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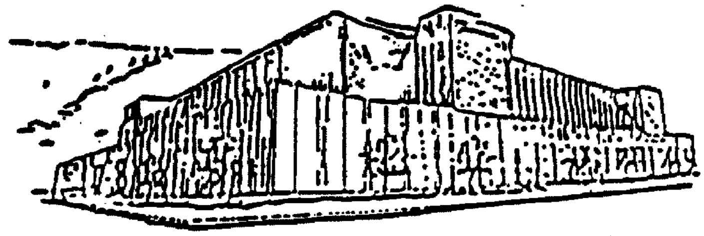

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Attention Deficits as Measured by Conners' CPT and Children's Performance on Neuropsychological Measures of Learning and Executive Function

by

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Conners' Continuous Performance Test (CPT) is a measure of attention and impulsivity commonly used in the assessment of Attention Deficit/Hyperactivity Disorder (ADHD). Research suggests that the impaired attention associated with ADHD may affect children's performance on measures of other cognitive functions such as memory, learning, and executive function but little research has addressed the relationship between children's performance on Conners' CPT and their performance on other neuropsychological instruments.

The present study utilizes the cutoff scores suggested by the CPT to define two groups: children whose scores suggest good attentional abilities, and children whose scores suggest impaired attention. These two groups' scores on neuropsychological measures of learning, memory, and executive functions were then compared. Multivariate analyses were used to determine if the CPT cutoff scores identify groups of children with distinct and homogeneous neuropsychological test scores.

The results did not strongly support the hypothesis that children with impaired attention as measured by the CPT exhibit greater deficits on the other neuropsychological measures than children with normal CPT scores. The secondary hypothesis, that the two groups defined by the CPT cutoffs would form distinct and homogeneous groups, was also not supported. Multivariate analyses supported a three-group structure within the sample that was not closely tied to CPT group assignment. The performance of these three groups on the neuropsychological measures is profiled.

Overall, the results do not support the use of Conners' CPT cutoff scores to define significantly different homogeneous groups among this clinical sample. Future research may address the validity and stability of the three-group solution suggested by the multivariate analyses.

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Introduction

Attention is part of the first level of central processing in which the sensory systems convey information about the environment to the brain (Reitan & Wolfson, 1992). Attention includes basic alertness, our ability to selectively focus on important stimuli, and our ability to maintain voluntary attention or vigilance (see Seidel & Joschko, 1991). As one of the first levels of processing, attention is closely tied to cognitive processes further downstream. If our ability to attend to important stimuli in the environment is impaired, our higher-level brain functions that analyze incoming information, form memories, and plan and implement our responses will be affected as well (Lyon & Krasnegor, 1996; Reitan & Wolfson, 1992). Attention-Deficit/Hyperactivity Disorder (ADHD) is just such an impairment; characterized by difficulties with attention and control of impulsive-hyperactive behavior, ADHD has widespread impact on other areas of cognitive functioning such as learning, memory, and executive functions (Lyon & Krasnegor, 1996).

ADHD is one of the leading reasons for referrals to family physicians, pediatricians, pediatric neurologists, and child psychiatrists and is the most commonly diagnosed learning and behavioral disorder in children (Biederman, Newcorn, & Sprich, 1991). The disorder poses a great financial cost to society, disrupts classrooms and families' homes, and is associated with later psychiatric disorders and adult antisocial behavior (see Biederman et al, 1991).

ADHD can be difficult to diagnose reliably. The criteria for the disorder are being continuously redefined. There is a wide range of possible symptoms and subtypes, comorbid conditions are common, and the etiology is not fully understood. Many critics claim that ADHD is being overdiagnosed and children with a developmentally normal level of inattention and activity are labeled with the disorder because they are difficult for their parents and/or teachers to control (see Garber, Garber, & Spizman, 1996).

Efforts have been made to identify assessment instruments to aid in the reliable diagnosis of ADHD, but the utility of psychological testing has been a long-standing controversy and managed care companies have restricted psychological testing in efforts to minimize expenses (Acklin, 1996; Korchin & Schuldberg, 1981). To counter such restrictions, psychological evaluation must demonstrate its efficacy in diagnosis, as well as treatment selection and evaluation (Korchin & Schuldberg, 1981).

