–TR*. These include ADHD plus externalizing disorders such as oppositional defiant disorder (ODD) or conduct disorder (CD), as well as ADHD plus internalizing disorders, such as anxiety and depression (Angold, Costello, & Erkanli, 1999; Barkley, 2005; Jensen et al., 2001; Stefanatos & Baron, 2007). ADHD plus internalizing disorders as an additional subtype is often discussed in the context of children who manifest characteristics of *sluggish cognitive tempo* (SCT) (Barkley, 2005).

Comorbid ODD or CD is most frequently seen in children with ADHD-CT or ADHD-HI (Acosta, et al., 2008; Elia et al., 2008). ADHD plus ODD or CD may represent a more severe form of ADHD (Barkley, 2005), which is characterized by increased impulsivity (Lynam, 1998), physical aggression (Waschbusch, 2002), and more severe social functioning difficulties. In fact, ADHD comorbid with conduct problems is officially recognized as a separate condition by the *International Classification of Diseases and Related Health Problems,* 10th revision (ICD–10; World Health Organization, 2007) referred to as *hyperkinetic conduct disorder* (Banaschewski et al., 2003).

An estimated 30% to 50% of children with ADHD-IA may manifest characteristics such as hypoactivity, daydreaminess, lethargy, sluggish motor function, easy confusion, and slow processing speed, which have been deemed sluggish cognitive tempo (SCT) (Barkley, 2005; Barkley et al., 2001; McBurnett, Pfiffner, & Frick, 2002). These characteristics often co-occur with internalizing disorders such as anxiety or depression (Barkley, 2005; Carlson & Mann, 2002; Schatz & Rostain, 2006).

As one can see, children with ADHD are a diverse population (e.g. Barkley, 2005; Hale et al., 2009a). Hence, an understanding of a child's unique needs is essential to treatment efficacy. One implication is in terms of pharmacotherapy. Though stimulant treatment has been shown to be a highly efficacious treatment for ADHD (Barkley, 2005; Zametkin & Ernst, 1999), approximately 10% to 20% of children with ADHD do not respond to stimulants (Greenhill, Halperin, & Abikoff, 1999). Children with comorbid anxiety, for example, may not be the best candidates for stimulant treatment, for stimulants often increase anxiety symptoms (Greenhill, Pliszka, & Dulcan, 2004). These children may respond better to selective serotonin reuptake inhibitors or SSRIs (Zametkin & Ernst, 1999), and may also benefit from cognitive behavioral therapy (Jensen et al., 2001; Kendall, 1994). Furthermore, differential effects of stimulant therapy have also been found based on ADHD subtype, with children with ADHD-CT demonstrating a more robust response than those with ADHD-IA (Hale et al., in press). Hale et al. (in press) found that within the inattentive group, those that had comorbid anxiety or depression were less likely to benefit from stimulant treatment than those with subthreshold hyperactive-impulsive symptoms.

A new approach to ADHD assessment.

Limitations of traditional behavioral assessment have fostered an interest in expanding the behavioral diagnosis of ADHD to include neuropsychological factors. ADHD is now widely accepted to be a disorder of neuropsychiatric origin (Konrad, Gunther, Hanisch, & Herpertz-Dahlmann, 2004), largely due to advances in neuroimaging. Neuroimaging studies have primarily implicated abnormalities of the prefrontal cortex (Castellanos et al., 2002), which play a significant role in many of the symptomatic difficulties seen in children with ADHD (Nigg, 2006). Key regions include the dorsolateral prefrontal cortex (associated with working memory), orbital prefrontal cortex (inhibiting inappropriate actions), and anterior cingulate cortex (emotional and cognitive control). Due to these meaningful neurological findings, current research has extended the use of neuropsychological instruments to the assessment of ADHD (Barkley, 2005; Baron, 2004; Hale & Fiorello, 2004).

Neuropsychological testing has not yet been widely accepted as a routine part of ADHD evaluations (Barkley, 2005), and studies seeking to use these instruments to differentiate children with ADHD from controls have not found them to be diagnostic in their own right (Frazier, Demaree, & Youngstrom, 2004; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005). In a meta-analysis of studies examining neuropsychological performance of children with ADHD, ADHD was best characterized by executive deficits in response inhibition, working memory, vigilance, and planning, with effect sizes in the medium range (Willcutt et al., 2005). However, a combined neuropsychological/behavioral approach may be of increased utility. Hale et al. (2009a) recently tested the utility of a psychosocial rating scale in combination with select neuropsychological measures of executive functioning and found that this battery correctly distinguished ADHD children from typical children at a rate of 87%.

The following chapter has four objectives: to (a) further discuss the presentation of ADHD with common comorbid conditions, (b) discuss the neuropsychology of ADHD and comorbid conditions, (c) discuss the impact of ADHD on neuropsychological processes, and (d) develop research questions.

Chapter 2

Literature Review

ADHD and common comorbid conditions.

Oppositional defiant disorder/conduct disorder. Comorbid ODD or CD is found in 40% to 90% of children with ADHD (Pfiffner et al., 1999) and as previously stated, has also been proposed as a distinct subtype of ADHD (Barkley, 2005). ODD, which is often a precursor to CD, is characterized by patterns of defiant, negativistic, disobedient, and hostile behavior toward authority figures (APA, 2000). CD is distinguished from ODD by more serious violations of rules or the rights of others, such as physical aggression toward people or animals and theft. Children with comorbid ADHD and ODD/CD have increased difficulty with hyperactivity, impulsivity, and social skills (Turgay, 2005), as well as higher rates of teacher conflict and school refusal than those with ADHD or ODD alone (Harada, Yamazaki, & Saitoh, 2002). Children diagnosed with comorbid ODD or CD also report increased levels of anger compared to those only with ADHD, with those with ODD manifesting more verbal aggression and those with CD displaying more physical aggression (Hart, Miller, Newcorn, & Halperin, 2009).

Differential diagnosis is challenged by an overlap in the symptoms of ODD/CD and ADHD. Children with ADHD often exhibit impulsive, noncompliant, and aggressive behavior, which can result in significant peer and familial conflicts (Harada et al., 2002; Johnston & Marsh, 2001). Hence, it is easy to envision how ADHD symptoms such as failing to follow through on assignments and avoiding tasks that require sustained mental effort, failing to remain seated, blurting out answers, and Intruding on others could be interpreted by parents and teachers as oppositional or defiant. Additionally, viewing a child's inattentive or hyperactive-impulsive behaviors as willful could result in power struggles that induce argumentativeness in a child (see Barkley, 1997b).

Anxiety and mood disorders. Comorbid anxiety disorders occur at a rate of 30% in children with ADHD (National Resource Center on ADHD, 2003). GAD, which is characterized by a pattern of pervasive and excessive worry about a number of different aspects of life (APA, 2000), is the most commonly seen anxiety disorder in children with ADHD (Manassis, Tannock, Young, & Francis-John, 2007). Studies have found that the addition of anxiety to ADHD is generally related to a worsening of outcomes. Those with this comorbidity have shown increased need for psychiatric treatment (Biederman et al., 1996), increased school fears, panic, and mood disorders (Bowen, Chavira, Bailey, Stein, & Stein, 2008), decreased social competence (Biederman et al., 1996; Bowen et al., 2008) and decreased academic performance (Manassis et al., 2007). Older studies suggested that children with ADHD-IA were more likely to manifest internalizing disorders, such as anxiety or unipolar mood disorders, compared to the other ADHD subtypes (Biederman, Newcorn, & Sprich, 1991). However, more recent studies suggest similar rates across ADHD subtypes (Acosta et al., 2008; Elia et al., 2008; Power et al., 2004).

A 10% to 30% comorbidity rate for mood disorders (depression) has been found in children with ADHD (National Resource Center on ADHD, 2003). Dysthymic disorder, a mild to moderate chronic depression (APA, 2000), co-occurs in ADHD children at the greatest frequency (Elia et al., 2008). Associated features of childhood depression can include school difficulties, school refusal, somatic complaints, aggression, negativism, withdrawal, and antisocial behavior (Spencer et al., 2007). Recent studies suggest similar rates of unipolar depression across ADHD subtypes (Acosta et al., 2008; Elia et al., 2008), while bipolar disorder has been associated more closely with ADHD-CT (Wilens, Biederman, & Wozniak, 2003) or ADHD-HI (Papalos & Papalos, 2006). Additionally, in those with ADHD-CT, males are more likely than females to develop major depressive disorder (Bauermeister et al., 2007).

Differentially diagnosing ADHD from internalizing disorders is challenged by similarities in behavioral symptoms. For example, a child who has concentration difficulties due to an increased focus on anxious or depressive thoughts, as opposed to stimuli in the external environment, may simply appear inattentive to outside observers (Jarret & Olendick, 2008; Reddy & Hale, 2007). Additionally, hyperactivity-impulsivity may be assumed when a child is actually manifesting restless due to anxiety (psychomotor agitation) (Jarrett & Ollendick, 2008; Nigg, Goldsmith & Sachek, 2004; Zametkin, & Ernst, 1999). Symptoms of childhood mania overlap greatly with those of hyperactivity-impulsivity, leading some researchers to posit that ADHD with hyperactivity may actually be an early developmental stage of bipolar disorder (see Papalos & Papalos, 2006). As previously discussed, an additional argument is that ADHD plus comorbid internalizing disorders may represent a distinct ADHD subtype (Barkley, 2005). Hale et al. (2010) posit that some children with ADHD-IA with comorbid anxiety or depression may actually have a type of "pseudo" ADHD characterized by different patterns of neuropsychological impairment than those with "true" ADHD.

Neuropsychology of ADHD.

The behavioral and cognitive dysfunction seen in individuals with ADHD arises from the interaction of multiple brain systems (Koziol & Budding, 2009), which is supported by findings from volumetric, activation likelihood estimation (ALE) and functional magnetic resonance imaging (fMRI) studies. ADHD is associated with an overall reduction in total brain volume that approximates 5% (Castellanos et al., 2002), with significant reductions having been found in the frontal lobes, basal ganglia (Castellanos et al., 1996), and the cerebellum (Valera, Faraone, Murray, & Seidman, 2007). Significant grey matter reductions have been found in the right superior frontal gyrus, right posterior gyrus, and the basal ganglia bilaterally, as well as white matter reductions concentrated in the left hemisphere anterior to the pyramidal tracts and superior to the basal ganglia (Overmeyer et al., 2001). Accordingly, children with ADHD demonstrate hypoactivity in the anterior cingulate, dorsolateral prefrontal, inferior prefrontal and orbitofrontal cortices, as well as in the basal ganglia and parietal cortices on tasks designed to isolate frontal regions (Dickstein, Bannon, Castellanos, & Milham, 2006). A reverse pattern of activation has been seen on tasks of response inhibition and interference tasks, where children with ADHD demonstrate a reliance on more posterior regions of the brain as compared to typical children, who activate more frontal regions, suggesting inefficient processing (Vaidya, Bunge, Dudukovic, Zalecki, Elliot, & Gabriel, 2005).

Prefrontal subcortical circuits, which facilitate anterior-posterior axis communication and involvement of subcortical structures, are believed to play a significant role in ADHD (Hale & Fiorello, 2004; Koziol & Budding, 2009; Nigg, 2006). These include the motor, oculomotor, dorsolateral, orbitofrontal, and the anterior cingulate circuits, which originate from various areas of the prefrontal cortex and then project to the striatum, globus pallidus, substantia nigra, and thalamus before looping back to the frontal cortex (Tekin & Cummings, 2002). These circuits work in concert with the neurotransmitters of dopamine, glutamate, and GABA, which serve modulatory, excitatory, and inhibitory functions, respectively (Nigg, 2006).

Integrity of the frontal subcortical circuits is important for everyday behavioral functioning, with dysfunction resulting in a variety of cognitive and/or behavioral disturbances (Hale & Fiorello, 2004; Koziol & Budding, 2009; Nigg, 2006; Tekin & Cummings, 2002). The dorsolateral, orbitofrontal, and anterior cingulate circuits in particular are important for self-regulatory functions (Nigg, 2006). Hale, Bertin, and Brown (2004) argue that children with ADHD likely experience dysfunction in one or more circuits, especially the dorsolateral circuit in ADHD-IA and the orbitofrontal circuit in ADHD-HI (as cited in Hale & Fiorello, 2004).

The motor circuit is important for procedural learning or learning of new motor routines, and the oculomotor circuit important in sustained visual attention and searching strategies (Koziol & Budding, 2009). The integrity of the motor circuit may be gauged through motor procedural learning tasks. Information regarding the integrity of the oculomotor circuit may be gained through pencil and paper copying or cancellation tasks (Koziol & Budding, 2009).

The dorsolateral circuit is believed to be important may in working memory, deliberate control of action (Nigg, 2006), and attention in the areas of selection and maintenance (Koziol & Budding). Dysfunction involving this circuit may also manifest as problems with executive functions such as organizing, planning, monitoring, and changing behavior (Hale & Fiorello, 2004). Additionally, individuals may present as perseverative, easily distracted in the absence of external prompting and structure, and inflexible in their reasoning styles (Tekin & Cummings, 2002). They may either appear apathetic due to difficulties in initiation or perseverative due to difficulties in shifting their thinking or focus. Most neuropsychological tests assess functions of the dorsolateral circuit (Ardila, 2008; Koziol & Budding, 2009). Dysfunction of this circuit may manifest in poor performance on working memory, planning, organizational (Lichter & Cummings, 2001), or attentional tasks (Koziol & Budding, 2009).

The orbitofrontal circuit is believed to be responsible for behavioral inhibition and impulse control (Hale & Fiorello, 2004; Koziol & Budding, 2009; Nigg, 2006). It assists in inhibiting responses to external distractions or competing distractions (Koziol & Budding, 2009). Orbitofrontal dysfunction is characterized by difficulties with affect regulation, judgment, and social behavior (Koziol & Budding, 2009). Dysfunction may also manifest as euphoria or mania (Cummings & Miller, 2007), emotional lability, explosive anger, and inappropriate response to social cues (Tekin & Cummings, 2002). Dysfunction of this circuit is not directly assessed by neuropsychological tests (see Koziol & Budding, 2009). Inferences about the integrity of this circuit are best made through observation or report of behavior.

The anterior cingulate circuit modulates persistence, motivation, and attentional control (Hale & Fiorello, 2004; Koziol & Budding, 2009; Nigg, 2006) and may also result in lack of creativity, apathy, or abulia (Tekin & Cummings, 2002). Dysfunction of this circuit is also not well assessed by current neuropsychological tests (see Koziol & Budding, 2009). Koziol & Budding (2009) explain that individuals with anterior cingulate dysfunction who have relatively intact cognitive profiles can elude detection on traditional neuropsychological tests. As a result, any signs of dorsolateral dysfunction may be overly attributed to psychological or emotional factors. Observations of behavior and self-report data may be valuable sources of information for assessing integrity of the anterior cingulate circuit.

The basal ganglia, cerebellum, and corpus callosum have also been implicated in the expression of ADHD (Nigg, 2006). Abnormalities of the basal ganglia are believed to influence motivation, emotion, motor control (Nigg, 2006), intention of motor actions (Koziol & Budding, 2009), and executive and cognitive functions (Nigg, 2006). Together with dopamine, dysfunction in this area may also be responsible for the hyporesponsiveness of ADHD children to rewards (Koziol & Budding, 2009). The cerebellum is likely involved in disturbances of motor timing or temporal processing, as well as behavioral regulation (Koziol & Budding, 2009). The corpus callosum assists in coordination of hemispheric communication, which is necessary for the selection of appropriate cognitive actions (Banich, 1998).

Neuropsychology of common ADHD comorbidities.

Neuroimaging research on ADHD comorbid with anxiety/mood disorders or ODD/CD appears to be limited at this time. However, studies exist that have examined these conditions separately. Similar to studies on ADHD, the following findings on anxiety, mood, and ODD/CD identify significant neurological differences between individuals with and without these disorders thus providing evidence for also considering anxiety, depression, and ODD/CD as neuropsychological conditions.

Abnormalities in prefrontal and limbic regions have been identified in both anxiety and mood disorders. Anxiety disorders have been linked to hyperarousal of the prefrontal cortex (PFC) (Berkowitz, Coplan, Reddy, & Gorman, 2007; Krain et al., 2008; Monk et al., 2006), with an overactive fronto limbic circuit responsible for social fear (Veit et al., 2002). GAD in particular is characterized by overactivity of the PFC regions (Berkowitz et al. 2007). Abnormal functioning has also been identified in the amygdala (McClure et al., 2007), orbitofrontal cortex (Rolls, 2004), and anterior cingulate cortex (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001). Specific abnormalities in individuals with mood disorders include functioning of the PFC, basal ganglia, cerebellum, and hippocampus/amygdala areas (Beyer & Krishnan, 2002; Caetano et al., 2005; Koziol & Budding, 2009; Steingard et al., 2002). Though amygdala dysfunction is found in both anxiety and mood disorders, the nature of this dysfunction is characterized by overactivity in anxiety and by blunted activity in depression (Thomas et al., 2001;Veit et al., 2002).

The neurological correlates seen in anxiety and mood disorders may result in a disruption of attention, especially as it relates to processing emotional stimuli. Selective attention biases toward threatening stimuli have been observed in individuals with anxiety and mood disorders (Joormann, Talbot, & Gotlib, 2007; Ladouceur, Dahl, Williamson, Birmaher, & Casey, 2006; Richards, French, Nash, Hadwin, & Donnelly, 2007; Taghavi, Dalgleish, Moradi, Neshat-Doost, & Yule, 2003). A decreased sensitivity toward reward (Forbes et al., 2006) and a memory bias for negative information (Lim & Kim, 2005) have also be found in those with mood disorders.