Some have argued that psychological tests have limited usefulness for assessing ADHD because although abnormal test scores do suggest a deficit, ADHD can not be ruled out by normal test performance (see Golden, 1996). However, many hold that the converging evidence of test performance, clinical interviews, and observation are necessary for reliable diagnosis in both clinical research and practice (Korchin & Schuldberg, 1981). Given the complexities of diagnosing ADHD and the concern that it may be overdiagnosed, the identification of valid and reliable assessment instruments for this disorder may be particularly valuable.

Neuropsychological assessment has become increasingly employed for the differential diagnosis of ADHD and its subtypes (Melamed & Wozniak, 1998). Research has shown children with ADHD demonstrate higher rates of deficits on a variety of neuropsychological measures than their peers, and that different patterns of deficits are evident between the subtypes of the disorder (Marks, Himelstein, Newcorn, & Halperin, 1999; Melamed & Wozniak, 1998). However these tests can not be used in isolation; no one test has demonstrated that it alone reliably distinguishes between ADHD and non-ADHD children.

Computerized Continuous Performance Tests (CPTs) have been developed to evaluate symptoms of ADHD such as inattentiveness and impulsivity and are commonly included in the assessment of ADHD. Research has demonstrated that children diagnosed with ADHD exhibit greater deficits on neuropsychological measures than their peers, but little research has examined the relationship between children's performance on CPT tasks and their performance on other neuropsychological measures.

The present research investigates the assessment of ADHD and whether attention deficits as measured by Conners' CPT represent a specific cognitive deficit or are related to a more generalized form of impairment that is evident on neuropsychological measures of other cognitive domains (Gorenstein, Mammato, & Sandy, 1989). To illustrate the factors complicating the diagnosis and assessment of ADHD, this introduction will first address the diagnostic criteria and clinical features of ADHD. Next, the etiology of ADHD will be discussed, followed by a review of the literature on the assessment and treatment of ADHD. Finally, the present research will be addressed.

Diagnostic Criteria & Clinical Feature of ADHD

Historically, ADHD has been recognized under a variety of names (see Kaplan, Sadock, & Grebb, 1994). In the early 1900's, the term "hyperactive syndrome" was used to describe impulsive, disinhibited, hyperactive children, including many who had neurological damage as the result of encephalitis. In the 1960's, children with poor coordination, learning disabilities, and emotional liability were labeled as having "minimal brain damage".

In more recent decades, our conceptualization of the symptoms associated with ADHD has continued to change. With each successive revision of the Diagnostic and Statistical Manual of Mental Disorders (DSM; American Psychiatric Association [APA]), our terminology of what is now known as ADHD has been redefined: hyperkinetic reaction (DSM-II), attention deficit disorder with and without hyperactivity (DSM-III), and ADHD (DSM-III-R & DSM-IV). Despite these revisions, the core symptoms of inattention, hyperactivity, and impulsivity have remained constant (Marks, Himelstein, Newcorn, & Halperin, 1999). For the purposes of the present research, the DSM-IV concept of ADHD will be used. In reviewing the literature, reference will be made to other earlier nomenclature as used in past research.

DSM-IV Diagnostic Criteria.

The APA classifies ADHD as an attention-deficit and disruptive behavior disorder among the disorders usually first diagnosed in infancy, childhood, or adolescence (DSM-IV, 1994). To meet the diagnostic criteria, a child must experience at least six developmentally inappropriate symptoms of either inattention or hyperactivity-impulsivity in at least two settings (e.g., school and home).

Symptoms of inattention include: lack of attention to detail, difficulty sustaining attention, failure to listen when spoken to, failure to finish projects, organizational difficulties, avoidance of tasks requiring mental effort, losing things, distractibility, and forgetfulness of daily activities. Symptoms of hyperactivity-impulsivity include: fidgeting, failure to remain seated, feelings of restlessness or excessive running and climbing, difficulty engaging in activities quietly, being often "on the go", excessive talking, blurting out answers, difficulty awaiting turn, and frequently interrupting or intruding on others.