Abnormalities in frontal and limbic regions have also been observed in subjects with ODD/CD or comorbid ADHD/ODD/CD. Children with CD have shown abnormal activation patterns in the frontal and parietal regions when performing attention/inhibitory tasks (Banaschewski et al., 2003, 2004). However, this activation did not differ from subjects with ADHD or those with comorbid ADHD/CD. In contrast, research that has compared boys with pure ADHD to those with pure CD/ODD on attention/inhibitory control tasks has found dissociable differences. Boys with CD have shown reduced activity in bilateral temporal-parietal areas, as well as the posterior cingulate gyrus during inhibition failures (Rubia et al., 2008). Subjects with ADHD only showed deactivation in the posterior cingulate gyrus (Rubia et al., 2008). Additionally, when attention/inhibitory tasks were rewarded, subjects deactivation was seen in the paralimbic regions of the insula, hippocampus, anterior cingulate, and cerebellum in subjects with CD (Rubia et al., 2009). In contrast, boys with ADHD showed reduced activity in the prefrontal regions, regardless of whether the task was rewarded (Rubia et al., 2008; Rubia et al., 2009). Rubia and colleagues (2009) concluded that problems of sustained attention may be attributed to dysfunction of the orbitofrontal-paralimbic motivation network in individuals with CD, whereas those with ADHD have disruption of the ventrolateral frontocerebellar network.

Aggressive behavior, whether alone or comorbid with ADHD, appears to result in reduced sensitivity to threatening/negative stimuli. Decreased activation in the anterior cingulate circuit and amygdala is seen in boys with CD when viewing negative emotional material (Sterzer, Stadler, Krebs, Kleinschmidt, & Poustka, 2005). This pattern is also seen in those with comorbid ADHD. Antisocial behavior in general may be attributed to hypoactivity of the frontolimbic circuit, which encompasses the orbitofrontal cortex, insula, anterior cingulate, and amygdala (Veit et al., 2002).

ADHD and neuropsychological processes.

Auditory-verbal. Auditory-verbal skills are associated with more posterior brain functions and primarily left hemisphere involvement for tasks of crystallized knowledge, such as vocabulary (Hale & Fiorello, 2004). However, frontal involvement is still necessary, given that all cognitive functions are governed by executive processes (Hale & Fiorello, 2004; Hale et al., 2009b; Luria, 1973). Brain lesion studies have correlated poor performance on tests of verbal intelligence to lesions in the left hemisphere, with the left inferior frontal cortex particularly affected (Gläscher et al., 2009).

Children with ADHD manifest a higher incidence of receptive, expressive, and language processing disorders than children without ADHD (Tannock & Brown, 2009). They have been found to score lower in every verbal ability area as measured on the Wechsler Intelligence Scale for Children–Third Edition (WISC–III) than typical children (Andreou, Agapitou, & Karapetsas, 2005). Additionally, two subtests of verbal crystallized knowledge (Information and Vocabulary), along with Digit Span and Picture Completion, were found to reliably discriminate ADHD children from typical children (Assessmany, Mcintosh, Phelps, & Rizza, 2001). Other studies have found deficits in verbal fluency and inferential listening comprehension (McInnes, Bedard, Hogg-Johnson, & Tannock, 2007). Children with ADHD tend to struggle with language tasks that involve executive functions, such as organizing and monitoring verbal responses (Purvis & Tannock, 1997). Methylphenidate treatment may facilitate improvements in higher-order listening comprehension skills in ADHD children through increased attendance to the salient details in spoken discourse (McInnes et al., 2007).

The interaction between language difficulties and ADHD is complex and may be bidirectional. Children who struggle with language may develop ADHD symptoms as a result of their learning frustrations (Andreou et al., 2005). Alternatively, ADHD children may manifest language disorders because they do not attend optimally to language development opportunities. In the case of central auditory processing disorder, some scholars have posited that this condition and ADHD may be different forms of a unitary disorder (Riccio, Hynd, Cohen, Hall, & Molt, 1994). In contrast, Hale, Fiorello, and Brown (2005) argue that children who demonstrate attention problems as the result of auditory processing problems do not manifest true or primary ADHD. ADHD subtype may also be related to the development of language problems, for language difficulties in preschoolers have correlated significantly with impulsivity, whereas this relationship was not found for inattention (Geurts & Embrechts, 2008).

Visuospatial. Visuospatial processes are associated with right hemisphere and posterior brain functions (Hale & Fiorello, 2004). These processes are generally not as impaired as executive processes, such as working memory (Mayes & Calhoun, 2006). Children with ADHD typically perform within the average range on tests of visuospatial reasoning such as block design and matrices tasks (Pendley, Myers, Brown, & Reagan, 2004), and compared to other cognitive processes, visuospatial skills are generally viewed as areas of strength for ADHD children (Mayes & Calhoun, 2006). However, given that frontallymediated executive functions govern all aspects of cognition (Luria, 1973), it is certainly feasible that executive deficits could affect visuospatial performance (Hale et al., 2009b). Silk and colleagues (2008) found that a progressive matrices task placed heavy demands on the prefrontal cortex, due in part to the need for visuospatial attention and mental manipulation (Silk, Vance, Rinehart, Bradshaw, & Cunnington, 2008). Though no performance differences were found on the matrices task, ADHD children in this study showed decreased activation in the right dorsolateral prefrontal cortex, the posterior parietal lobe, and the temporal lobe compared to typical children.

A process analysis of the neuropsychological constructs needed to perform visuospatial reasoning tasks also revealed heavy executive demands (see Hale & Fiorello, 2004). In the case of block design tasks, for example, processes such as visual attention, working memory, planning/organizing, and self-monitoring are necessary. An examinee must visually attend to the details in the design to reproduce it correctly and then self-monitor performance for errors. Self-monitoring is used when an examinee regulates the speed the designs are constructed. Holding the target design in working memory and utilizing a planful/organized approach also facilitates faster performance. Visual neglect (particularly of the left hemispace) (Jones, Craver-Lemley, and Barrett, 2008; Sandson, Bachna, & Morin, 2000), deficits in visual-spatial working memory (Bedard, Martinussen, Ickowicz, & Tannock, 2004), and problems with planning/organizing and self-monitoring have all been associated with ADHD (Willcut et al., 2005).

Processing speed. Generally defined, processing speed refers to the speed at which different cognitive operations can be performed or executed (Reichenberg & Harvey, 2007). Speed of performance is related to the frontostriatal system (Rabbitt et al., 2007), and as tasks become more automatic, decreased cortical activity is seen in regions such as the dorsolateral prefrontal cortex in exchange for increased activity in subcortical regions such as the basal ganglia (Koziol & Budding, 2009; Saling & Phillips, 2007). However, individuals who perform tasks more slowly sustain this pattern of cortical activity (Saling & Phillips, 2007), thus suggesting the need for increased concentration and cognitive control than those who perform tasks quickly (Koziol & Budding, 2009).

Processing speed tasks are multifaceted, in that different neuropsychological processes/neuroanatomical networks are engaged depending on the nature of the task (Koziol & Budding, 2009). For example, the Coding and Symbol Search subtests from the Wechsler Intelligence Scales differ in that the Coding subtest places greater demands on working memory, whereas the Symbol Search subtest places more emphasis on perceptual discrimination (Koziol & Budding, 2008). Further evidence is provided by Gläscher and colleagues (2009) who were unable to localize the Processing Speed Index from the Wechsler Adult

Intelligence Scale (WAIS) to any one area of the brain. Activation was found across various frontal and parietal regions of both hemispheres. Symbol Search overlapped to a greater degree with Perceptual Organizational subtests on the WAIS, while the Coding subtest overlapped with locations of Verbal Comprehension and Working Memory. An additional neuroimaging study of the Symbol Search subtest showed that subjects activated regions of the occipital, parietal, temporal, and dorsolateral prefrontal cortexes (Sweet et al., 2005).

Measures of processing speed have shown significant promise in differentiating ADHD children from typical children. As compared to typical children, children with ADHD have shown significantly decreased processing speed scores on the Wechsler scales (Calhoun & Mayes, 2005; Elk et al., 2007; Mayes & Calhoun, 2004; Mayes & Calhoun, 2007a), with lower performance found on the Coding subtest than the Symbol Search subtest (Calhoun & Mayes, 2005). Lower processing speed also appears to reliably differentiate ADHD children from those with mental retardation, ODD, and anxiety disorders. However, a lower processing speed has also been found in children with autism, bipolar disorder, unipolar depression, and learning disabilities (Calhoun & Mayes, 2005).

Studies that have differentiated between ADHD subtypes on measures of processing speed have yielded mixed results. Chhabildas, Pennington, and Willcutt (2001) found that combined and inattentive groups both demonstrated deficits in processing speed that were not seen in the hyperactive-impulsive group. Other research groups have found that children with inattentive type ADHD perform significantly worse on processing speed tasks as compared to those with combined type (Mayes, Calhoun, Chase, Mink, & Stagg, 2009; Solanto et al., 2007). The conflicting findings between these two studies may be attributed to the different definitions of processing speed of each research group. As previously discussed in this section, different processing speed tasks engage different neurological networks (Koziol & Budding, 2009). Mayes et al. (2009) and Solanto et al. (2007) used the same measures that will be used in the proposed study.

Working memory. Working memory refers to the capacity to mentally manipulate information placed in immediate storage (Miller, 2007), and is likely primarily a function of the dorsolateral prefrontal cortex (Levy & Goldman-Rakic, 2000). Working memory facilitates the activation of many neurocognitive processes (see Hale & Fiorello, 2004) and has been equated with self-directed speech, (Barkley, 2005), which permits children to reflect on events, question their actions, plan, problem solve, utilize metacognition, and follow directions (Dawson & Guare, 2004). Additionally, internal dialogues facilitate self-regulation of motor and emotional responses (Barkley, 2005). Furthermore, working memory is closely intertwined with attention (see Barkley, 2006; Baron, 2004), because irrelevant stimuli must be ignored when performing working memory tasks (Nigg, 2006).

Tests of working memory, such as digit span tasks, have been consistently found to reliably differentiate ADHD children from typical children (Assessmany et al., 2001; Elk et al., 2007; Mayes & Calhoun, 2002, 2007a, 2007b). The degree of working memory impairment found in children with ADHD is even greater on tasks of spatial working memory than those of verbal working memory (Willcutt et al., 2005). However, the less robust finding of verbal working memory may be due in part to the common approach of not considering forward and backward versions of digit span tasks separately (Hale, Hoeppner, & Fiorello, 2002). Digits backward measures attention and executive function processes and is associated with dorsolateral prefrontal involvement, whereas digits forward measures short-term auditory memory associated with left hemisphere auditory-verbal processes (Hale et al., 2002). While working memory measures have been found to discriminate ADHD children from typical children, as well as those with anxiety, depression, or ODD, results are similar for children with autism and learning disabilities (Mayes & Calhoun, 2004, 2007a;). Studies that have examined working memory performance by ADHD subtype have found no significant differences between inattentive and combined groups (Mayes & Calhoun, 2009; Solanto et al., 2007).

Sustained attention. Sustained attention is defined as an individual's ability to stay on-task over periods of time (Mirsky et al., 1991). Neurological models of sustained attention implicate interaction of cortical (frontal, prefrontal, parietal) and subcortical structures (limbic system, basal ganglia), as well as ascending and descending pathways between the basal ganglia, frontal lobes, and thalamus (Riccio, Reynolds, Lowe, & Moore, 2002). These models have been supported by neuroimaging data (Riccio et al., 2002).

Continuous performance tests (CPTs) are frequently utilized to assess the construct of sustained attention and have shown sensitivity to neurological impairment/damage (Riccio et al., 2002). CPTs exist in various formats, such as auditory and visual. One popular version is the Conners' Continuous Performance Test, which is a computerized measure that requires the examinee to press the spacebar in response to visual stimuli displayed at varying speeds on a computer screen. This instrument yields measures of inattention, impulsivity, and vigilance (Conners & MHS Staff, 2004).

CPTs are most commonly utilized to assist in evaluating children for ADHD and to determine stimulant therapy response (Barkley, 2005; Conners & MHS Staff, 2004). A meta-analytic review of CPT research found that children with ADHD manifest higher error rates of omission (failure to respond to targets) and commission (responding to non targets) (Losier, McGrath, & Klein, 1996). They also show increased difficulties distinguishing between targets and non targets (signal detection). Performance measured by commissions, omissions, and signal detection has been shown to improve in ADHD children treated with methylphenidate.

Though some ADHD subtype differences have been found on CPTs, these instruments have shown limited specificity for distinguishing among the different forms of ADHD. Some studies suggest that children with ADHD-CT tend to demonstrate greater impulsivity than those with IA (Solanto et al., 2007), and children with ADHD-IA and CT tend to have slower reaction times than those with HI (Querne & Berquin, 2009). However, research that has directly compared *DSM–IV* symptoms to performance variables on the Conners' CPT found that the combination of increased overall omission and commission errors, as well as of omission errors as the test progressed, was related to almost all of the 18 ADHD symptoms in the *DSM–IV* (Epstein et al., 2003). Hence, Epstein and colleagues concluded that the CPT is a good general measure of ADHD rather than ADHD subtype.

Despite the popularity of utilizing CPT measures in the assessment of ADHD, they may also be of value in assessing other psychiatric conditions where attention is impaired (Riccio et al., 2002). In a review of CPT studies, Riccio and colleagues (2002) concluded that CPTs demonstrate sensitivity to attentional system dysfunction, whether the damage to neurological attention systems was diffuse or focal. Thus, CPTs more accurately identify attentional disturbance rather than specific conditions such as ADHD. For example, learning disabilities

(Advokat, Martino, & Gouvier, 2007), schizophrenia (Nieuwenstein, Aleman, & de Haan, 2001), and major depression with psychosis (Nelson, Sax, Strakowski, 1998) have all been linked to abnormal CPT performance.

Neuropsychological processes in ADHD plus comorbid conditions.

There appears to be a paucity of research that has examined neuropsychological performance in ADHD with comorbid conditions such as anxiety, depression, or ODD/CD. Of the existing studies, mixed results for meaningful group differences have been found. It has been suggested that neuropsychological differences are similar for children with ADHD compared to those with comorbid anxiety, depression, or CD (Klorman et al., 1999; Seidman et al., 1995). Related to verbal processes, one study found lower verbal intelligence in children with comorbid CD (Waschbusch, 2002). No studies could be located related to visuospatial processes. Some evidence exists that working memory may be more impaired in ADHD children with comorbid anxiety (Schatz & Rostain, 2006) and also less amenable to improvements with methylphenidate treatment (Bedard & Tannock, 2008; Tannock, Ickowicz, & Schachar, 1995). However, Mayes et al. (2009) found that the addition of comorbid anxiety or depression did not account for further declines in working memory or processing speed performance. Rucklidge (2006) found processing speed deficits in children with ADHD/bipolar disorder, but these were less severe than those seen in children with pure ADHD. The addition of ODD to ADHD also does not appear to further decrease working memory (Mayes et al., 2009; Thorell & Wåhlstedt, 2006) or processing speed (Mayes et al., 2009).

More research has been conducted on ADHD comorbidities in the area of sustained attention/response inhibition. Studies examining comorbid anxiety or depression have provided mixed support for performance deficits that differ from those in individuals who have ADHD without comorbidity. Children with ADHD/anxiety have shown response inhibition deficits, but these deficits did not remain once ADHD was factored out (Korenblum, Chen, Manassis, & Schachar, 2007). Other studies have suggested that comorbid anxiety may offset impulsivity/response inhibition deficits (Manassis, Tannock, & Barbosa, 2000; Schatz & Rostain, 2006). However, this effect may vary based on the nature of anxiety, with physiological anxiety serving to increase response inhibition and cognitive anxiety serving to decrease response inhibition (Epstein, Goldberg, Conners, & March, 1997). A study conducted with adults with ADHD comorbid with depression found that this group performed slightly worse on a sustained attention task than those with ADHD alone (Riordan et al., 1999). Some studies examining comorbid bipolar disorder suggest that this comorbidity leads to increased impairment on CPT tasks (Rucklidge, 2006), while others have suggested that performance is similar between ADHD/bipolar and ADHD groups (Adler et al., 2005).

Studies examining performance on sustained attention tasks in individuals with ADHD/ ODD/CD have also yielded mixed results. ADHD comorbid with ODD/CD may increase impulsivity (Banaschewski et al., 2004; Matier, Halperin, Sharma, Newcorn, & Sathaye, 1992; Newcorn et al., 2001), an effect that is not remediated by methylphenidate treatment (Matier et al., 1992). However, another study that found boys with comorbid CD outperformed those with ADHD alone on a CPT task (Banaschewski et al., 2003).

Research problem and limitations of past research.

The diagnosis of ADHD can be a complex process. Traditional behavioral diagnosis is complicated by factors such as interrater disagreement (Angtrop et al., 2002; Bird et al., 1992; Grills & Ollendick, 2002), high comorbidity rates (National Resource Center on ADHD, 2003) and shared symptomatology among different psychiatric disorders (Hale et al., 2001; Mahone et al., 2002; Sullivan & Riccio, 2007). Due to these complexities and mounting evidence of neurological differences in children with ADHD, many researchers have turned to the use of neuropsychological instruments to aid in the diagnostic process. While performance trends have been discovered, the sole use of neuropsychological instruments has not proven diagnostic of ADHD (e.g. Barkley, 2005; Frazier et al., 2004; Willcutt et al., 2005). In contrast, fewer studies have utilized a combined behavioral/neuropsychological approach, which has proven more sensitive in diagnosing ADHD (Hale et al., 2009a). The present study was intended to add to the research base on whether a combined neuropsychological/behavioral approach can be of value in the diagnosis of ADHD. Additionally, comorbid conditions and ADHD subtype were considered, which represented further strengths as compared to past literature. Furthermore, all were free of psychotropic medication at time of assessment, a confound in many past studies that have examined attentional processes (Ottowitz, Dougherty, & Savage, 2002).