Initial symptoms of inattention and/or hyperactivity-impulsivity must be present before the age of seven and present symptoms must be at least six months in duration and cause clinically significant impairment in functioning. These symptoms must not only be present in the context of a pervasive developmental disorder, psychotic disorder, or another mental disorder.

Subtypes of ADHD.

Given the long list of possible symptoms of ADHD, the clinical presentation of children meeting the diagnostic criteria is quite heterogeneous. Over time, the DSM has conceptualized this diversity in a variety of ways (see Cantwell & Baker, 1992; & Faraone, Biederman, Weber, & Russell, 1998). The second edition of the DSM (DSM-II) recognized only hyperkinetic reaction, characterized by motoric disinhibition. The third edition (DSM-III) divided attention deficit disorder into two subtypes: with and without hyperactivity (ADD+H and ADD-H, respectively). The third edition, revised (DSM-III-R) combined the symptoms of inattention, impulsivity, and hyperactivity into one disorder, ADHD. The fourth edition (DSM-IV) describes three ADHD subtypes based on field trials and factor-analytic studies (see Faraone et al., 1998 for review).

Research suggests that most individuals with ADHD manifest symptoms of both inattention and hyperactivity-impulsivity, but some experience predominantly one or the other. To highlight these different possible patterns of symptoms, the DSM-IV (1994) recognizes three subtypes of ADHD: predominantly inattentive type, predominately hyperactive-impulsive type, and combined type. Some researchers have suggested that the DSM-IV subtypes of ADHD may in part reflect developmental phases of the disorder (Faraone et al., 1998); hyperactivity is the often the first symptom to emerge and remit, and distractibility and inattention often persists the longest (Kaplan et al., 1994).

Children whose symptoms fall within these three subtypes differ in clinically meaningful ways (see Cantwell & Baker, 1992; Faraone, et al., 1998). The three groups differ significantly in age: the inattentive being oldest, followed by the combined, and the hyperactive-impulsive children are the youngest. Significantly more inattentive children are female. The children in the combined subtype appear more impaired on global assessment scales. Youth in the combined and inattentive subtypes experience higher rates of academic difficulties and comorbid anxiety and depression than those with primarily hyperactive-impulsive symptoms (see Faraone et al., 1998). Children with predominately hyperactive-impulsive symptoms are more likely to be referred for treatment, to have a stable diagnosis over time, and to have concurrent conduct disorder or oppositional defiant disorder than those whose primary symptoms are of inattention (see Faraone et al., 1998; Goodyear & Hynd, 1992; Halperin et al., 1990; Kaplan et al., 1994).

Prevalence & Gender Ratio.

It is estimated that 3-5% of prepubertal school-age children meet the diagnostic criteria for ADHD (DSM-IV, 1994). The hyperactive-impulsive subtype is less prevalent than the other two subtypes (9%-15% of clinical referred cases of ADHD, and 21-27% of community cases of ADHD) (Faraone et al., 1998). ADHD is more common in boys than girls (4:1 – 9:1 depending on setting; DSM-IV, 1994) and is most common in first-born boys (Kaplan et al., 1994).

Clinical Features & Course.

Symptoms of ADHD may begin quite young, and two patterns of symptoms of ADHD may be present in infancy (Kaplan et al., 1994). In the first pattern, the infant cries easily, is very active, needs little sleep, and is highly sensitive to stimuli and easily upset by changes in the environment (e.g., noise, light, temperature). The second and more rare pattern of symptoms of ADHD in infancy includes being placid and limp, sleeping a great deal, and having the appearance of being developmentally slow.

Although the onset of symptoms is often before the age of three, ADHD is usually first diagnosed in elementary school when children experience difficulty with the attention, concentration, and structured behavior required to succeed in a formal learning situation (DSM-IV, 1994; Kaplan et al., 1994). In school, children with ADHD may experience difficulty sitting still, completing assignments and tests, and waiting to be called on (Kaplan et al., 1994). It is estimated that over 90% of children with ADHD do not perform at their known level of potential in school (Barkley, 1989).

In addition to academic difficulties, children with ADHD often experience low frustration tolerance, emotional lability, accident-proneness, and strained relationships with peers and family members (DSM-IV, 1994; Kaplan et al., 1994). Roughly 75% of youth with ADHD experience additional difficulties with aggression, oppositional behavior, and defiance (Barkley, 1989; Kaplan et al., 1994). Children with ADHD also experience associated cognitive impairments such as difficulties with language, right-left confusion, motor coordination problems, poor handwriting, and neurological "soft signs" (Barkley, 1989; Carte, Nigg, & Hinshaw, 1996; Kaplan et al., 1994).

Comorbid Disorders.

Research suggests that ADHD is characterized by frequent comorbidity cross-culturally, including concurrent mood, anxiety, learning, communication disorders, Tourette's Disorder, and behavioral disorders (DSM-IV, 1994; Biederman et al., 1991). The presence of such comorbid diagnoses complicates the diagnosis, assessment, prognosis, and treatment of ADHD (see Biederman et al., 1991). Children with different comorbid conditions may have different risk factors, clinical courses, neurobiology, and pharmacological responses (see Biederman et al., 1991). Children with ADHD and comorbid disorders may experience greater social, emotional, and psychological difficulties than those with ADHD alone (see Biederman et al., 1991). Bellak and Black (1992) suggest that some cases of dysthymia, cyclothymia, anxiety disorder, and psychoses may be misdiagnosed and suffer primarily from ADHD. Each of the more frequent comorbid disorders of ADHD will be discussed in turn.

In their review of the literature, Biederman et al. (1991) report that ADHD and mood disorders co-occur in 15-75% of epidemiological and clinical samples. Children with ADHD and a mood disorder may be at increased risk of greater psychiatric morbidity and suicide than children with ADHD alone (see Biederman et al., 1991). ADHD and mood disorders may share a common familial vulnerability; first-degree relatives of children with ADHD experience higher rates of mood disorders than relatives of normal control children (see Beiderman et al., 1991).

Children with ADHD also experience higher rates of anxiety disorders than community samples. Studies of epidemiological and clinical samples of children have found a comorbid association between ADHD and anxiety disorders of roughly 25% (see Biederman et al., 1991). Research suggests that relatives of children with ADHD are at an increased risk of anxiety disorders compared to the relatives of normal children, but that ADHD and anxiety disorders are transmitted independently in families (see Biederman et al., 1991).

Among their sample of children referred to a pediatric clinic with ADD+H, Jensen, Shervette, Xenakis, and Richters (1993) found that roughly 49% also met the diagnostic criteria for an internalizing disorder such as depression, an anxiety disorder, or both. Further analyses revealed that the children with ADD+H and a comorbid mood or anxiety disorder experienced significantly higher levels of stress and their mothers reported experiencing more psychiatric symptoms themselves than the children diagnosed with only ADD+H.

Why ADHD and mood and anxiety disorders commonly co-occur remains unclear. Jensen et al. (1993) and Biederman et al. (1991) suggest several possible relationships. Depression and anxiety may underlie children's symptoms of ADHD or may be the result of the academic, family, and social difficulties often associated with ADHD. ADHD and comorbid disorders may be expressions of the same disorder. Or perhaps symptoms of both ADHD and anxiety and mood disorders are due to other factors such as a genetic vulnerability or psychosocial stress.

Learning disorders (LD) are also often comorbid with ADHD (Kaplan et al., 1994). LDs are perceptual handicaps in cognitive processing that produce disorders of language, reading, writing, spelling, or arithmetic. Estimations of comorbidity indicate that 50% to 80% of children with ADHD also have a learning disability, and 20% to 25% of children with learning disabilities also have ADHD (see Bellak & Black, 1992). In their review of the literature, Biederman et al. (1991) observed a wide range of reported overlap between children with ADHD and LD (10-92%). They attribute this variability to differences between studies in the selection criteria, sampling, measurements, and diagnostic criteria.

ADHD often co-occurs with other behavior disorders such as conduct disorder (CD) or oppositional defiant disorder (ODD). Roughly 45-70% of community and clinic youth with CD or ADHD also meet the criteria for the other disorder (see Kazdin, 1997).

Children with ADHD and CD have more serious clinical courses and poorer outcomes than children with ADHD without CD (see Biederman et al., 1991).