Many neuropsychological instruments that have shown promise in the evaluation of children with ADHD are generally reserved for practitioners with specialized training in neuropsychological assessment (Miller, 2007). In contrast, the present study utilized the Wechsler Intelligence Scale for Children–Fourth Edition (WISC–IV; Wechsler, 2003) and Conners' Continuous Performance Test–Second Edition (CPT–II; Conners & MHS Staff, 2004), two instruments commonly used by psychologists with generalist training. Though the WISC is traditionally utilized for the diagnosis of learning disorders or cognitive impairments (see Sattler, 2001) and the CPT is used to supplement behavioral data in ADHD evaluations (Barkley, 2005), these instruments have both shown sensitivity in identifying neurological impairment (Belanger, Curtiss, Demery, Lebowitz, & Vanderploeg, 2005; Hale et al., 2002; Mayes & Calhoun, 2004; Riccio et al., 2002). Furthermore, profile differences have been found in children with ADHD on WISC and CPT assessments (Calhoun & Mayes, 2005; Losier et al., 1996; Mayes & Calhoun, 2004, 2006, 2007a, 2007b).

The present study explored the behavioral and neuropsychological patterns found in children with ADHD children and those with comorbid conditions, as well as the utility of a combined neuropsychological/behavioral approach in differentiating among ADHD groups. The groups of focus in the present study included ADHD-IA, IA comorbid with an internalizing disorder (IA + INT), CT, and CT comorbid with an externalizing disorder (CT + EXT). The comorbid groups were chosen on the basis of past research that suggests that ADHD IA + INT and CT + EXT may represent distinct ADHD subtypes (Angold, Costello, & Erkanli, 1999; Barkley, 2005; Jensen et al., 2001; Stefanatos & Baron, 2007).

Using assessment data derived from mental health clinics within the midwestern and northeastern United States, subject performance was analyzed based on scores from the WISC-IV, CPT-II, and the Achenbach System of Empirically Based Assessment Child Behavior Checklist (ASEBA CBCL) and Teacher Report Form (TRF) (Achenbach & Rescorla, 2001). The following specific research questions were explored: (a) Do different neuropsychological and behavioral patterns, as measured by the WISC-IV, CPT-II, CBCL, and TRF exist in the different ADHD subgroups; and (b) Can the neuropsychological (WISC-IV and CPT-II) and behavioral (CBCL and TRF) variables discriminate between the ADHD groups with and without comorbid internalizing and externalizing comorbidities.

The research questions of this study were exploratory in nature. Hence, no directional hypotheses were developed. However, diverse findings were expected to emerge among the ADHD subgroups on all measures utilized, and the WISC–IV, CPT–II, CBCL, and TRF variables were expected to reliably differentiate between the subgroups. Furthermore, the results of this study were expected to further illustrate the heterogeneous nature of ADHD (Barkley, 2005; Hale et al., 2009a) and support the utility of a combined behavioral/neuropsychological approach in the diagnosis of ADHD (Hale et al., 2009a), as opposed to one that relies on neuropsychological or behavioral measures alone.

Chapter 3

Method

Subjects.

All subjects in the present study were drawn from three different clinics within the midwestern and northeastern U.S. All had previously received comprehensive ADHD evaluations, which included the WISC–IV (Wechsler, 2003), CPT–II (Conners & MHS Staff, 2004), CBCL (Achenbach & Rescorla, 2001), as well as a semi structured interview and a behavior rating scale designed to measure ADHD. Many assessments also included the TRF, though it was not necessary for subject selection. Diagnosis of ADHD was rendered by licensed psychologists based on clinical evaluation and clinic ADHD rating scales (not the CBCL/TRF). To control for intellectual deficits that could potentially confound results, only children with full scale ability standard scores ≥75 were selected. Additionally, potential subjects who were taking any kind of psychotropic medication at the time of testing and those who had a known traumatic brain injury or a medical condition that may affect psychological functioning (e.g., epilepsy) were excluded. Subjects were not eliminated from the analysis due to a comorbid learning or language disorder.

The total sample consisted of 85 children ranging between the ages of 6 and 16 (Sample A). From the total sample, subjects whose files contained all necessary information were then divided into IA (n = 18), IA + INT (n = 8), CT (n

= 25), and CT + EXT (*n* = 12) groups to examine the research questions of the present study. This resulted in a total sample size of 63. Because many subjects in Sample B had ASEBA TRF results in addition to the required ASEBA CBCL results, a third sample was later formed for advanced analysis (Sample C, *n* = 42).

Several criteria were used to form the IA, IA + INT, CT, and CT + EXT subgroups, which were used in the statistical analyses of samples B and C. Due to small sample size, subjects classified as having ADHD-NOS were included in the IA groups and those with HI were included in the CT groups, which could be consistent with neuropsychological characteristics of these ADHD subtypes (Hale et al., 2009). According to the *DSM–IV* (APA, 2000), ADHD-NOS often is reserved for individuals demonstrating characteristics of sluggishness, daydreaming, and hypoactivity. These characteristics have been deemed sluggish cognitive tempo, which research suggests may be a subset of the IA category (Barkley, 2005; Barkley et al., 2001, McBurnett et al., 2002). Additionally, CT may present as HI in its earlier stages or at younger ages (Barkley, 2005).

Further criteria were used to determine subject membership in the comorbid groups (IA + INT and CT + EXT). Because full criteria for a *DSM* disorder were not met, not otherwise specified (NOS) comorbid disorders (e.g. DRB NOS, Anxiety NOS, etc.) were not recognized as comorbid conditions. CT subjects with a comorbid internalizing disorder (including those with an adjustment disorder with anxiety and/or depression; *n* = 11), as well as those with comorbid Asperger's disorder (n = 4) were eliminated from further analysis because these profiles were not relevant to the research questions. IA subjects who had a comorbid adjustment disorder were included in the IA + INT. One CT subject with an adjustment disorder with mixed emotions and conduct was included in the CT + EXT group due to a disturbance of conduct..

Instrumentation

Wechsler Intelligence Scale for Children–Fourth Edition (WISC–IV). The WISC–IV is an individually administered test of cognitive abilities for children ages 6 to 16 (Wechsler, 2003) and served as one measure of neuropsychological functioning in the present study. Reliability coefficients of the WISC–IV suggest good internal consistency, with subtests ranging from .79 to .90 and indexes ranging from .88 to .97 (Wechsler, 2003). The WISC has also shown sensitivity in identifying neurological impairment (Belanger et al., 2005; Hale et al., 2002; Mayes & Calhoun, 2004), thus suggesting its utility as a neuropsychological instrument.

The standard battery of the WISC–IV is comprised of 10 subtests: Block Design, Similarities, Coding, Vocabulary, Digit Span, Picture Concepts, Matrix Reasoning, Letter Number Sequencing, Comprehension, and Symbol Search (Wechsler, 2003). These subtests are represented by the following indexes: Verbal Comprehension (Vocabulary, Similarities, and Comprehension), Perceptual Reasoning (Block Design, Picture Concepts, and Matrix Reasoning), Working Memory (Digit Span and Letter-Number Sequencing), and Processing Speed (Coding and Symbol Search). Two process scores, Digits Forward and Digits Backward, can also be calculated from an examinee's performance on the Digits Span subtest (Wechsler, 2003).

WISC-IV scores range from 40 to 160 (see Wechsler, 2003). Average performance is represented by standard scores within the range of 90 to 109 and subtest scaled scores that range from 8 to 12 (see Wechsler, 2003). Standard scores within 80 to 89 and scaled scores from 5 to 7 are considered low average. The borderline range is defined by standard scores ranging from 70 to 79 and scaled scores of 6 or 7. Standard scores < 70 and scaled scores < 3 are considered extremely low. On the other end of the distribution, the high average range is represented by standard scores of 110 to 119 and scaled scores of 13 to 14. The superior range is represented by standard scores of 120 to 129 and a scaled score of 15. Standard scores ≥ 130 and scaled scores ≥ 16 are considered very superior.

The Verbal Comprehension Index (VCI) is designed to measure an individual's verbal reasoning, verbal concept formation, and environmental knowledge (Wechsler, 2003). Within a Catell-Horn-Carol model (CHC), the subtests that comprise the VCI are regarded as measures crystallized knowledge (Gc) (Keith, Fine, Taub, Reynolds, & Kranzler, 2006).

Similarities, the first core VCI subtest, was designed to be a measure of verbal reasoning and concept formation (Wechsler, 2003). It also requires auditory comprehension (Miller & Hale, 2007; Wechsler, 2004), distinction between nonessential and essential features of words (Miller & Hale, 2007), and oral expression. Examinees must engage in concordant and convergent thought to perform this subtest, which are facilitated by long-term retrieval of verbal information (crystallized knowledge and memory, left hemisphere processes) and verbal reasoning (left hemisphere frontal executive functions) (Miller & Hale, 2007).

The Vocabulary subtest was designed to assess word knowledge and concept formation (Wechsler, 2003). It also involves the processes of auditory perception, receptive language, and expressive language (Miller & Hale, 2007). Examinees utilize Broca's area due to the word retrieval, grammar, and language formulation demands of the Vocabulary subtest.

Comprehension, the final core VCI subtest, is designed to measure verbal reasoning, conceptualization, and comprehension, oral expression, and practical knowledge (Wechsler, 2003). It also involves elements of social judgment and common sense problem solving (Sattler, 2001). Receptive language, retrieval of semantic information from long-term storage memory, and oral expression are necessary neuropsychological constructs needed to perform the Comprehension subtest (Miller & Hale, 2007). Left hemisphere concordant/convergent and right hemisphere discordant/divergent language processes are likely invoked on novel or ambiguous items (Bryan & Hale, 2001).

The Perceptual Reasoning Index (PRI) is designed to measure spatial processing, visual-motor integration, perceptual reasoning, and fluid reasoning (Wechsler, 2003). According to the WISC-IV factor structure, Block Design, the first core PRI subtest, measures visuospatial processing, organization, and coordination (Wechsler, 2003). In a CHC model, it is best regarded as a measure of visual processing (Gv) (Keith et al., 2006). The neuropsychological processes of nonverbal concept formation, simultaneous/holistic processing, visual-motor coordination, learning, and processing speed may also be required (Miller & Hale, 2007). Global/holistic (right parietal) and local/detail (left parietal) functions are needed in order to engage in perceptual analysis and synthesis (Miller & Hale, 2007). The frontally mediated executive functions (Hale & Fiorello, 2004) of attention to detail and planning are also advantageous on this subtest (Sattler, 2001).

Picture Concepts, the second core PRI subtest, is designed to be a measure of abstract and categorical reasoning (Wechsler, 2003), and is regarded as a solid measure of fluid reasoning (Gf) in a CHC model (Keith et al., 2006). Examinees invoke right hemisphere discordant/ divergent and left hemisphere convergent/concordant thought processes in order to perceive meaningful pictures and produce categorical responses (Bryan & Hale, 2001).

The final core PRI subtest, Matrix Reasoning, is designed to assess visual information processing and abstract reasoning skills (Wechsler, 2003). It is also regarded as a good measure of Gf (Keith et al., 2006). This subtest also requires the use of executive function demands (Hale & Fiorello, 2004), namely attention to detail and concentration (Sattler, 2001), as well as deductive problem-solving (Miller & Hale, 2007). Examinees utilize their left ventral stream when solving meaningful matrices and their right ventral stream when solving abstract visual patterns (Miller & Hale, 2007).

The Working Memory Index (WMI) assesses an individual's ability for temporarily holding information in memory and manipulating this information in some way (Wechsler, 2003). Attention, concentration, and mental control are also necessary for performing these tasks (Wechsler, 2003). Digit Span measures attentional capacity, verbal immediate memory, sequential processing, and sustained attention/concentration (Miller & Hale, 2007). However, Digits Forward requires short-term rote auditory memory, while Digits Backward requires working memory, mental flexibility, and shifting cognitive set (Hale et al., 2002). The other core WMI subtest, Letter-Number Sequencing, is designed to measure mental alertness, attention, concentration, short- and long-term memory, mental manipulation, and numerical reasoning ability (Wechsler, 2003). The neuropsychological processes of divided attention, sequential processing, visuospatial imaging, and processing speed are also involved on this subtest (Miller & Hale, 2007).

The Processing Speed Index (PSI) is designed to assess an individual's ability to scan, sequence, and discriminate simple visual stimuli under timed conditions (Wechsler, 2003). Coding, the first PSI subtest, involves visual acuity, attention, speeded mental operation, cognitive flexibility, speed and accuracy of visual-motor coordination, and graphomotor speed (Sattler, 2001). This subtest also requires the use of perceptions of abstract visual stimuli, visual selective and sustained attention, short-term visual sensory memory, associative learning, visual scanning ability, and motivation (Miller & Hale, 2007). The Symbol Search subtest assesses perceptual discrimination, attention and concentration, short-term memory, cognitive flexibility, speed and accuracy (Sattler, 2001). It is regarded as a measure of Gv in the CHC model (Keith et al., 2006). Visual-motor coordination is also involved in this subtest, though to a lesser degree than on Coding (see Sattler, 2001). This subtest also requires the neuropsychological constructs of visual scanning, visual selective attention, and perception of abstract visual stimuli (Miller & Hale, 2007).

Conners' Continuous Performance Test-Second Edition (CPT–II). The CPT–II (Conners & MHS Staff, 2000) also served as a neuropsychological instrument in the present study. The CPT–II is a computerized assessment designed to assess sustained attention/vigilance in individuals ages 6 and older

(Conners & MHS Staff, 2000). For approximately 14 minutes, non target letters (other than X) and target (the letter X) letters are flashed on a computer monitor at 1-, 2-, and 4-second intervals (Interstimulus Intervals; ISIs) with a display time of 250 milliseconds. The examinee is instructed to press the spacebar each time a letter other than X appears on the screen. An examinee's performance is evaluated along 12 dimensions broadly representing impulsivity, inattention, and vigilance. T scores generated for each of the 12 scales were all utilized in the present study.

In past research, the CPT has shown sensitivity in identifying neurological impairment (Conners & MHS Staff, 2004, Riccio et al., 2002,). This test also has shown high test-retest reliability for most subscales and good validity (Conners & MHS Staff, 2004). Czerny, O'Laughlin, and Griffioen (1999; as cited in Conners & MHS Staff, 2004) found a 70% to 75% classification accuracy rate when comparing an ADHD clinical group to a group that contained individuals with major depression, bipolar disorder, anxiety disorder, post traumatic stress disorder, depressive disorder, and ODD. Relatively low correlations have been found between behavioral rating scale information and CPT results (Cohan, 1995, as reported by Conners and MHS Staff, 2004). However, Cohan posited that these low correlations suggest that rating scales and CPTs assess different aspects of attention.

An examinee's accuracy is measured by the presence of Omissions (failure to respond to targets) and Commission*s* (responses to non-targets) (Conners & MHS Staff, 2004). Signal detection, or an examinee's skill in discriminating between targets and non-targets and carefulness in responding, is represented by Detectability (d′), and the Response Style Indicator (ß), respectively. The speed at which an examinee responds to targets/non targets is measured through Hit Reaction Time (Hit RT, mean response time for targets across 6 time blocks), Hit RT Standard Error (Hit RT SE, consistency in response times), Variability (within respondent variability), and Perseverations (presence of reaction times less than 100 ms, which suggests either anticipatory responding or slow reaction times to preceding stimuli). An individual's variation in speed/reaction time is also analyzed throughout the 6 time blocks of the test (Hit RT Block Change and Hit SE Block Change), as well as throughout the different ISIs (Hit RT ISI Change and Hit SE ISI Change). The CPT–II also groups the above scales together to broadly measure inattention (Omissions, Commissions, Hit RT, Hit RT SE, Variability, d′, Hit RT ISI Change, and Hit SE ISI Change), impulsivity (Commissions, Hit RT, and Perseverations), and vigilance (Hit RT Block Change and Hit SE Block Change).

CPT–II t scores are evaluated using the following guidelines: < 40 represents very good performance, 40 to 44 represents good performance, 45 to 54 represents average performance, 55 to 59 represents mildly atypical performance, 60 to 64 indicates moderately atypical performance, and scores of 65 or greater are considered markedly atypical (see Conners & MHS Staff, 2004). In general, t scores of 60 or higher are considered problematic. However, low t scores (< 40) on β and Hit RT can also be significant, indicating unusual response styles and impulsivity, respectively.

Achenbach System of Empirically Based Assessment Child Behavior Checklist (ASEBA CBCL). The ASEBA CBCL (Achenbach & Rescorla, 2001) served as the primary behavioral measure in the present study. The ASEBA CBCL is a 113-item parent-completed psychosocial measure designed to assess maladaptive behaviors in children ages 6 to 18. The ASEBA Teacher Report Form (TRF) is the teacher counterpart to the CBCL, and when available, this data was also analyzed in the present study. Inter interviewer reliability of the ASEBA is .96, and content validity studies suggest that this instrument discriminates well between referred and non referred groups of children ($p < .01$). The ASEBA has been found to have good predictive power of DSM-IV diagnoses (Krol, De Bruyn, Coolen, & van Aarle, 2006), as well as reliably identify patterns of comorbidity within ADHD children (Biederman, Ball, Monuteaux, Kaiser, & Farone, 2008; Biederman, Monuteaux, Kendrick, Klein, & Farone, 2005).

The various scales contained on the ASEBA CBCL and TRF were formed from factor analysis of individual items (Achenbach & Rescorla, 2001). Of primary interest to this study were the syndrome scales (Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, Social Problems, Thought Problems, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior) and composite scales (Internalizing Problems, Externalizing Problems, and Total Problems). The Internalizing scale is comprised of the Anxious/Depressed, Withdrawn/Depressed, and Somatic Complaints syndrome scales. The Externalizing scale includes Rule-Breaking Behavior and Aggressive Behavior. The Social Problems, Thought Problems, and Attention Problems scales are regarded as mixed syndromes, for they showed moderate loadings on both the Internalizing and Externalizing factors during scale development.