Children with ADD and ODD experience similar difficulties to children with ADD plus CD, but generally not as severe (see Biederman, 1991). They experience higher rates of school dysfunction than children with ADD alone, but not as great a rate as among children with ADD and CD. They also have higher rates of antisocial disorders and ADD among relatives than children with ADD alone, but not as high a rate as among the relatives of children with ADD and CD. Given these similar but less severe features, some have suggested that ODD is a subsyndromal manifestation of CD and children with ADD plus ODD form an intermediate subgroup between children with ADD and children with ADD and CD (see Biederman, 1991).

Higher rates of a variety of other disorders have been observed among children with ADHD. ADHD is three to four times more prevalent in children who are mentally retarded than in children with normal IQ scores (see Biederman et al., 1991). Approximately 60% of youth with Tourette's syndrome also have ADHD (see Biederman et al., 1991). Some reports have indicated that adults with borderline personality disorder may have an increased prevalence of current or past ADHD (see Biederman et al., 1991).

Long-term outcome.

The course of ADHD varies widely; symptoms may remit at the time of puberty, or some or all of an individual's symptoms may persist into adolescence or adulthood (Kaplan et al., 1994). Most individuals with ADHD go into partial remission between the ages of 12 and 20, but continue to experience some significant symptoms into adolescence and adulthood (Kaplan et al., 1994). Often the overt symptoms of hyperactivity remit, but symptoms such as poor concentration and subjective feelings of restlessness continue. There have been fewer long-term follow-up studies of girls, and less is known about the natural history of ADHD in girls (Klein & Mannuzza, 1991). Efforts to identify childhood characteristics that predict the long-term outcome of cases of ADHD have had little success (Klein & Mannuzza, 1991).

Symptoms of ADHD can have long-term effects on children's academic performance, adolescence, and adulthood. Children with ADHD experience higher rates of poor grades, more frequently repeat grades and are placed in special classrooms, end their education earlier, receive more tutoring, and have poorer performance on academic tests than their peers (see Biederman et al., 1991; Klein & Mannuzza, 1991). Without treatment, children with ADHD are at two to three times more likely to drop out of school before graduating than other children (Barkley, 1989). In their 8 year follow-up of ADHD children Fischer, Barkley, Edelbrock, and Smallish (1990) observed higher rates of grade retention, suspensions, expulsions, and dropping out than among control children.

For many children with ADHD, their difficulties continue into adolescence. As adolescents, 25-35% of youth with ADHD engage in delinquent activity, and they are at an increased risk of drug abuse, depression, low self esteem, and automobile accidents (Barkley, 1989; Hechtman, Weiss, & Perlman, 1984). Many adolescents with ADHD also continue to experience academic and learning problems (see Biederman et al., 1991).

In their review of the adolescent outcome of children with ADHD, Klein and Mannuzza (1991) report that by the age of fifteen roughly 70% of adolescents continue to experience symptoms of ADHD (e.g., restlessness, poor concentration, low grades, and poor performance on cognitive tasks) and 40% are diagnosed with conduct disorder. Hechtman (1985) reports that adolescents who have received stimulant treatment for ADHD in childhood also appear to experience difficulties. Many continue to experience antisocial behavior problems (20-30%), residual symptoms, poor peer relationships, low self-esteem, and be an average of two grades behind in core academic subject areas.

Few follow-up studies of children with ADHD have utilized standardized tests or measures. Fischer et al. (1990) sought to address this concern in their eight-year follow-up of ADHD children into adolescence. At follow-up, the participants that had initially been diagnosed with ADHD by research criteria scored significantly lower than controls on measures of academic achievement, attention and impulse control, and being "off task" during an academic assignment.

For some children, the effects of ADHD span into adulthood. An estimated 30-70% of children diagnosed with ADHD continue to experience significant symptoms as adults including impulsivity, lower educational attainment, and accident-proneness (Bellak & Black, 1992; Biederman et al., 1993; Jackson & Farrugia, 1997; Jenkins et al., 1998; Kaplan et al., 1994). The estimated prevalence of ADHD among adults is 1% or 2% (Bellak & Black, 1992). For those who do not experience significant symptoms as adults, the sequelae of a history of ADHD may still continue to negatively affect their psychological, educational, social, and vocational functioning (see Bellak & Black, 1992).