Achenbach and Rescorla (2001) indicate that the scores on all scales are quantitative and not intended to mark categorical differences. To aid clinicians in identifying which areas warrant intervention, t scores can be divided into average (syndrome scores < 65, composite scores < 60), borderline clinical (syndrome scores of 65 to 69, composite scores of 60 to 63), and clinical ranges (syndrome scores > 70, composite scores > 63). However, if clinicians wish to use a dichotomous method of classification, they may consider syndrome scores ≥ 65 and composite scores ≥ 60 to be within the clinical range. The latter method was used for qualitative description of the ASEBA scores in the present study.

Achenbach and Rescorla (2001) caution against identifying children as either an internalizer or an externalizer based on variation in scores on the Internalizing and Externalizing scales, for the categories are not mutually exclusive. Moderate correlations have been found between the two areas, suggesting that children who have very high problem scores in one of the two areas also tend to have at least above average scores in the other areas (see Achenbach & Rescorla, 2001). The authors recommend that the internalizer or externalizer distinction only be made if a child's Total Problems t score is greater than or equal to 60, and the difference between scores on the Internalizing and Externalizing scales is at least 10.

Achenbach and Rescorla (2001) also provide additional guidance in score interpretation for research purposes. They advise that raw scores should be utilized when analyzing the syndrome scales because the t scores truncate at 50. However, the use of t scores in statistical analyses is recommended for the composite scales (Internalizing Problems, Externalizing Problems, and Total Problems), as they do not truncate at 50. These guidelines were followed in the present study.

Procedure.

The data were gathered through file reviews conducted on-site at the clinics by employees of these organizations. To protect subject confidentiality, relevant information was recorded on a data collection form, without the use of personal identifiers. This data collection form required the recording of demographic information and scores from the WISC–IV, CPT–II, and CBCL (see Appendix). Demographic data included the following: age at assessment, gender, grade in school, educational classification, and comorbid diagnoses. Socioeconomic status was estimated on the basis of payment source, with Medicaid serving as an indication of low SES and private insurance representing middle SES. Standard/scaled scores were collected for all composites and subtests of the WISC–IV including Digits Forward and Digits Backward. T scores from all scales on the CPT–II were recorded and raw and t scores from the CBCL (and TRF when available) syndrome and composite scales. Each completed data collection form was assigned a numerical code for tracking purposes. Completed data forms were stored in a locked file cabinet. Information from the data collection forms was later transferred to SPSS version 18 for statistical analysis.

Analysis.

Three major groups of analyses were performed. First, demographic statistics were calculated on the entire sample of 85 subjects to examine the characteristics of the sample (Sample A). Nonparametric chi-square analyses were conducted to examine possible group differences in demographic data, as this could affect interpretation of subsequent parametric analyses.

Using cases that included all necessary diagnostic information, subjects were then classified into IA, IA + INT, CT, and CT + EXT groups to address the research questions of this study. Descriptive statistics were then calculated for this Sample B ($n = 63$) for subjects who had no missing data for core subtests of the WISC–IV (including Digits Forward and Digits Backward), WISC–IV Indices, CPT–II variables, and CBCL syndrome and composite scales divided into the four (IA, IA + INT, CT, CT + EXT) groups. To examine profile differences among groups, profiles were graphically displayed and one-way ANOVAs were conducted to assess for effects between groups differences on the dependent measures. The independent variable (ADHD group) included four levels (IA, IA + INT, CT, and CT + EXT), with WISC–IV, CPT–II, and CBCL scores representing the dependent variables. TRF data are also reported on a smaller subsample of children (Sample C; $n = 42$) also divided into groups. As advised by Achenbach and Rescorla (2001), raw scores were used for the syndrome scales (because t scores are truncated at 50) and t scores were used for the composite scales.

For the variables that showed significant subgroup by score interactions through ANOVA, post hoc tests using Tukey's honestly significant difference (HSD) statistic were performed. There were a few cases where the HSD statistic failed to find significant between-group differences at the $p < .05$ level despite significant F tests. This was likely due to small group sizes affecting the power of the test, which controls for Type I error. In these instances, between-group significance was determined using the Fisher's Least Significance Difference (LSD) statistic (which does not control for Type I error). Additionally, LSD values are also reported in the narrative portion of the Results section when the HSD statistic indicated a trend toward significance.

The final set of analyses involved forced-entry discriminant analyses to examine whether the neuropsychological and behavioral measures utilized in this study could accurately predict ADHD group membership. The predictors included scaled scores from the WISC–IV subtests (Digits Forward and Digits Backward substituted for Digit Span), t scores for the CPT–II scales, and raw scores on the CBCL and TRF subscales. The first discriminant analysis included the cognitive/neuropsychological data and behavior ratings. Additional discriminant analyses using different combinations of the predictors were completed to evaluate the utility of a combined approach compared to one that just relies on neuropsychological or behavioral information alone. These analyses are presented in a table that illustrates the relative contribution of parent (CBCL; n = 63; Sample B) or teacher (TRF; n = 42; Sample C) behavior ratings alone, cognitive/neuropsychological data alone (WISC–IV/CPT–II; n = 63; Sample B), cognitive/ neuropsychological data plus parent ratings (WISC–IV, CPT–II, CBCL; n = 63; Sample B), and cognitive/neuropsychological data plus parent and teacher ratings (WISC–IV, CPT–II, CBCL, TRF; n = 42; Sample C).

Chapter 4

Results

Descriptive statistics.

The total sample (Sample A) consisted of 85 children ranging between the ages of 6 and 16 (M = 9.66, SD = 2.88). As can be seen in Table 1, the majority of subjects were males (69.4%) and White (63%). Those who were Black (15.3%) or biracial/multiracial (10.6%) were represented at smaller percentages. Lower and middle socioeconomic status (SES) groups, as estimated by a funding source of Medicaid (58.2%) or private insurance (51.8%), were relatively comparable. Subjects in kindergarten through 10th grade were represented, with 76.5% in the elementary grades of kindergarten through fifth grade. The majority of children were served within general education placements (77%). The remainder were served through part-time special education support (5.9%), self-contained classrooms (2.4%), or inclusion placements (1.2%).

The frequencies of ADHD subtypes found in the present study aligned closely with national prevalence rates that suggest that ADHD-CT is the most commonly diagnosed (50% to 75%), followed by IA (20% to 30%), and then HI (less than 15%) (Spencer et al., 2007). In the present study, the majority of the sample had ADHD-CT (56.5%). ADHD-IA represented the second largest group (27.1%). Those with ADHD-HI or ADHD-NOS each accounted for 8.2% of the sample size.

Chi square tests of independence indicated that the clinical subtypes did not differ significantly in regard to gender (χ^2 (3, *N* = 85) = 3.25, *p* = .355), ethnicity (χ^2 (6, *N* = 85) = 3.61, *p* = .729), SES (χ^2 (3, *N* = 85) = 6.18, *p* = .103), grade (χ^2 (3, *N* = 85) = 3.25, *p* = .355), or educational placement (χ^2 (3, *N* = 85) = 3.87, *p* = .920). A trend toward significance was found for age (χ^2 (6, *N* = 85) = 12.18, *p* = .058), with most subjects within the age range of 6 to 8 (50.6%), followed by the 9 through 12 age range (34.1%) across the clinical subtypes.

Table 1

Demographic Variables by ADHD Clinical Subtype (Sample A)

	IA (27.1%)	HI (8.2%)	CT (56.5%)	NOS (8.2%)	χ^2	ϕ
Gender						
Male	69.9	85.7	70.8	42.9	3.25	0.20
Female	30.4	14.3	29.2	57.1		
Age						
6 to 8	21.7	71.4	62.5	42.9	12.18	0.06
9 to 12	52.2	14.3	10.4	14.3		
13 to 16	26.1	14.3	10.4	14.3		
Ethnicity						
White	78.3	57.1	14.6	85.7	3.61	0.21
Black	17.4	28.6	53.8	0.0		
Biracial/Multiracial	4.3	15.4	66.7	14.3		
Socioeconomic Status Estimate						
Low	39.1	71.4	54.2	14.3	6.18	0.27
Middle	60.9	28.6	45.8	85.7		

	IA (27.1%)	HI (8.2%)	CT (56.5%)	NOS (8.2%)	χ^2	ϕ
Grade						
Kindergarten to fourth (elementary)	47.8	85.7	77.1	57.1	8.62	0.20
Fifth to eighth (middle)	34.8	14.3	18.8	28.6		
Ninth to eleventh (high)	17.4	0.0	4.2	14.3		
Educational Placement						
Regular education	95.7	100.0	87.5	85.7	3.87	0.21
Inclusion classroom	0.0	0.0	2.1	0.0		
Part-Time learning support	4.3	0.0	6.3	14.3		
Self-Contained classroom	0.0	0.0	4.2	0.0		

Note. ADHD = attention-deficit/hyperactivity disorder. IA = ADHD inattentive type. HI = ADHD hyperactive/impulsive type. CT = ADHD combined type. NOS = ADHD not otherwise specified.

Consistent with past statistics on ADHD, (Biederman et al., 1992; Ollendick, et al., 2008), comorbidity was also the norm in this sample, with 43.5% of subjects having one, 22.4% having two, 2.4% having three, and 1.2% having four or five additional psychiatric diagnoses. Disruptive externalizing behavior disorders (ODD and disruptive behavior disorder, not otherwise specified; DRB, NOS) occurred at rates of 8.7% in the IA group, 42.9% in the HI group, 35.4% in the CT group, and 14.3% of the NOS group. Internalizing disorders (dysthymic disorder, MDD, GAD, posttraumatic stress disorder, mood disorder NOS, and depressive disorder NOS) occurred at relatively commensurate rates in the IA (21.7%) and CT groups (20.8%). Comorbid internalizing disorders also occurred in the HI and NOS groups at equal rates (14.3%). The IA (13.0%), HI (14.3%), and CT (14.6%) demonstrated commensurate levels of comorbid adjustment disorders (adjustment disorder with depressed mood, adjustment disorder with anxiety, adjustment disorder with anxiety and depression, adjustment disorder with mixed emotions and conduct). No subjects in the NOS subtype were diagnosed with a comorbid adjustment disorder. The highest percentage of learning/language disorders (reading learning disorder (LD), math LD, written expression LD, and expressive language disorder) was found in the CT group (22.9%), followed by the NOS (14.3%), IA (13.0%), and HI groups (0%). Elimination disorders were diagnosed in 14.3% of the HI and NOS groups, 8.3% of the CT group, and 4.3% of the IA group. Asperger's disorder was seen in

13.0% of the IA subjects and 2.1% of the CT subjects which could suggest right hemisphere learning disability (e.g., nonverbal learning disability; Hale, Kaufman, Naglieri, & Kavale, 2006). Other comorbid diagnoses included cannabis and alcohol abuse (seen in 1 CT subject) and tic disorder (1 CT subject).

Table 2 displays the means, standard deviations, and ranges for Sample B across the WISC-IV variables. The mean scores are also graphically displayed in Figure 2. The mean full scale IQ (FSIQ) for the ADHD subgroups was within the Average range, with subject scores ranging from borderline to very superior ranges. The mean scores for the WISC–IV indexes also were within the average range, with stronger performance seen on the PRI and VCI (PRI > VCI) and weaker performance seen on the WMI and PSI (WMI > PSI). Subject scores ranged from low average to very superior on the PRI, extremely low to very superior on the VCI and WMI, and extremely low to superior on the PSI. These findings are consistent with past literature, which has found VCI and PRI to be relative areas of strength for children with ADHD in comparison to WMI and PSI (e.g. Mayes & Calhoun, 2006). The standard deviations for the FSIQ and index scores were all relatively similar, thus suggesting variability in scores across the different WISC–IV areas.

The mean WISC–IV subtest scores for the entire sample all were within the average range, with the exception of the score for the Coding subtest, which was within the low average range. The highest subtest mean was seen on the

Picture Concepts subtest and the lowest mean score was found on the Coding subtest. Several studies have found the Coding subtest to be one of the most sensitive WISC–IV subtests for identifying ADHD (e.g. Calhoun & Mayes, 2005). Subject performance on the Vocabulary subtest ranged from low average to high average. Scores ranged from borderline to very superior on all remaining VCI subtests, as well as on all PRI subtests and the Digit Span subtest. Subject scores on the Letter-Number Sequencing and Coding subtests ranged from extremely low to superior, and scores on the Symbol Search subtest ranged from extremely low to high average. The standard deviations for the WISC–IV subtests were all relatively similar, suggesting relatively even variance across subgroups.

Table 2

Means, Standard Deviations, and Ranges for Sample B Across WISC–IV Variables

	M	*SD*	Range
Full Scale Intelligence Quotient	98.84	12.21	75 to 132
Verbal Comprehension Index	100.87	13.35	69 to 134
Perceptual Reasoning Index	102.5	11.64	82 to 133
Working Memory Index	97.60	12.38	65 to 123
Processing Speed Index	92.95	12.46	59 to 121
Vocabulary	9.89	2.36	6 to 15
Similarities	10.59	2.96	4 to 19
Comprehension	10.19	2.74	4 to 16
Block Design	9.65	2.42	5 to 16
Matrix Reasoning	10.38	2.68	5 to 18
Picture Concepts	11.02	2.80	4 to 17
Digit Span	9.70	2.80	4 to 19
Digits Forward	9.33	2.83	4 to 18
Digits Backward	9.60	2.56	3 to 16
Letter-Number Sequencing	9.70	2.61	2 to 15
Coding	8.41	2.75	3 to 15

	M	*SD*	Range
Symbol Search	9.13	2.33	2 to 14

Note. WISC-IV = Wechsler Intelligence Scale for Children–Fourth Edition (Wechsler, 2003).

Table 3 depicts the means, standard deviations, and ranges for Sample B on the CPT–II variables. Subject scores ranged from very good to markedly atypical on all scales except Perseverations, which ranged from good to markedly atypical. Mean scores indicate that the sample as a whole performed within the Average range on Commissions, Hit RT, d′, β, Hit RT BC, and Hit SE BC. Mean t scores for Omissions, Hit RT SE, Variability, Hit RT ISI Change, and Hit SE, ISI Change were within the mildly atypical range. A moderately atypical elevation was found on Perseverations. The sample as a whole performed best on Commissions, which is considered an indicator of both inattention and impulsivity (Conners & MHS Staff, 2004). The worst mean performance was seen on Perseverations, which is regarded as an indicator of impulsivity (see Conners & MHS Staff, 2004). A review of the standard deviations suggests that the sample subjects varied most greatly on the variables of Omissions and

Perseverations. The least degree of variability was seen on Detectability and Hit SE ISI Change.

Table 3

Means, Standard Deviations, and Ranges for Sample B Across CPT–II Variables

	M	*SD*	Range
Omissions	59.50	18.89	31.27 to 134.39
Commissions	50.56	10.17	27.64 to 83.53
Hit Reaction Time	54.67	13.69	29.71 to 84.22
Hit Reaction Time Standard Error	57.81	11.44	35.41 to 79.92
Variability	57.04	10.65	33.51 to 76.06
Detectability (d′)	52.98	8.68	34.59 to 80.39
Response Style (β)	52.98	10.60	32.74 to 85.59
Perseverations	62.93	25.54	41.35 to 151.86
Hit Reaction Time Block Change	53.40	12.31	35.05 to 83.72
Hit Standard Error Block Change	54.58	10.55	34.67 to 84.03
Hit Reaction Time ISI Change	56.34	12.14	33.51 to 90.86
Hit Standard Error ISI Change	55.60	8.47	38.89 to 70.25

Note. CPT–II = Conners Continuous Performance Test–Second Edition (Conners & MHS Staff, 2004). ISI = Interstimulus Interval

The means, standard deviations, and ranges for the Sample B on the parent reported behavioral variables (CBCL) are reported in Table 4. Subject scores on all scales and composites ranged from average to clinical. The mean scores for the entire sample were within the average range on the Anxious/Depressed, Somatic Complaints, Social Problems, Thought Problems, and Rule-Breaking Behavior scales. The mean score for the Aggressive Behavior scale was just slightly below the clinical range. The mean score for Attention Problems was within the clinical range. Externalizing Problems and Total Problems also were within the Clinical range, while the mean score for Internalizing Problems was within the upper-limits of the average range. The standard deviations suggested the greatest degree of variability in scores on the Attention Problems and Aggressive Behavior scales. The least degree of variability was found on the Thought Problems, Somatic Complaints, and Social Problems scales. The standard deviations in the composite scales were all relatively commensurate, thus suggesting similar variance along these dimensions.

Table 4

Means, Standard Deviations, and Ranges for Sample B Across Parent Reported Behavioral Variables

	M	*SD*	Range
Anxious/Depressed	58.63	9.21	50 to 86
Withdrawn/Depressed	58.19	9.00	50 to 89
Somatic Complaints	59.11	8.00	50 to 80
Social Problems	58.43	8.61	50 to 88
Thought Problems	60.38	7.96	50 to 78
Attention Problems	69.52	10.79	51 to 99
Rule-Breaking Behavior	60.56	9.00	50 to 80
Aggressive Behavior	64.57	11.59	50 to 97
Internalizing Problems	57.77	11.45	33 to 84
Externalizing Problems	62.27	11.92	54 to 83
Total Problems	62.92	9.88	36 to 81

Table 5 depicts the means, standard deviations, and ranges for Sample C on the teacher reported behavioral variables (TRF). Subject scores on all scales and composites ranged from average to clinical. Clinical elevations were found on the Attention Problems and Aggressive Behaviors scales and the mean score on the Rule-Breaking Behavior scale was slightly below the clinical range. The mean scores on all other syndrome scales were within the average range. On the composite scales, the mean scores for Externalizing Problems and Total Problems were within the clinical range, while the Internalizing Problems score was within the average range. The standard deviations on the syndrome scales suggest that subjects varied the most on the Aggressive Behavior and Withdrawn/Depressed scales. The greatest degree of variation on the composite scales was seen on the Internalizing Behaviors scale.