Follow-up studies suggest that adults with a history of childhood ADHD move more frequently, have more car accidents, and have failed more grades. They report more gambling disorders and marital discord, higher rates of incarceration and substance abuse, and more inconsistent work records. They also have more impulsive and immature personality traits, rate their childhoods more negatively, and have poorer self esteem and social skills (see Hechtman, 1985; Jackson & Farrugia, 1997; Jenkins et al., 1998).

The comorbid diagnoses associated with childhood ADHD (e.g., behavioral, mood, and anxiety disorders) and academic underachievement are also evident in adults with childhood onset ADHD (Biederman et al., 1993). Conditions associated with ADHD in adults include learning disabilities, generalized anxiety disorder, antisocial behavior, drug and alcohol abuse, and dysthymic and cyclothymic disorders (Bellak & Black, 1992). There is evidence of a pattern of sequential diagnoses in which children are diagnosed with ADHD, then diagnosed with ODD in middle childhood, CD in adolescence, and antisocial personality disorder (APD) as an adult (see Bellak & Black, 1992).

APD is more common among adults previously diagnosed as ADHD in childhood (23% vs. 2.4% of general population) (Klein & Mannuzza, 1991). The relationship between childhood ADHD, CD, and adult APD appears to be mediated by aggression (see Bellak & Black, 1992). About 25% of children with ADHD develop APD in young adulthood, and approximately 66% of these individuals eventually get arrested (Mannuzza, Klein, Konig, & Giampino, 1990). APD appears to provide a link between childhood ADHD and adult substance abuse and criminality; few individuals with ADHD and no APD go on to abuse drugs (see Bellak & Black, 1992; Klein & Mannuzza, 1991).

Not all adults with a history of childhood ADHD are at an equally high risk of antisocial behavior, substance abuse, and emotional distress; their difficulties are correlated with symptoms of ADHD persisting into adulthood (see Bellak & Black, 1992). Young adults with a history of ADHD are at greater risk than controls of APD and substance use disorder (excluding alcohol; 18% vs. 2% & 16% vs. 4% respectively); but it is those with residual symptoms of ADHD that are at the greatest risk (48% vs. 13%) (see Klein & Mannuzza, 1991).

Etiology of Attention Deficits

The etiology of attention deficits is complex and many factors appear to be involved. Psychosocial factors have not been strongly implicated in the etiology of ADHD; however, stressful life events, family disequilibrium, and prolonged emotional deprivation may exacerbate symptoms of ADHD or trigger a pre-existing risk factor (Kaplan et al., 1994). There is no evidence to support theory that ADHD is caused by food additives, colorings, preservatives, or sugar (Kaplan et al., 1994). A combination of genetic, biological, and environmental factors appear to play a role in the etiology and expression of ADHD (see Bellak & Black, 1992). These factors will each be addressed.

Genetic Factors.

Studies of families, twins, and adoptions suggest a genetic basis for ADHD (see Sprich-Buckminster, Biederman, Milberger, Faraone, & Lehman 1993). An estimated 30% to 40% of youth with ADHD have a familial pattern of the disorder (Bellak & Black, 1992). First degree biological relatives of children with ADHD have an increased prevalence of ADHD, mood and anxiety disorders, conversion disorders, learning disorders, substance-related disorders, and antisocial personality disorder (DSM-IV, 1994; Kaplan et al., 1994). There is a greater familial risk of ADHD and antisocial disorders among relatives of children with ADHD with concomitant conduct disorder (see Biederman et al., 1991). Siblings of children with ADHD are at twice the risk of the general population of having ADHD, and there is a greater concordance of ADHD among monozygotic twins than dizygotic twins (Kaplan et al., 1994). Many parents and adult siblings of children with ADHD also have ADHD (see Biederman et al., 1993).

Despite the evidence for a genetic risk factor for ADHD, not all children with a genetic predisposition develop the disorder, and not all children with the disorder have a familial risk (see Sprich-Buckminster et al., 1993). If the disorder is not entirely genetic, environmental factors must also play a role in the etiology of ADHD.

Prenatal, Perinatal, & Postnatal Factors.

The presence of ADHD symptoms in infancy, the neurological soft signs, and the long-standing nature of the disorder suggest damage to the brain during the prenatal, perinatal, and postnatal periods of development. Such subtle damage to the central nervous system (CNS) could be the result of problems with circulation, toxins, metabolism, stress, or physical insult as the result of infection, inflammation, or trauma (see Kaplan et al., 1994).

Prenatal and perinatal factors that have been associated with ADHD include prenatal toxic exposure, prematurity, prenatal mechanical insult to the CNS, low birth weight, maternal cigarette smoking, convulsions during pregnancy, low fetal heart rate during second stage of labor, lower placental weight, breech presentation, and chorionitis (see Bellak & Black, 1992; Kaplan et al., 1994). Postnatal factors include viral encephalitis and head injury (see Bellak & Black, 1992).

The areas of the brain that are believed to play a role in the etiology of ADHD are particularly vulnerable to early hypoxic ischemic insults and may be damaged before other structures during any adverse events that occur during the antenatal and perinatal periods (see Lou, Henriksen, Bruhn, Borner, & Nielsen, 1989). For example, the position of the striatum, between the anterior and middle cerebral arteries, increases the risk of neuronal damage to this region.

Sprich-Buckminster et al. (1993) examined the relationship between perinatal complications and ADD among children with and without comorbid disorders and familial risk of ADD. Their results revealed higher rates of pregnancy, delivery, and infancy complications (PDICs) among the children with nonfamilial comorbid ADD than in children with familial or noncomorbid ADD. These results are interpreted as suggesting that PDICs are a nonspecific risk factor for psychopathology including, but not restricted to, ADD.

Neurobiological Factors.

The subtle neurological deficits associated with ADHD suggest the possibility of neurobiological factors in the disorder. The behavioral similarity of children with ADHD and individuals with frontal lobe damage (e.g., inattention, impulsivity, and hyperactivity) has implicated this region in the development of ADHD. Animals studies indicate that lesion of the prefrontal cortex lead to an inordinate level of reactivity to external stimuli, hyperactivity, distractibility, and poor attentive capacity (Fuster, 1989). Similarly in humans, pathology of the frontal lobes is associated with attention deficits, including an increased distractibility, poor concentration, and difficulty ignoring irrelevant stimuli (Fuster, 1989).

Researchers suggest that delayed maturation of the frontal lobes may play a role in the etiology of ADHD (see Heaton, Chelune, Talley, Kay, & Curtiss, 1993; Stuss & Benton, 1986; Welsh, 1994). The premotor and superior prefrontal cortex play an essential role in the control, preparation, and execution of motor activity, as well as in attention and the inhibition of inappropriate response (see Bellak & Black, 1992). In cases of ADHD, the underdeveloped frontal lobes may not be performing their normal inhibitory role leaving lower structures of the brain disinhibited (Kaplan et al., 1994).

Anatomical studies of the brain have suggested that dysfunction in the right frontal-striatal circuitry plays a role in ADHD. Castellanos et al. (1996) have utilized quantitative brain magnetic resonance imaging (MRI) techniques to compare the volume of brain regions among boys with and without ADHD. Their results revealed that the boys with ADHD had significantly less total cerebral volume than controls. Boys with

ADHD had less volume in the prefrontal cortex, caudate nucleus, and globus pallidus, particularly on the right side of the brain.

Functional studies of the brain support the theory that impairment in the frontostriatal circuitry may play a role in ADHD. Positron emission tomography (PET) scans of children with ADHD show decreased cerebral blood flow and metabolic rates in frontal lobe areas relative to controls (see Kaplan et al., 1994). Zametkin et al. (1990) used PET scans to reveal decreased global cerebral glucose metabolism in adults with ADD of childhood onset relative to normal controls. Two of the regions with the greatest levels of decreased metabolism (the premotor and superior prefrontal cortex) are involved in the control of attention and motor activity. Zametkin et al. (1993) conducted a similar PET scan study with adolescents with ADHD. The results did not reveal any difference from controls on global measures of metabolism, but the adolescents with ADHD did have significantly reduced regional glucose metabolism in the left anterior frontal lobe.