Table 5

Means, Standard Deviations, and Ranges for Sample C Across Teacher Reported Behavioral Variables

	M	*SD*	Range
Anxious/Depressed	55.62	6.98	50 to 77
Withdrawn/Depressed	57.05	8.90	50 to 81
Somatic Complaints	53.40	6.50	50 to 70
Social Problems	60.95	8.41	50 to 85
Thought Problems	59.83	7.71	50 to 77
Attention Problems	67.33	8.14	52 to 87
Rule-Breaking Behavior	64.86	7.25	50 to 85
Aggressive Behavior	65.83	10.69	50 to 92
Internalizing Problems	54.00	11.91	37 to 85
Externalizing Problems	65.83	9.32	43 to 83
Total Problems	65.64	7.83	49 to 84

Exploration of the ADHD subgroup profiles.

The means, standard deviations, *F* statistics, and *p* values for the ADHD subgroups across the neuropsychological variables are reported in Tables 6 and 7, and graphically displayed in Figures 1 and 2. On the WISC–IV variables, significant subgroup-by-score interactions were found on WMI, Digit Span, and Digits Backward. Significant main effects were also found on the CPT–II variables of Hit Reaction Time SE, Variability, Perseverations, Hit SE Block Change, and Hit SE ISI Change. A trend toward significance was also seen for Omissions. Overall, the results of these one-way ANOVAs support meaningful neuropsychological performance differences among the ADHD subgroups.

Table 6

Means, Standard Deviations, and Significance Levels for WISC–IV Variables Across ADHD Subgroups (Sample B)

	IT		IT + INT		CT		CT + EXT			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*
FSIQ	101.61	11.08	94.13	8.06	100.36	14.05	94.67	3.23	1.32	.275
VCI	103.94	11.57	94.13	9.33	101.88	15.61	96.50	12.78	0.98	.410
PRI	104.56	11.68	101.88	10.01	102.36	12.89	97.75	9.78	0.82	.486
WMI	103.11[b]	12.83	87.75	8.07	98.72	11.90	93.58	10.88	3.83	.014
PSI	89.17	11.88	90.50	6.55	96.04	13.97	93.83	12.39	1.20	.317
Vocabulary	10.78	2.51	8.88	1.55	9.84	2.50	9.33	2.02	1.62	.194
Similarities	11.50	2.31	10.12	2.90	10.68	3.22	9.33	3.14	1.39	.256
Comprehension	10.22	2.39	9.88	1.81	10.52	3.02	9.67	2.90	0 .29	.831
Block Design	10.22	2.29	8.38	2.20	9.68	2.80	9.58	1.78	1.08	.364
Matrix Reasoning	11.06	3.35	10.38	1.77	10.20	2.52	9.75	2.45	0 .63	.599
Picture Concepts	11.44	2.62	12.13	2.30	11.08	2.81	9.50	2.65	1.80	.157
Digit Span	10.94	3.46	7.88[a]	1.81	9.92	2.41	8.58	2.12	3.35	.025
Digits Forward	10.17	3.38	8.63	2.26	9.28	2.23	8.67	3.39	0 .91	.444
Digits Backward	11.00	2.33	7.00[ac]	2.07	9.68	2.34	9.08	2.23	5.84	.001
LNS	10.28	2.40	7.88	2.70	10.04	2.57	9.33	2.64	1.90	.139
Coding	7.56	2.09	8.13	2.17	8.92	3.07	8.83	3.19	0.99	.403
Symbol Search	8.67	2.87	8.63	1.19	9.68	2.41	9.00	1.76	0.83	.482

Note. WISC–IV = Wechsler Intelligence Scale for Children-Fourth Edition (Wechsler, 2003). ADHD = Attention-Deficit/Hyperactivity Disorder. IA = ADHD inattentive type. IA + INT = inattentive type plus internalizing disorders. CT = ADHD combined type. CT + EXT = combined type plus externalizing disorders. FSIQ = Full Scale IQ. VCI = Verbal Comprehension Index. PRI = Perceptual Reasoning Index. WMI = Working Memory Index. PSI = Processing Speed Index. LNS = Letter-Number Sequencing

[a] Lower than IA group. [b] Lower than IA +INT group. [c] Lower than CT group. [d] Lower than CT + EXT group.

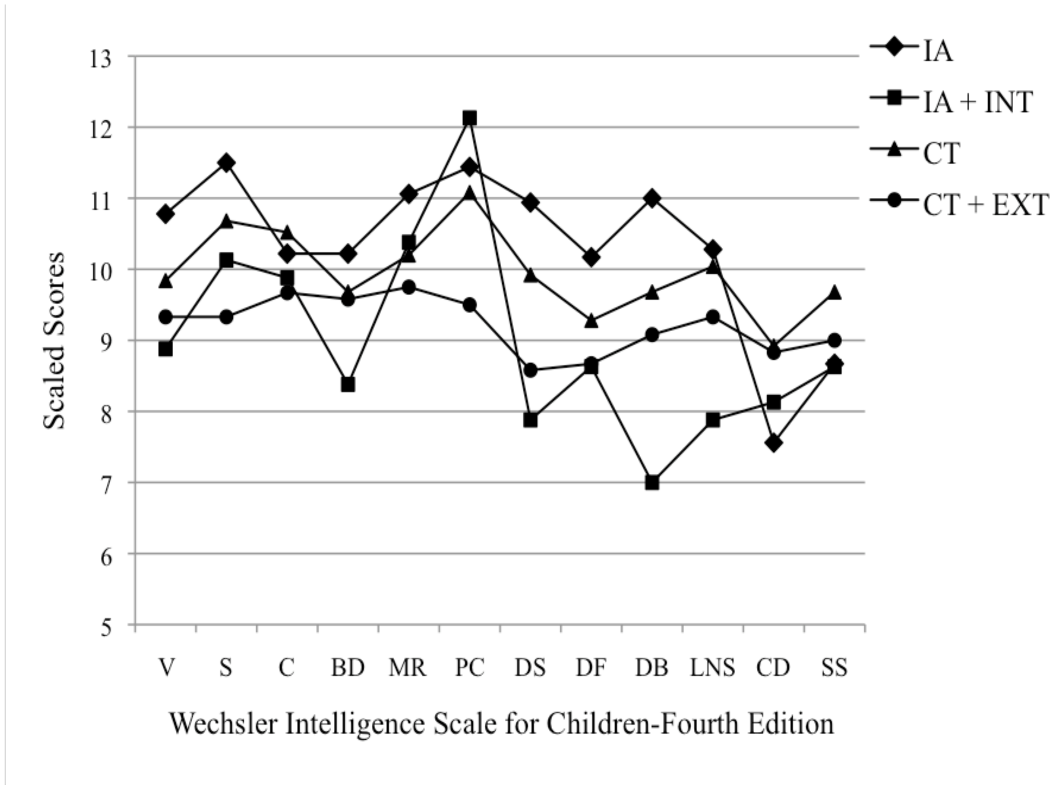

Figure 1. Cognitive profiles for ADHD subgroups. IA = inattentive type. IA + INT = inattentive type + internalizing disorders. CT = combined type. CT + EXT = combined type + externalizing disorders. V = Vocabulary. S = Similarities. C = Comprehension. BD = Block Design. MR = Matrix Reasoning. PC = Picture Concepts. DS = Digit Span. DF = Digits Forward. DB = Digits Backward. LNS = Letter-Number Sequencing. CD = Coding. SS = Symbol Search.

Table 7

Means, Standard Deviations, and Significance Levels for CPT–II Variables Across ADHD Subgroups (Sample B)

	IT		IT + INT		CT		CT + EXT			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*
Omissions	53.04	10.31	54.68	15.91	60.24	21.75	70.88	20.64	2.51	.067
Commissions	52.45	9.42	43.72	8.46	51.24	11.85	50.87	7.28	1.45	.227
Hit RT	51.21	13.75	54.94	12.75	54.97	14.86	59.07	11.77	0.79	.503
Hit RT SE	54.01[d]	9.27	50.97[d]	8.54	58.74	12.69	66.10	8.53	4.39	.007
Variability	54.56[d]	9.67	48.17[d]	8.89	58.02	11.03	64.62	6.87	5.13	.003
Detectability	52.67	7.03	50.35	9.93	53.69	10.10	53.70	7.48	0.32	.808
Response Style	52.50	10.98	51.37	12.13	53.80	12.24	53.08	4.76	0.12	.949
Perseverations	57.32[d]	20.10	47.61[d]	3.08	65.07	29.76	77.13	25.71	2.76	.050
Hit RT Block Change	52.07	12.99	44.76	7.97	55.81	11.97	55.13	12.75	1.99	.125
Hit SE Block Change	53.30	11.98	44.29[cd]	4.65	56.54	10.18	49.30	7.28	4.31	.008
Hit RT ISI Change	53.57	9.31	51.78	8.14	56.84	14.24	62.50	11.92	1.80	.157
Hit SE ISI Change	53.69	9.04	50.78[d]	7.97	55.83	7.49	61.18	7.65	3.23	.029

Note. ADHD = attention-deficit/hyperactivity disorder. IA = ADHD inattentive type. IA + INT = inattentive type plus internalizing disorders. CT = ADHD combined type. CT + EXT = combined type plus externalizing disorders. ISI = Interstimulus Interval. RT = Reaction Time

[a] Lower than IA group. [b] Lower than IA +INT group. [c] Lower than CT group.

[d] Lower than CT + EXT group.

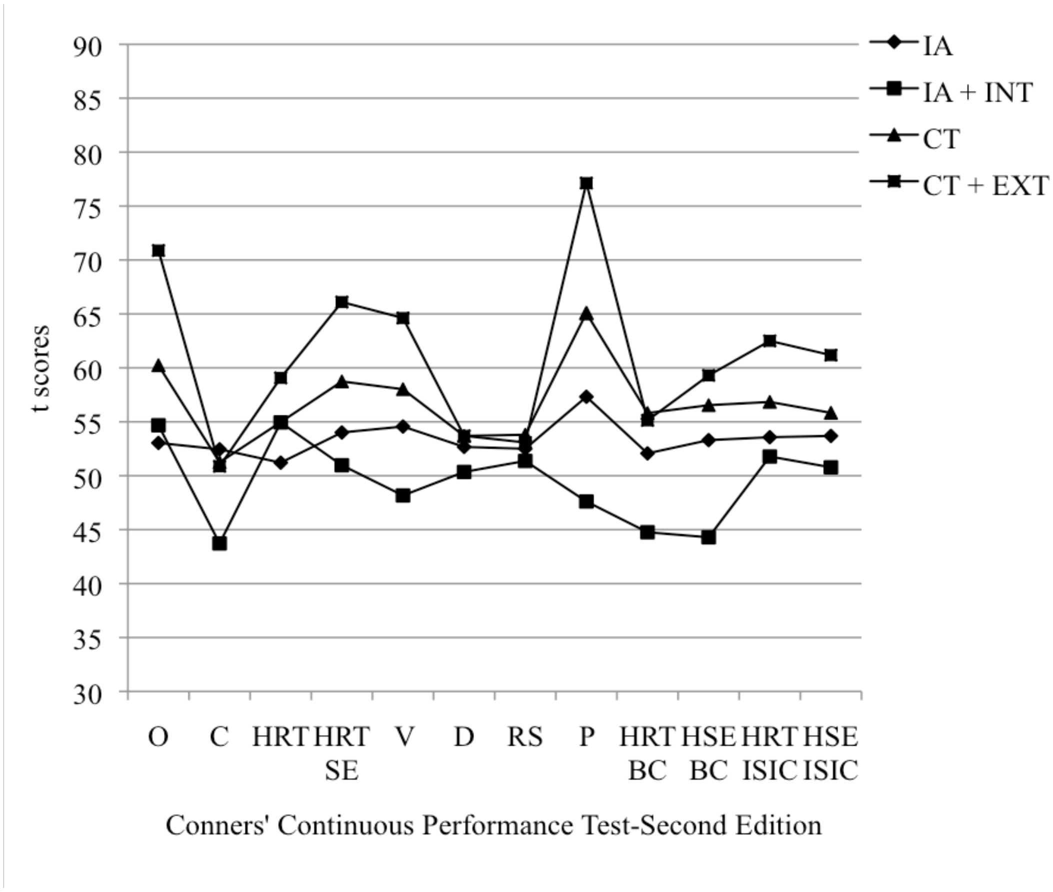

Figure 2. Attention profiles for ADHD subgroups. IA = inattentive type. IA + INT = inattentive type + internalizing disorders. CT = combined type. CT + EXT = Combined Type + externalizing disorders. O = Omissions. C = Commissions. HRT = Hit Reaction Time. HRT SE = Hit Reaction Time Standard Error. V = Variability. D = Detectability. RS = Response Style. P = Perseverations. HRT BC = Hit Reaction Time Block Change. HRT ISIC = Hit Reaction Time Interstimulus Interval Change. HSE ISIC = Hit Standard Error Interstimulus Interval Change.

Findings for the ASEBA CBCL and TRF behavioral variables are reported in Tables 8 and 9, and graphically displayed in Figures 3 and 4, respectively. ANOVA identified many significant differences among the ADHD subgroups along the behavioral dimensions. Parent ratings of behavior suggested significant differences among the ADHD subgroups on the Anxious/Depressed, Social Problems, Thought Problems, Rule-Breaking Behavior, and Aggressive Behavior syndrome scales. ANOVAs conducted with teacher ratings yielded significant findings for the Withdrawn/Depressed, Somatic Complaints, Attention Problems, Rule-Breaking Behavior, and Aggressive Behavior syndrome scales. Parent and teacher ratings both suggested significant ADHD subgroup differences on the Externalizing and Total Problems scales. Teacher ratings also yielded a significant finding for the Internalizing scale. In summary, the results of these one-way ANOVAs support meaningful differences in the ADHD subgroups on parent and teacher ratings of behavior.

Table 8

Means, Standard Deviations, and Significance Levels for Parent Reported Behavioral Variables Across ADHD Subgroups (Sample B)

	IT		IT + INT		CT		CT + EXT			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*
Anxious/Depressed[i]	56.00[bd]	7.83	64.63	12.01	56.56[b]	7.12	62.92	10.67	2.80	.048
Withdrawn/Depressed	56.28	7.46	66.00	11.45	57.56	9.17	57.17[b]	7.16	2.44	.074
Somatic Complaints	58.94	6.44	59.38	8.55	58.36	9.20	60.75	7.82	0.36	.784
Social Problems	54.11[d]	4.00	63.25	11.88	57.00	5.94	64.67	11.44	5.19	.003
Thought Problems	56.56[b]	6.79	63.88	10.34	60.72	7.61	63.08	7.10	3.11	.033
Attention Problems	66.33	10.47	75.50	6.53	68.52	12.07	72.42	9.39	1.11	.353
Rule-Breaking Behavior	55.33[bd]	5.52	64.25	11.06	59.88	8.75	67.33	7.66	5.50	.002
Aggressive Behavior	57.56[bd]	6.89	70.50	12.11	61.28[d]	6.97	78.00	12.53	14.55	.000
Internalizing Problems	55.50	10.84	64.75	11.89	55.33	11.46	61.00	10.55	2.20	.128
Externalizing Problems	54.81[d]	11.44	66.63	14.96	60.58[d]	8.74	72.67	7.91	12.06	.000
Total Problems	57.56[bd]	8.44	68.63	9.57	60.88[d]	9.15	70.33	7.68	8.19	.001

Note. ADHD = attention-deficit/hyperactivity disorder. IA = ADHD inattentive type. IA + INT = inattentive type plus internalizing disorders. CT = ADHD combined type. CT + EXT = ADHD combined type plus externalizing disorders. As advised in the ASEBA manual, *F* and *p* values for the syndrome scales were calculated using raw scores, and t scores were used for the composite scales (Achenbach & Rescorla, 2001).

[a] Lower than IA group. [b] Lower than IA +INT group. [c] Lower than CT group.

[d] Lower than CT + EXT group.

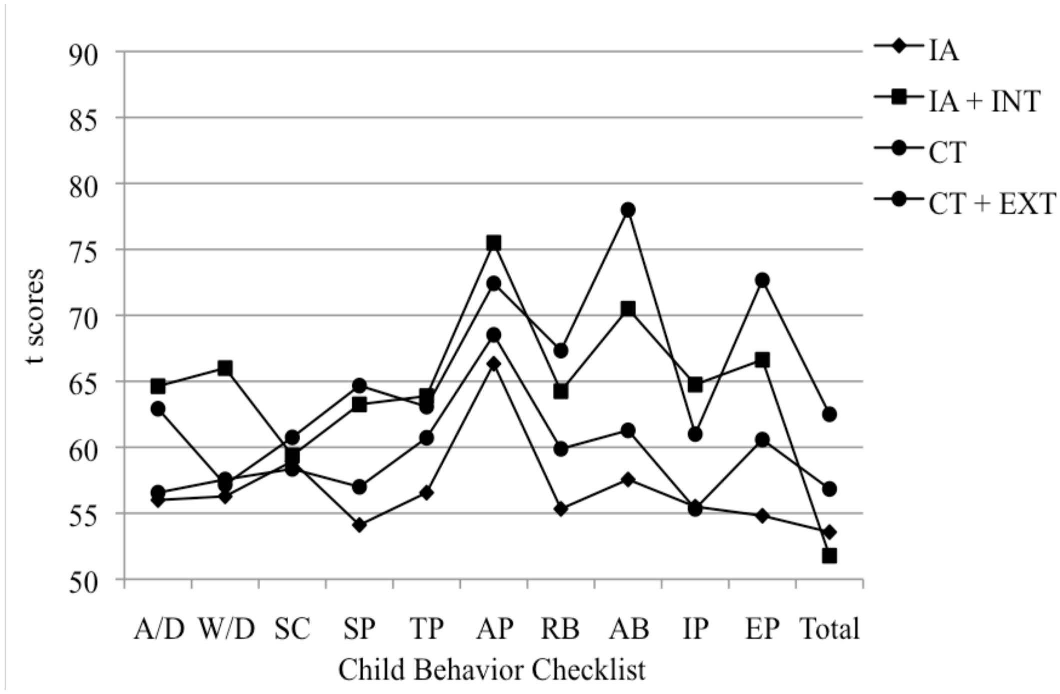

Figure 3. Parent reported behavioral profiles for ADHD subgroups. IA = inattentive type. IA + INT = inattentive type + internalizing disorders. CT = combined type. CT + EXT = combined type + externalizing disorders. A/X = Anxious/Depressed. W/D = Withdrawn/Depressed. SC = Somatic Complaints. SP = Social Problems. TP = Thought Problems. AP = Attention Problems. RB = Rule-Breaking Behavior. AG = Aggressive Behavior. IP = Internalizing Problems. ET = Externalizing Problems. Total = Total Problems.

Table 9

Means, Standard Deviations, and Significance Levels for Teacher Reported Behavioral Variables Across ADHD Subgroups (Sample C)

	IT		IT + INT		CT		CT + EXT			
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*
Anxious/Depressed	51.44	2.88	57.00	4.87	56.54	7.25	56.83	9.22	1.41	.254
Withdrawn/Depressed	56.56[b]	8.73	68.88	9.02	53.15[b]	3.70	53.75[b]	6.41	12.70	.000
Somatic Complaints	52.22	6.67	60.50	7.56	50.85[b]	2.30	52.33	2.30	3.23	.033
Social Problems	56.78	6.22	64.13	11.21	61.00	8.28	61.92	7.62	1.40	.258
Thought Problems	57.33	7.79	58.50	6.16	61.38	8.08	60.92	8.54	0.47	.705
Attention Problems[1]	63.56[bcd]	10.78	68.88	5.99	67.08	4.39	69.42	10.01	3.02	.042
Rule-Breaking Behavior	57.67[cd]	6.04	66.00	8.42	67.31	7.02	66.83	3.97	3.87	.016
Aggressive Behavior	57.00[d]	9.70	67.38	13.39	66.77	6.71	70.42	10.23	3.05	.040
Internalizing Problems	48.89[b]	10.03	63.88	8.00	53.92	12.02	51.33	12.56	4.87	.045
Externalizing Problems	56.67[bcd]	9.34	67.38	10.76	67.92	6.63	69.92	6.63	3.40	.006
Total Problems	59.44[b]	9.02	69.13	7.89	66.46	7.89	67.08	7.34	2.91	.044

Note. ADHD = attention-deficit/hyperactivity disorder. IA = ADHD inattentive type. IA + INT = inattentive type plus internalizing disorders. CT = ADHD combined type. CT + EXT = combined type plus externalizing disorders. As advised in the ASEBA manual, *F* and *p* values for the syndrome scales were calculated using raw scores and t scores were used for the composite scales (Achenbach & Rescorla, 2001). [a] Lower than IA group. [b] Lower than IA +INT group. [c] Lower than CT group. [d] Lower than CT + EXT group.

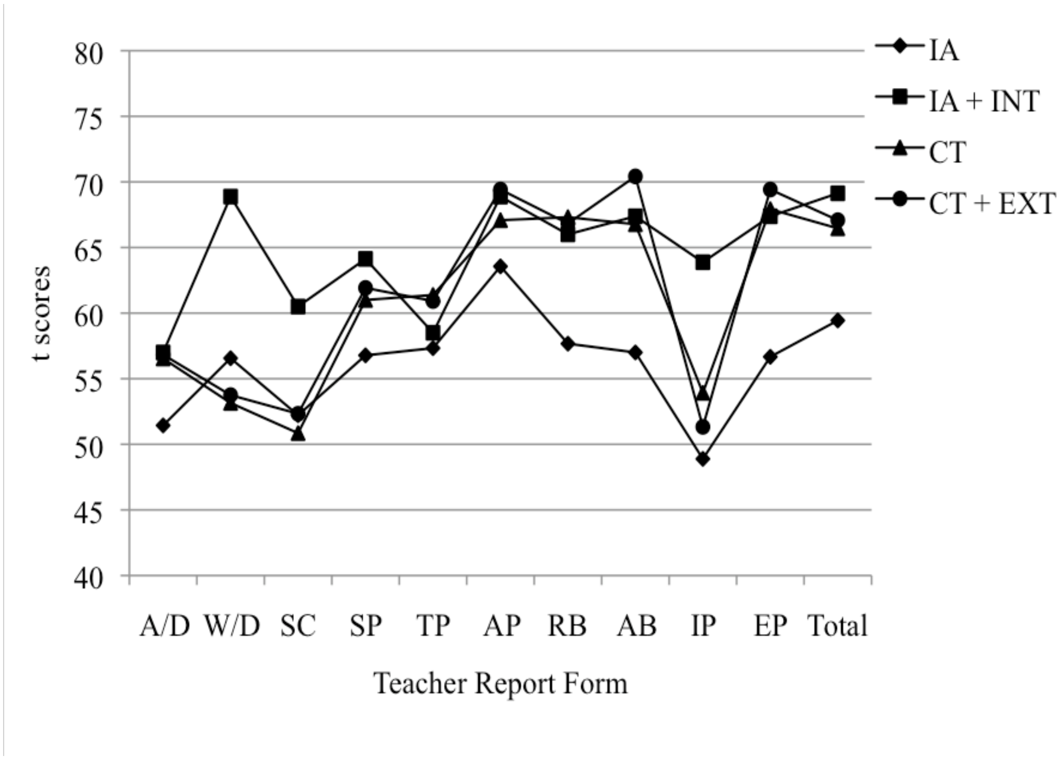

Figure 4. Teacher reported behavioral profiles for ADHD subgroups. IA = inattentive type. IA + INT = inattentive type + internalizing disorders. CT = combined type. CT + EXT = combined type + externalizing disorders. A/D = Anxious/Depressed. W/D = Withdrawn/Depressed. SC = Somatic Complaints. SP = Social Problems. TP = Thought Problems. AP = Attention Problems. RB = Rule-Breaking Behavior. AB = Aggressive Behavior. IP = Internalizing Problems. EP = Externalizing Problems. Total = Total Problems.

Neuropsychological and behavioral characteristics of the inattentive type subgroup. As reported in Table 6, the IA group had an overall mean FSIQ within the average range. Though not statistically significant, compared to the other subgroups, this score was the highest. Furthermore, the IA group also had the highest mean performance on the VCI, PRI, and WMI, as well as the corresponding subtests in those indexes (average range), but these values were not significantly higher than the other group means. Despite strong performance on the VCI, PRI, and WMI areas, the IA group's mean PSI score was the lowest among the ADHD subgroups, falling within the low average range. Their mean score on the Coding subtest was within the low average range, and was the lowest among the ADHD subgroups. The IA group's mean score on Symbol Search fell within the Average range, and was slightly lower than that of the IA + INT group. Again, none of these differences were significant when compared to the other groups.

Statistical significance was reached on select working memory measures. The IA group's mean scores on the WMI (p = .015), Digit Span (p = .041), and Digits Backward (p = .001) subtests represented significant strengths in comparison to the IA + INT group. Additionally, a trend toward significance on Digit Span was also found as compared to the CT + EXT group (HSD p = .090, LSD p = .020), with the IA group demonstrating stronger performance.

In comparison to the CPT–II typical population norms, the IA group performed within the average (non problematic) range on all scales, with the exception of Perseverations, the score for which was within the mildly atypical range (see Table 7). This suggests that the IA group generally demonstrated good accuracy, consistency, and sustained attention/vigilance throughout the test (Conners & MHS Staff, 2004). However, they were somewhat prone to repetitive behavior, impulsive responding, or responding slowly to stimuli.

The IA group outperformed the other ADHD subgroups (lower t scores indicating better performance) on Omissions and Hit RT. They had the second best scores (following the IA + INT, group) on Hit RT SE, Variability, d′, β, Perseverations, and Hit RT Block Change. Although still within the non-problematic range, the IA group's mean score on Commissions was the lowest in comparison to the other subgroups.

Mean scores suggest that compared to the CT + EXT group, the IA group demonstrated several areas of strength. Mean scores for the IA group on Hit RT SE (p = .017), Variability (HSD p = .036), and Perseverations (HSD p = .144, LSD p = 011) were significantly lower than those of the CT + EXT group. Trends toward significance were also found on Omissions (HSD p = .052, LSD p = .011) and Hit SE ISI Change (HSD p = .070, LSD p = .015). These findings suggested that the IA group correctly responded to an increased number of targets throughout the test and maintained better consistency in reaction time as changes in ISI lengths occurred, compared to the CT + EXT group (Conners & MHS Staff, 2004).

Parent behavioral report data, as presented in Table 8, suggests few areas of concern areas for the IA group. With the exception of the Attention Problems scale, the mean scores for the IA group all were within the average range. Their mean scores on the various CBCL scales were also the lowest of all the subgroups, with the exceptions of the Withdrawn/Depressed (IA > CT, and CT + EXT groups) and the Somatic Complaints (IA > CT) scales.

Compared to the groups with comorbidity, the IA group had significantly lower levels of parent-reported problematic behavior in several areas. Despite significance identified by ANOVA on the Anxious/Depressed scale, the HSD statistic did not find significant differences. However, using the LSD statistic, the IA group had lower mean scores than the IA + INT (HSD p = .145, LSD p = .034) and CT + EXT groups (HSD p = .189, LSD p = .047). The IA group also displayed a lower mean level of Thought Problems (p = .046) than the IA + INT group. The mean scores for the IA group were significantly lower on the Rule-Breaking Behavior and Aggressive Behavior scales than the IA + INT group (p = .025, p = .009, respectively) and CT + EXT group (p = .003, p < .001, respectively). The Social Problems score was significantly lower than in the CT + EXT group (p = .004), and nearly significant in the IA + INT group (HSD p = .056, LSD p = .012). The IA group's mean score on the Externalizing Problems scale was significantly lower than that of the CT + EXT group ($p < .001$), and the difference approached significance with the IA + INT group (HSD $p = .051$, LSD $p = .011$). A lower mean score on the Total Problems Scale suggests that the IA group was less behaviorally impaired overall than the groups with comorbidity (IA + INT $p = .025$, CT + EXT $p = .017$).

Similar results to the CBCL were found on the TRF variables for the IA group (see Table 9). The IA group's mean scores on all scales were within the average range, with the exception of Withdrawn/Depressed and Somatic Complaints scales. These scores were the lowest out of the ADHD subgroups, with relative elevations on the Withdrawn/Depressed scale (IA > CT and CT + EXT) and Somatic Complaints scale (IA > CT).

Numerous areas of statistical significance were found on teacher report data for the IA group. Compared to the IA + INT group, the IA group was rated significantly lower on the Withdrawn/Depressed scale ($p < .001$). Compared to the CT + EXT group, the IA group had a lower mean score on Aggressive Behavior ($p = .026$). A significantly lower level of Rule-Breaking Behavior was found in the IA group than the CT group ($p = .025$) and CT + EXT ($p = .027$) group, with a trend toward significance also seen with the IA + INT group (HSD $p = .067$, LSD $p = .015$). Using the LSD statistic (HSD statistic was not significant despite a significant ANOVA), the IA group had a significantly lower level of Attention Problems than all other ADHD subgroups (IA + INT HSD $p =$

.191, LSD *p* = .048; CT HSD *p* = .056, LSD *p* = .012; CT + EXT HSD *p* = .053, LSD *p* = .011).

The IA group also had significantly lower between-group mean scores on the teacher report composite scales. The Internalizing Problems score was significantly lower in the IA + INT group (*p* = .041). Externalizing Problems was significantly lower in the IA group than in all other groups (IA + INT *p* = .011, CT *p* = .003, CT + EXT *p* = .001). Finally, the IA group had a significantly lower mean score on the Total Problems scale, compared to the IA + INT group (*p* = .046).

Neuropsychological and behavioral characteristics of the inattentive plus internalizing disorders group. The IA + INT group's mean FSIQ was within the average range (see Table 6). However, it was the lowest among the ADHD subgroups. The mean VCI and PRI scores were within the average range. On the VCI and PRI, the IA group was outperformed by the IA and CT groups, but the IA group fared slightly better than the CT + EXT group in these areas. The IA + INT group's mean performance on Picture Concepts subtests was noteworthy, as it bordered on high average and was the highest among the ADHD subgroups. The IA + INT group experienced the most difficulty on the WMI composite and related subtests, with WMI, Digit Span, Digits Forward, Digits Backward, and Letter Number Sequencing scores representing the lowest performance among the ADHD subgroups. While the mean score on Digits

Forward was within the average range, the WMI, Digits Span, Digits Backward, and Letter-Number Sequencing scores all were within the low average range. The IA + INT group scored slightly higher than the IA group on the PSI, with a mean score that fell within the lower limits of the average range. However, unlike the IA group, which had demonstrated more difficulty on Coding than Symbol Search, the IA + INT group had similar performance on these subtests.

The IA + INT had significant between-group differences on select working memory measures. In comparison to the IA group, the IA + INT group's scores on WMI ($p = .015$) and Digit Span ($p = .041$) were significantly lower. Additionally, the score on Digits Backward was significantly worse than both the IA ($p = .001$) and CT ($p = .029$) groups.

On the CPT–II, the IA + INT group's mean scores fell within the good range (indicating better than average performance) on Commissions, Hit RT Block Change, and Hit SE Block Change. Their performance on all remaining variables was within the average range. This pattern of performance suggests that subjects in the IA + INT group were average in the number of targets that they correctly responded to, the speed at which they responded, and their consistency in response speed (Conners & MHS Staff, 2004). Better than average scores on Commissions, Hit RT Block Change, and Hit SE Block Change suggest that these subjects exercised an unusual level of care to only respond to the correct targets, they maintained their alertness and vigilance throughout the test, and their reaction time became increasingly consistent as the test progressed (Conners & MHS Staff, 2004). Overall, mean scores suggest that the IA + INT group demonstrated the strongest performance on all CPT–II indices, with the exception of Omissions, which was slightly higher than the IA group's mean score. However, their Omissions score was still within normal limits (i.e., average range).

The CPT–II mean scores of the IA + INT group reached statistical significance in several areas. Compared to the CT + EXT group, the IA + INT group had significantly stronger performance on the Hit RT SE (p = .014) and Hit SE ISI Change (p = .031) indices. An additional trend toward significance was seen on Perseverations (p = .051, LSD p = .011). These findings suggest that the IA + INT group was significantly more consistent in their response speed, including when ISI length increased, compared to the CT + EXT group (Conners & MHS Staff, 2004). The mean score differences on Perseverations suggests that the IA + INT group was also less impulsive/more controlled in their responding (Conners & MHS Staff, 2004). The IA + INT also significantly outperformed both the CT (p =.016) and CT + EXT groups (p = .007) on Hit SE Block Change, which suggests that their response speed remained more consistent as the test progressed (Conners & MHS Staff, 2004). Additionally, they also performed significantly better on Variability than the CT + EXT group (p = .003) and demonstrated a trend toward significance with the CT group (HSD p = .071, LSD *p* = .000). These findings suggest that the IA + INT group showed less inter-respondent variability in their performance as compared to the CT groups (Conners & MHS Staff, 2004).

On the parent report behavioral report (see Table 8), the IA + INT group had clinical elevations on the Withdrawn/Depressed, Attention Problems, Aggressive Behavior, Internalizing Problems, Externalizing Problems, and Total Problems scales. The mean scores on the Anxious/Depressed and Rule-Breaking Behavior scales were slightly below the clinical range. The IA + INT group had the highest mean scores on the Anxious/Depressed, Withdrawn/Depressed, Thought Problems, and Attention Problems scales.

The IA + INT group's mean scores on CBCL on the Anxious/Depressed (HSD *p* = .145, LSD *p* = .034), Thought Problems (*p* = .046), Rule Breaking Behavior (*p* = .025), Aggressive Behavior (*p* = .009), Externalizing Problems (*p* = .007), and Total Problems scales (*p* = .006) were significantly higher than those of the IA group. Additionally, their Anxious/Depressed score was significantly greater than that of the CT group (HSD *p* = .189, LSD *p* = .047). A trend toward significance was also found in comparison to the IA group on the Social Problems scale (HSD *p* = .056, LSD *p* = .012), suggesting that subjects in the IA + INT group exhibited increased social difficulties.

On the teacher report, (Table 9), the mean scores for the IA + INT group were within the clinical range on the Withdrawn/Depressed, Attention Problems, Rule-Breaking Behavior, and Aggression syndrome scales. The mean score on Social Problems also was slightly below the clinical range. Additionally, Internalizing Problems, Externalizing Problems, and Total Problems were all elevated in the IA + INT group.

Among TRF data for the ADHD subgroups, the IA + INT group's mean scores on the Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, and Social Problems scales were the highest. Attention problems ranked second highest among the ADHD subgroups (below the CT + EXT group). The IA + INT group also had the highest mean scores on the Internalizing Problems and Total Problems scales.

Statistical support was found for the IA + INT group's TRF scores related to internalizing factors. Mean scores on the Withdrawn/Depressed and Internalizing Problems scales were higher than those of the IA group (p = .001, p = 012, respectively), CT group (p = < .001, p = .007, respectively) and the CT + EXT group (p = <.001, p = .012, respectively). Additionally, the IA + INT group's mean score on Somatic Complaints was higher than that of the CT group (p = .021).

Neuropsychological and behavioral characteristics of the combined type group. As seen in Table 6, the CT group performed within the average range on all WISC–IV indexes and subtests. After the IA group, they earned the second highest mean scores on FSIQ, VCI, PRI, and WMI. Their PSI performance was the strongest among the ADHD subgroups. The CT group appeared to demonstrate a relative strength in Picture Concepts and a relative weakness in Coding. Despite these patterns, no between-group differences reached statistical significance.

More notable results were found for the CT group on the CPT–II (see Table 7). The CT group's mean score on Perseverations was within the markedly atypical range. The score for Omissions was also relatively high, falling within the moderately atypical range. Hit RT SE, Variability, Hit RT Block Change, Hit SE Block Change, and Hit RT ISI Change were mildly atypical. The CT group's mean scores on all other CPT-II indices were in the Average range. This pattern of performance suggests that the CT group demonstrated increased difficulties with inattention, impulsivity, and vigilance (Conners & MHS Staff, 2004). In comparison to the ADHD subgroups in the present study, the CT group demonstrated the second weakest performance on the CPT (after the CT + EXT group). However, the only statistically significant finding for the CT group on CPT–II performance was a significantly lower mean score on Hit SE Block Change with the IA group (p = .016).

On the parent report behavioral variables (see Table 8) the CT group's mean scores indicated clinical elevations on the Attention Problems, Externalizing Problems, and Total Problems scales. The mean scores on all remaining scales were within the average range. The CT group had similar mean scores to the IA group on the internalizing scales. However, the scores on the Rule-Breaking Behavior, Aggressive Behavior, and Thought Problems scales were higher than those of the IA group.

Parent report data for the CT group showed several areas of statistically significant between-group differences. The CT group's mean scores were significantly lower than those of the IA + INT group on the Anxious/Depressed scale (HSD p = .189, LSD p = .047). Compared to the CT + EXT group, the mean scores of the CT group were significantly lower on the Externalizing Problems (p = .002) and Total Problems (p = .017) scales. Additionally, a trend toward significance was found on the Social Problems scale (HSD p = .069, LSD p = .015), suggesting that the CT group exhibited a lesser degree of social difficulties than the CT + EXT group.

TRF mean scores for the CT group were within the clinical range on the Attention Problems, Rule-Breaking Behavior, Aggressive Behavior, Externalizing Problems, and Total Problems scales (see Table 9). Their scores on the Anxious/Depressed, Withdrawn/Depressed, Somatic Problems, Social Problems, Thought Problems, and Internalizing Problems scales were within the average range, results common in children with CT (Barkley, 2005).

Significant between-group differences were found on the TRF scores for the CT group. The CT group's mean scores were significantly lower than the IA + INT group's on the Withdrawn/Depressed scale (p = .001) and Somatic

Complaints scale (p = .021). Additionally, the CT group's mean score was significantly lower on the Internalizing Problems scale than the IA + INT group (p = .007).

Neuropsychological and behavioral characteristics of the combined type plus externalizing disorders group. As can be seen in Table 6, the CT + EXT group earned an FSIQ mean score within the average range. However, it was relatively commensurate with the IA + INT group's score. The CT + EXT group appeared to demonstrate the least degree of variance in their WISC–IV profile. Their performance on all composites and subtests was within the average range. At the composite level, relative strengths were seen on the VCI and PRI and relative weaknesses on the WMI and PSI. However, at the subtest level, their mean performance did not differ by more than one point across the entire test. The CT + EXT group did not exhibit any statistically significant between-group differences on the WISC–IV.

Compared to the other ADHD subgroups, mean scores suggest that the CT + EXT group generally demonstrated the highest degree of difficulty on the CPT–II indices (see Table 7). The mean scores on Omissions and Perseverations were within the markedly atypical range. Moderately atypical elevations were found on Variability, Hit RT ISI Change, and Hit SE ISI Change. Additionally, the mean scores on Hit RT, Hit RT Block Change, and Hit SE Block Change were mildly atypical. This pattern of performance suggests that the CT + EXT group had significant difficulties with inattention, impulsivity, and vigilance (Conners & MHS Staff, 2004).

The CT + EXT group demonstrated several areas of significant weakness on the CPT. The mean scores were significantly higher than those of the IA group on Hit RT SE (p = .017), Variability (p = .036), and Perseverations (HSD p = .144, LSD p = .011). Trends toward significance were also found on Omissions (HSD p = .052, LSD p = .011) and Hit SE ISI Change (HSD p = .070, LSD p = .015), as compared to the IA group's scores. In comparison to the IA + INT group, the CT + EXT group had significantly higher mean scores on the Hit RT SE (p = .014), Hit SE Block Change (p = .007), Hit SE ISI Change (p = .031), and Variability (p = .003) indices. An additional trend toward significance was seen on Perseverations (HSD p = .051, LSD p = .011).

As previously discussed, the CT group also had difficulties with inattention, impulsivity, and vigilance on the CPT. However, the performances of these two groups differed in that the CT + EXT demonstrated a higher level of impairment than the CT group, especially in failure to respond to targets (Omissions) and maintaining reaction time speed and consistency as the ISIs increased in length (Hit RT ISI Change and Hit SE ISI Change). Additionally, the CT + EXT group had slower than average response speeds (Hit RT), whereas the CT group was not impaired in this area.

CBCL mean scores for the CT + EXT group were within the clinical range on the Attention Problems, Rule-Breaking Behavior, Aggressive Behavior, Internalizing Problems, Externalizing Problems, and Total Problems scales (see Table 8). Social Problems bordered on the clinical range. Scores on the Anxious/Depressed, Withdrawn/Depressed, Somatic Complaints, and Thought Problems scales were within the average range. The CT + EXT group had the highest mean scores on the Rule-Breaking Behavior, Aggressive Behavior, Social Problems, Somatic Complaints, Externalizing Problems, and Total Problems scales.

The CT + EXT group had statistically significant differences from the other ADHD groups in several areas of parent-reported behavior. They had a higher level of Anxious/Depressed behavior (HSD $p = .189$, LSD $p = .047$) and Social Problems ($p = .004$) than the IA group. Additionally, a trend toward significance was found on the Social Problems scale with the CT group (HSD $p = .069$, LSD $p = .015$). The CT + EXT group had higher mean scores on the Rule-Breaking Behavior ($p = .003$), Aggressive Behavior ($p < .001$), Externalizing Problems ($p < .001$), and Total Problems scales ($p = .017$) than the IA group. The scores on the Aggressive Behavior ($p < .001$), Externalizing Problems ($p = .002$), and Total Problems ($p = .017$) scales were also significantly higher than those of the CT group.

TRF mean scores for the CT + EXT group were within the clinical range on the Attention Problems, Rule-Breaking Behavior, Aggressive Behavior, Externalizing Problems, and Total Problems scales (see Table 9). The scores on Attention Problems, Rule-Breaking Behavior, Aggressive Behavior, Externalizing Problems, and Total Problems were the highest among the ADHD subgroups.

Several areas of statistical significance were also found on the TRF. As compared to the IA group, the CT + EXT group had significantly lower mean scores on the Withdrawn/Depressed scale ($p < .001$), and a trend toward significance was also found on the Internalizing Problems scale with this group (HSD $p = .082$, LSD $p = .018$). The CT + EXT group demonstrated significantly higher mean scores on Attention Problems (HSD $p = .053$, LSD $p = .011$), Rule-Breaking Behavior ($p = .027$), and Aggression ($p = .026$) scales than the IA group.

Discriminant analysis of the ADHD subgroups.

A series of forced-entry discriminant analyses were then conducted to determine whether the neuropsychological and behavioral measures used in this study could accurately predict ADHD subgroup membership. The first discriminant analysis included all WISC–IV subscales (with Digits Forward and Digits Backward replacing Digit Span), CPT–II scales, and CBCL syndrome scales for Sample B. Table 10 presents the pooled within-groups correlations between the predictors and the discriminant functions, individual Wilks lambda, and *F* values. This analysis was used for comparison to behavior data alone approaches (CBCL only, Sample B; TRF only, Sample C), cognitive/ neuropsychological data alone approaches (WISC–IV/CPT–II only, Sample B), and the combined approach with teacher data (WISC–IV/CPT–II, CBCL, TRF, Sample C).

For the major discriminant analysis, the first canonical discriminant function had an eigenvalue of 2.18, and the second function had an eigenvalue of 1.39, but neither was significant, possibly due to small sample size. The Wilks lambda for tests of functions one to three accounted for sufficient variance but was not significant ($\Lambda = .093$, χ^2 (93, $N = 63$) = 105.74, $p = .170$), and the Wilks lambda for tests of functions two to three accounted for sufficient variance but was not significant ($\Lambda = .295$, χ^2 (60, $N = 63$) = 54.28, $p = .684$), indicating that the discriminant functions were not sufficient for subgroup differentiation and should be interpreted with caution. The small number of subjects and large number of predictor variables included in this equation likely contributed to the failure to find significant Wilks lambdas that corresponded to the various functions because of reduced power.

Table 10

Pooled Within-Group Correlations With Standardized Canonical Discriminant Functions for Cognitive/Neuropsychological/Parent Report Discriminant Analysis

	Pooled Correlations				
Variable	Function 1: Behavior/Attention	Function 2: Executive	Function 3: Efficiency	Wilks Λ	*F*
WISC–IV					
Similarities	-.17			.934	1.39
Vocabulary	-.16	.12	-.12	.924	1.62
Comprehension			.12	.985	0.29
Block Design		.17		.948	1.08
Matrix Reasoning	-.10		-.15	.969	0.63
Picture Concepts	-.15	-.18		.916	1.80
Digits Forward	-.13		-.10	.956	0.91
Digits Backward	-.24	.34	-.11	.771	5.84**
Letter-Number Sequencing	-.13	.20		.912	1.90
Coding			.29	.952	0.99
Symbol Search			.31	.959	0 .83
CPT–II					
Omissions	.21	.13	.16	.887	2.51
Commissions		.21		.930	1.49
Hit RT	.13		.10	.961	0 .79
Hit RT SE	.22	.26	.23	.818	4.39**
Variability	.18	.35	.22	.793	5.13**
Detectability			.11	.984	0.32

	Pooled Correlations				
Variable	Function 1: Behavior/Attention	Function 2: Executive	Function 3: Efficiency	Wilks Λ	*F*
Response Style			.10	.994	0.12
Perseverations	.15	.24	.19	.887	2.76*
Hit RT Block Change		.22	.27	.820	1.99
Hit RT ISI Change	.15	.16	.13	.916	4.31**
Hit SE ISI Change	.18	.25	.13	.859	1.80
Anxious/Depressed	.22	-.14	-.15	.875	3.23*
Withdrawn/Depressed		-.30		.890	2.44
Somatic Complaints			-.20	.982	0.36
Social Problems	.34			.791	5.19**
Thought Problems	.22	-.17	.18	.864	3.11**
Attention Problems	.13	-.10		.947	1.11
Rule-Breaking Behavior	.33	-.12	.20	.781	5.50**
Aggressive Behavior	.58			.575	14.55**

Note. Only absolute values of .10 are reported. Raw scores were used in the analysis of CBCL variables due to truncation at 50 (Achenbach & Rescorla, 2001). RT = Reaction Time. ISI = Interstimulus Interval.

$^{*}p < .05$. $^{**}p < .01$

Despite the nonsignificant discriminant functions, this combination of predictor variables still correctly classified 88.9% of individuals in the sample. For children with IA, 14 were correctly classified, while 2 were misclassified as CT. All children with IA + INT were correctly classified. For those with CT, 23 were correctly classified on the basis of discriminant functions, 4 misclassified as IA and 1 predicted to be in the CT + EXT group. Finally, all 11 of the children with CT + EXT were correctly classified. As a result, the WISC–IV, CPT–II, and CBCL seem to be fairly good at differentiating between ADHD subgroups, especially if children have IA + INT or CT + EXT.

Comparing neuropsychological and behavioral approaches in ADHD diagnosis. One of the objectives of this study was to examine whether utilizing a combined neuropsychological/behavioral approach could be of value in the differential diagnosis of ADHD. The author only knows of one such study that evaluated such an approach (Hale et al., 2009a). Strictly behavioral and strictly neuropsychological discriminant analyses were conducted to compare correct classification rates of the ADHD subgroups with the combined approach.

Discriminant analyses that placed a sole reliance on either neuropsychological or behavioral data alone to predict ADHD subgroup membership resulted in similar classification rates. An analysis that included all WISC–IV (Digits Forward and Digits Backward instead of Digit Span) and CPT–II scales resulted in an overall classification rate of 68.3% ($\Lambda = .24$, χ^2 (69, $N =$

63) = 68.39, p = .398). This classification rate suggests that cognitive and neuropsychological variables alone are insufficient for diagnosing ADHD groups, but this should not be surprising, given that diagnoses are based on summative judgments of overt behavior (Hale et al., 2009a). An analysis that used the CBCL syndrome scale scores resulted in a correct classification rate of 71.4% ($\Lambda = .35$, χ^2 (24, $N = 63$) = 58.58, $p < .001$). Conducting this analysis with the corresponding TRF data resulted in a correct classification rate of 69.0% ($\Lambda = .21$ χ^2 (24, $N = 42$) = 54.63, $p = < .001$). These significant findings would be expected, given that diagnosis is made on the basis of behavioral report (Hale et al., 2009a), but classification rates were comparable to the cognitive and neuropsychological variables alone and still poor. These classification rates suggest that using the neuropsychological or behavioral data alone was not as effective as using a combined approach, which resulted in 88.9% of individuals correctly classified, as noted earlier.

A final discriminant analysis was conducted that included the TRF data (Sample C) to determine if the addition of teacher reports of behavior could further improve the overall correct classification rate in a combined neuropsychological/behavioral approach. The predictors for this analysis included the CBCL and TRF syndrome scales, WISC–IV subscales (Digits Forward and Digits Backward substituted for Digit Span), and CPT–II scales. This combination of predictors yielded a 100% correct classification among subjects in the ADHD-IA, IA + INT, CT, and CT + EXT groups (Wilks $\Lambda = .01$, χ^2 (93, $N = 42$) = 117.51, $p = .044$). Clearly, the combination of cognitive and neuropsychological assessment data and parent and teacher behavior ratings provides a highly effective method for differential diagnosis of ADHD, with or without comorbid conditions.

Chapter 5

Discussion

ADHD is a heterogeneous condition that occurs comorbidly with both internalizing and externalizing disorders (Barkley, 2005), which may be distinct among ADHD subtypes given that meta-analyses suggest these may be different disorders (Angold et al., 1999). This study investigated the neuropsychological and behavioral patterns seen in a clinic-referred sample of children aged 6 to 16 who were diagnosed with ADHD IA and CT subtypes, with and without comorbid conditions. The study purpose was to identify whether distinct patterns of neuropsychological/behavioral performance existed among the ADHD-IA, IA + INT, CT, and CT + EXT groups and to determine whether a combined neuropsychological/behavioral approach could accurately differentiate these subgroups. Building upon the premise that ADHD is a heterogeneous condition that can affect both cognition and overt behavior (Hale et al., 2009a, 2009b), neuropsychological and behavior rating variation was expected to be found among the subgroups included in the present study.

This study had several strengths in comparison to past research. Though past studies have examined WISC–IV and CPT–II performance in ADHD children, relatively few studies have included ADHD children with comorbid conditions. In the present study, WISC–IV performance was also analyzed at the subtest level instead of the composite level, which is important, given the subtests within each composite activate diverse cognitive processes (Fiorello et al., 2009; Hale & Fiorello, 2004; Miller & Hale, 2008). Additionally, this study utilized a sample free of psychotropic medication, which could potentially affect neuropsychological performance (Gualtieri, Johnson, & Benedict, 2006; Semrud-Clikeman, Pliszka, & Liotti, 2008).

The first research question explored whether neuropsychological/ behavioral differences existed among the ADHD-IA, IA + INT, CT, and CT + EXT groups, as measured by the WISC–IV, CPT–II, CBCL, and TRF. Each measure revealed some degree of variation among the subgroups, thus suggesting the presence of meaningful neuropsychological and behavioral differences. In general, the comorbid groups (IA + INT and CT + EXT) showed more distinct profiles and more areas of concern than the pure IA and CT groups. This finding may be related to past research that suggests the addition of comorbidity to ADHD generally results in a worsening of outcomes and greater impairment (Biederman et al., 1996; Bowen et al., 2008; Harada et al., 2002; Manassis et al., 2007).

Findings from the WISC-IV proved to be most relevant to the IA + INT group. The IA + INT group was distinguished from the IA group by lower scores on the WMI and Digit Span subtest. Their performance on Digit Span Backwards was also significantly lower than both the IA and CT groups. Past studies have found auditory-verbal working memory to be an area of deficit for individuals with ADHD (Assessmany et al., 2001; Elk et al., 2007; Mayes & Calhoun, 2002, 2007a, 2007b). However, the findings from this study suggest that this deficit may be specific to the inattentive type with comorbid internalizing disorders.

The Digit Span findings in the present study also underscore the importance of considering performance on Digits Forward and Backwards in addition to performance on Digit Span, especially when evaluating a child for ADHD. Other potentially meaningful patterns were seen in the present study among the subgroups in addition to decreased Digits Backward performance in the IA + INT group. The IA and CT + EXT groups demonstrated a reverse pattern to what was seen in the IA + INT group, for they performed better on Digits Backward than Digits Forward. In contrast, the CT group did not vary on Digits Forward vs. Backward.

It is theoretically plausible that the wording of the WISC–IV Digit Span directions may make a difference for IA and CT + EXT groups. Directing the examinee to say the digit strands backward may serve as an executive function prompt that cues the examinee to increase their auditory attention and reward motivation (Sonuga-Barke, 2002). A pattern of lower performance on Digits Forward and better performance on Digits Backward could also suggest deficits in the executive function capacities of *perceive* (cueing the use of sensory and perceptual processes needed to get information from the external environment) and *gauge* (cueing the level of effort needed to meet performance demands)

(McCloskey, Hewitt, Henzel, & Eusebio, 2009). Future studies that utilize larger samples may further reinforce the ADHD subgroup Digit Span performance differences seen in the present study.

The CPT–II was best at distinguishing the IA + INT and CT + EXT groups from each other. The CT + EXT group was significantly less consistent, less vigilant, and demonstrated more lapses of attention than the IA + INT group. They were also more prone to impulsive responding than both IA groups. Individuals with ADHD-CT have been found to respond more impulsively on CPT measures than individuals with ADHD-IA (Solanto et al., 2007). The CT group in this study demonstrated a similar clinical profile to that of the CT + EXT group on the CPT–II. However, the CT + EXT group demonstrated a higher level of impairment than the CT group, especially in areas related to impulsivity and consistency. These results may be consistent with past research that has found an ADHD + ODD/CD presentation to result in poorer CPT performance (Banaschewski et al., 2004; Matier et al., 1992; Newcorn et al., 2001).

Also noteworthy was that the IA + INT group demonstrated a clinical pattern of better than average performance in a number of areas on the CPT-II. This may be related in part to past studies that have found comorbid anxiety to offset impulsivity/response inhibition deficits seen in the CPT performance of ADHD individuals (Manassis et al., 2000; Schatz & Rostain, 2006). However, the IA +INT group's level of consistency and accuracy could also be considered hypervigilant. This may translate to a tendency to become hyperfocused in real world tasks, which may be an additional unique feature of ADHD-IA with comorbid internalizing disorders. *Hyperfocus*, or becoming excessively focused on certain activities to the degree of having difficulty shifting attention to other stimuli, is a symptom of ADHD sometimes discussed in the adult literature (Faraone, Spencer, Montano, & Biederman, 2004). Similarly, this pattern of performance in the IA + INT group may also indicate the presence of too much executive function, which can also lead to high levels of impairment (Hale et al., 2009b). Hale and colleagues(2010) believe that too much executive function may be attributed to hyperactivity of the frontal subcortical circuits, whereas limited executive function is attributed to circuit hypoactivity (Lichter & Cummings, 2001).

Overall, the CPT–II findings of the present study suggest that clinicians may wish to consider using both standard and process-oriented methods when interpreting CPT results. CPT–II guidelines advise that the presence of two or more areas of elevation ($t \geq 60$) generally indicates that an examinee had difficulties with the task. If these guidelines were applied to the mean CPT performance on the subgroups, the performance of the IA + INT group would likely be regarded as clinically insignificant. However, their pattern of performance may convey important information about the neuropsychological functioning of these individuals and the implications it has for their everyday lives.

The behavioral measures proved to be the best way to identify variation among the subgroups, which was not surprising, given that sample subjects were originally diagnosed on the basis of behavioral, not neuropsychological factors (see Hale & Fiorello, 2004; Hale et al., 2009a, 2009b for further discussion on the limitations of relating behavioral/neuropsychological data). The ADHD subgroups differed the most on factors related to anxiety and/or depression, as well as conduct disturbance. Parents viewed the children in the IA + INT group as significantly more anxious and depressed than those in the IA and CT groups, while teachers viewed the IA + INT group as more withdrawn/depressed than children in all other subgroups.

With regard to disruptive/externalizing behaviors, parents and teachers viewed the CT + EXT group as the most prone to aggressive and rule-breaking behavior. This finding is in alignment with past research that suggests children with ADHD + ODD/CD demonstrate increased levels of anger, aggression (Hart et al., 2009), and teacher conflict (Harada et al., 2000). However, the IA + INT group was also rated as demonstrating high levels of rule-breaking and aggressive behavior by teachers and parents.

High levels of rule-breaking and aggressive behavior in the IA + INT group were unexpected because children with anxiety or depression are commonly believed to be quiet and conforming. However, poor frustration tolerance and irritability are associated symptoms of ADHD (Brown, 2009), as well as of anxiety or mood disorders in children (see APA, 2000). Furthermore, severity of irritability has been found to differentiate children with ADHD alone, those with comorbid unipolar depression, and those with comorbid bipolar depression on a continuum of low to high (Mick, Spencer, Wozniak, & Biederman, 2005). This increased irritability may also combine with a selective bias toward threatening stimuli in their environment, as seen in individuals with anxiety or mood disorders (Joormann, Talbot, & Gotlib, 2007; Ladouceur, Dahl, Williamson, Birmaher, & Casey, 2006; Richards, French, Nash, Hadwin, & Donnelly, 2007; Taghavi, Dalgleish, Moradi, Neshat-Doost, & Yule, 2003). As a result, perhaps the combination of ADHD plus an internalizing disorder can result in more volatile behavior than what is normally seen in ADHD-IA or internalizing disorders alone. It could also suggest that consideration of unipolar vs. bipolar symptoms may need to be considered in children with ADHD and mood problems.

It is posited, however, that the nature of aggression seen in the IA + INT group may differ from that of the CT + EXT group. The IA + INT group may behave aggressively out of fear or irritability. In contrast, aggression seen in the CT + EXT group may be more spiteful or vindictive in nature, in accordance with one of the core symptoms of ODD/CD (see APA, 2000). Perhaps the nature of aggression seen in the IA + INT versus CT + EXT groups could be compared to Leonard-Zabel & Feifer's (2009) delineation between *impulsive aggression* (aggression resulting from a quick response to a stimulus while in a state of agitation, more likely in IA + INT) and *premeditated aggression* (executed/planned aggressive acts for individual gain, more likely in CT + EXT). Future studies that analyze item responses on the ASEBA Rule-Breaking and Aggressive Behavior scales by ADHD subgroup may provide additional guidance.

Ratings on the Attention Problems scale also resulted in some interesting findings. The findings suggest that parents rated children in the different subgroups as having similar levels of attention problems (all within clinical range), with no statistically significant subgroup differences found. However, teachers rated the IA group as having significantly lower levels of attention problems than all other groups. In fact, the IA group's mean score on the Attention Problems scale was below the clinical range. Perhaps the IA group struggles more with areas of executive functioning, which are often not well assessed by behavioral rating scales. In contrast, the nature of inattention as exhibited by the IA group may have a more behavioral presentation in the home setting, where the environment is usually less structured and predictable.

The results of the discriminant analyses suggest that the WISC–IV, CPT–II, CBCL, and TRF can effectively differentiate among ADHD-IA, IA + INT, CT, and CT + EXT groups. Incorporating information from all of the measures resulted in the highest correct classification rates. In contrast, analyses conducted with neuropsychological or behavioral information separately resulted in much lower correct classification rates. In accordance with the work of Hale et al. (2009a), the findings of the present study provide additional support for the value of a combined neuropsychological/behavioral approach in ADHD assessment.

The results of the discriminant analyses also have broader implications. In the current economic climate, clinicians are feeling compelled to arrive at diagnostic decisions with increasingly less information (Eisman et al. 2000). Billing allowances are making it more difficult to justify the medical necessity of direct assessments such as the WISC–IV and CPT when evaluating a child for ADHD when the same objectives can be accomplished through the sole use of rating scales. However, the results of the present study suggest that more diversity exists in ADHD than is captured by rating scales alone. Therefore, a sole reliance on behavioral information may result in less accurate diagnosis, which could also have negative implications for treatment efficacy (Hale & Fiorello, 2004; Hale et al., 2009a, 2009b for further discussion on this topic).

Neuropsychological implications.

The findings of this study may also be provide clues about frontal subcortical circuitry involvement in ADHD-IA, IA + INT, CT, and CT + EXT groups. Hale, Bertin, and Brown (2004) posited that children with ADHD likely have dysfunction in one or more of the five main frontal-subcortical circuits. Additionally, dorsolateral dysfunction has been associated with IA and orbitofrontal dysfunction with HI (Hale et al., 2004; as cited in Hale & Fiorello, 2004). Stronger conclusions could be drawn for the comorbid groups than the pure groups within this study, given more variation in results was found in these subgroups.

Findings for the IA group may suggest mild dorsolateral and oculomotor involvement. Though not significantly different from the other ADHD subgroups, the IA group had the lowest PSI score on the WISC–IV, with particular difficulties in Coding. This may be indicative of oculomotor dysfunction (Koziol and Budding, 2009). Their mean scores on the CPT were average in every area, and on the behavioral measures, Attention Problems as rated by parents was the only area found to be in the clinical range. Teachers rated this area as slightly below the clinical level. This may suggest some degree of attentional control problems associated with dorsolateral circuit dysfunction (see Koziol & Budding, 2009). As previously mentioned, the IA group may manifest more executive difficulties, which was not well assessed by the instruments used in the present study. Further compounding this issue is that few studies have compared how the ADHD subtypes compare on tasks of executive functioning (Barkley, 2005).

The findings of this study suggest that dysfunction of the dorsolateral and orbitofrontal circuits may be implicated in ADHD + IA. The dorsolateral circuit is often associated with working memory functions (Nigg, 2006), and the IA + INT group demonstrated difficulties in this area. Furthermore, they struggled with Digits Backward the most, which Hale et al. (2002) found to be related to executive function processes associated with the dorsolateral prefrontal cortex. The dorsolateral circuit is also involved in the deliberate control of action (Nigg, 2006), which could be relevant to the IA + INT group's better than average performance on CPT–II measures of consistency and vigilance. This, in turn, may suggest that the ADHD + IA group has a tendency to be overly controlled and rigid in everyday life situations, which could also to help explain high levels of aggressive behavior. Inflexibility in thought is also believed to be associated with dorsolateral dysfunction (Koziol & Budding, 2009; Tekin & Cummings, 2002). Given the high levels of both internalizing and externalizing behaviors in the IA + INT group, as reported by parents and teachers, orbitofrontal involvement is also likely. Emotional lability, explosive anger, and inappropriate responses to social cues have been related to dysfunction of the orbitofrontal circuit (Koziol & Budding, 2009; Tekin & Cummings, 2002).

Though both IA groups demonstrated dorsolateral involvement, it is suggested that the nature of dorsolateral dysfunction seen in the IA + INT group may differ from that in the IA group. Perhaps the IA + INT group is more prone to hyperactivity in this circuit. In contrast, the IA group may be prone to hypoactivity of the dorsolateral circuit. Differential patterns of dorsolateral dysfunction have been found, with some individuals having difficulties initiating attention, while others have difficulty shifting attention (Koziol & Budding, 2009). It is suggested that the ADHD-IA + INT group in the present study was more prone to problems in shifting attention, whereas the IA group struggled more with initiating attention.

Dorsolateral and orbitofrontal circuit dysfunction are also likely involved in both CT and CT + EXT presentations. This would be logical, given that by definition, children with ADHD-CT have problems with both attention and hyperactivity-impulse control (APA, 2000). Additionally, the orbitofrontal circuit has been associated with behavioral inhibition and impulse control, as well as explosive anger (Koziol & Budding, 2009; Hale & Fiorello, 2004; Nigg, 2006). The CT and CT + EXT groups in the present study also both had difficulties with impulse control and attention on the CPT-II, though the CT + EXT showed greater impairment.

Dorsolateral and orbitofrontal dysfunction may be apparent in the CT and CT + EXT groups, in addition to the IA + INT group. However, it is suspected that the nature of orbitofrontal dysfunction may vary by subgroup in terms of severity and/or activation patterns. The continuum of irritability described by Mick and colleagues (2005) may also be related to orbitofronal circuit involvement. Those with CT likely have the fewest problems due to lower levels of aggression and impulse control. Those with IA + INT may rank next, due to the absence of hyperactivity-impulsivity, but the addition of a mood/anxiety disorder that can add to baseline levels of irritability often seen in ADHD. Finally, those in the CT + EXT group may have the most severe orbitofrontal dysfunction due to hyperactivity/impulsivity plus a conduct disturbance. However, these differences are difficult to parse out, especially for the comorbid groups in the absence of additional information.

Limitations of the present study.

Sample size was a major limitation of the present study. The sample size utilized for the ANOVA and discriminant analysis was relatively small ($N = 63$), thus limiting the power of the statistical tests. The comorbid groups, who showed the most interesting findings, in particular suffered from small sample sizes. Had the sample size been bigger, more significant between-group differences may have been found. For example, Picture Concepts appeared to be emerging as an area of strength for the IA + INT group in comparison to the CT + EXT group. This difference may have been found to be significant with a larger group of subjects.

This study utilized a convenience sample and data was gathered from three different clinics. Hence, controlling for possible extraneous variables, such as examiner characteristics, was not possible. Subjects were children presenting for clinical services. In real world practice, a certain degree of clinical judgment must be exercised in order to obtain the best outcomes for clients and to work within the framework of managed care. In contrast, if subjects were evaluated solely for experimental purposes, more uniform control could be imposed such as the combination of information needed in order to diagnose a comorbid condition. Additionally, most subjects came from the clinic in the Midwest, which may hinder how well the results can be generalized to other populations, such as those residing in the other regions of the U.S.

The composition of the ADHD subgroups in this study may also represent an additional limitation. Due to limited sample size, subjects with ADHD-NOS were combined with the IA group and those with HI were combined with the CT group. Though similar methods have been used in past research, it is possible that meaningful differences may have existed between these clinical groups had they been analyzed independently. For example, the NOS group may demonstrate more SCT characteristics such as slow processing speed as compared to the IA group, for only 30-50% of ADHD-IA individuals are believed to manifest these characteristics (see Barkley, 2005). Less concern exists for combining the HI subjects in with the CT group. In population samples, ADHD-HI is the subtype diagnosed the least (see Spencer, 2007), and inattentive symptoms often become more apparent as a child ages, thus revealing a true CT presentation (see Barkley, 2005). On the other hand, it is also possible that ADHD-HI may represent a distinct condition all together, for some researchers have suggested that it may be an early presentation of bipolar disorder (see Papalos & Papalos, 2006).

The use of ASEBA (CBCL and TRF) rating scales as measures of subject behavior also represent a possible limitation to this study. The ASEBA like other psychosocial self-report measures of behavior is subjective in nature, for it relies on a rater's impressions of a child's behavior. Additionally, the primary analyses for this study were conducted using parent-report data (CBCL). Parents have been shown to be less reliable reporters of child behavior than teachers (Youngstrom, Loeber, & Stouthamer-Loeber, 2000). Therefore, having TRF data on all subjects would have been ideal.

Directions for future research.

In addition to the use of a larger sample size, future researchers may wish to consider additional ADHD subgroups. The focus of the present study was on ADHD-IA, IA with internalizing conditions, CT, and CT with externalizing conditions. However, it would also be of value to explore ADHD-CT with comorbid internalizing disorders. Some research suggests that internalizing disorders occur at similar rates across ADHD subtypes (Acosta et al., 2008; Elia et al., 2008; Power et al., 2004). Exploring the neuropsychological/behavioral patterns seen in ADHD + learning disorders could also be considered, for comorbid learning disorders occur in an estimated 31% cases (DuPaul & Stoner, 2003). Additionally, it is recommended that comorbid anxiety and depression be explored as separate comorbidities instead of grouping them together as internalizing disorders. Finally, larger sample sizes may also permit the use of cluster analysis, which could minimize concerns about the subjective nature of behavioral diagnosis.

Future researchers may also wish to compare medicated and unmedicated ADHD groups on WISC–IV and CPT–II performance. All subjects in the present study were unmedicated at the time of assessment. However, many potential subjects for the present study were eliminated because they had been assessed while taking psychotropic medication, with stimulant and SSRIs being prescribed at the greatest frequency. This was most often the result of psychopharmacological intervention being tried before a comprehensive ADHD evaluation was conducted.

In subjects who were medicated with stimulants, a common practice was to complete the WISC–IV while the child was taking medication and then perform the CPT assessment both with and without medication. An argument for completing cognitive assessments while a child is medicated is that performance may be closer to the child's true potential. However, this practice may also obscure cognitive differences that may be beneficial in differential diagnosis. Therefore, a comparison of unmedicated and medicated ADHD groups may not only add to the literature on the efficacy of medications on neurocognition, but may also provide guidance on the question of whether testing unmedicated children is beneficial to the diagnostic process. To date, there are no definitive guidelines on whether children suspected of having ADHD should be assessed with or without medication.

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Footnote

[1]The LSD was statistic used because though the overall ANOVA was significant, the post hoc tests failed to reach significance using the HSD statistic. This was likely due to small sample size.

Appendix

SUBJECTDATA COLLECTION FORM

INCLUSION CRITERIA:

- Ages 6-16
- Medication free at time of testing (all psychotropics)
- Diagnosed ADHD by physician, psychiatrist, or psychologist using a rating scale and semi-structured Interview (diagnosis can be made pre or post assessment)
- No known brain injury or medical condition affecting psychological status at time of evaluation
- Full scale Intelligence score of at least 75
- CBCL completed
- WISC-IV given

DEMOGRAPHICS:

Chronological age at time of assessment	
Sex	
Ethnicity	
SES (Medicaid or private insurance)	
Grade (at time of assessment)	
Educational placement at time of assessment (general education, inclusion, resource room, self-contained)	
ADHD subtype	
Other psychiatric diagnoses	

WISC-IV SCORES:

Area:	**Standard/Scaled Score:**
Full scale ability	
Vocabulary	
Similarities	
Comprehension	
Block Design	
Picture Concepts	
Matrix Reasoning	
Digit Span	
Digits Forward (raw score if not calculated)	**(Indicate raw or scaled)**
Digits Backward (raw score if not calculated)	**(Indicate raw or scaled)**
Letter-Number Sequencing	
Coding	
Symbol Search	

CPT-II SCORES:

Area:	**T Score:**
Omissions	
Commissions	
Hit RT	
Hit RT Standard Error	
Variability	
Detectability (d)	
Response Style	
Perseverations	
Hit RT Block Change	
Hit SE Block Change	
Hit RT ISI Change	
Hit SE ISI Change	

ASEBA CBCL/TRF:

Scale:	**Raw Score:**
Anxious/Depressed	
Withdrawn/Depressed	
Somatic Complaints	
Social Problems	
Thought Problems	
Attention Problems	
Rule-Breaking Behavior	
Aggressive Behavior	