Lou et al. (1989) assessed the regional cerebral blood flow (CBF) in children with ADHD, children with ADHD plus other neurological symptoms, and controls using emission computed tomography. Their results indicated that the right striatal regions of the children with ADHD appeared hypoperfused relative to controls', and their sensorimotor regions (i.e., occipital lobe, and left sensorimotor and primary auditory regions) appeared hyperperfused. Hypoperfusion suggests low metabolic and functional activity in these regions. Among the children with ADHD plus other neurological symptoms, both striatal regions showed decreased CBF and a significant increase in CBF to the occipital lobe. Administration of methylphenidate was associated with clinical improvement and significant increase in CBF to the left striatal and posterior periventricular regions of children in both ADHD groups.

These results suggest low neural activity in the striatal region of children with ADHD. This is consistent with animal models in which lesions to striatal structures (i.e., the head of the caudate) or prefrontal regions produces hyperactivity, as well as poor attention, memory consolidation, and performance on cognitive tasks (see Lou et al., 1989). The prefrontal cortex has efferent connects to the head of the caudate and is thought to mediate higher forms of attention (see Lou et al., 1989). Dysfunction of the caudate nucleus may be related to the increased activity observed in the primary sensory and sensorimotor regions. The caudate is thought to inhibit polysensory perception, and decreased activity in the neostriatum may lead to a lack of inhibition of sensory perception. Lou et al. (1989) conclude that striatal dysfunction plays a central role in the pathogenesis of ADHD.

Neurotransmitter systems, particularly the catecholamines, have also been implicated in the etiology of ADHD. Bellak and Black (1992) suggest that it is a deficiency of dopamine and norepinephrine (as well as serotonin in aggressive cases) behind ADHD symptoms. The effectiveness of stimulant drugs in treating ADHD supports the role of the catecholamines in ADHD. Stimulants are catecholamine agonists that enhance noradrenergic and dompamineric transmission by promoting their release and blocking their reuptake (Grilly, 1994).

Assessment of Attention

As is evident from the preceding discussion of the diagnostic criteria, clinical features, and etiology, ADHD is a complex disorder with may factors that may cloud its assessment and diagnosis. An accurate diagnosis of ADHD is particularly important because children with the disorder may qualify for special services by schools under the Individuals with Disabilities Education ACT (IDEA) and Section 504 of the Rehabilitation Act of 1973 (see Landau & Burcham, 1995). Early identification and intervention of ADHD may help lessen the negative sequelae of ADHD such as poor self-image, academic problems, and interpersonal difficulties.

Treating the behaviors described in the DSM-IV diagnostic criteria as a checklist for diagnosing ADHD without including a comprehensive evaluation overlooks the many other possible sources of ADHD-like symptoms. Medical, psychological, and learning problems may manifest in symptoms very similar to ADHD and must be ruled out (Garber et al., 1996). Unfortunately, many children are diagnosed as having ADHD without the use of any standardized diagnostic measures and even more are diagnosed with only parent or teacher rating scales (see Garber et al., 1996).

A child who does not receive a comprehensive assessment may be misdiagnosed and may not receive the interventions best suited to his/her needs. A wide range of assessment instruments has been developed to measure attention deficits and associated impairments. Some of the more popular methods are outlined below.

Informants' Reports & Observational Methods.

The report of parents and teachers is commonly used to assess symptoms of ADHD and structured interviews and behavior rating scales have been developed for this purpose. Examples of structured interviews for parents based on DSM criteria include the Diagnostic Interview for Children and Adolescents (DICA; Herjanic & Campbell, 1977), the Diagnostic Interview Schedule for Children (DISC; Costello, Edelbrock, & Castello, 1985), and the Schedule for Affective Disorders and Schizophrenia for School-Age Children (SADS; Chambers, Puig-Antick, Hirsh, et al., 1985). These structured interviews provide for DSM-IV diagnosis, but require a minimum of two hours to complete.

A variety of objective measures have been developed for parents and teachers to rate children's ADHD behavior. These include the parent and teacher versions of the Child Behavior Checklist and Conners Rating Scales, the Attention-Deficit/Hyperactivity Disorder Test (ADHDT), the ADD-H: Comprehensive Teacher Rating Scales (ACTeRS), and the Barkley Home Situations Questionnaire and School Situation Questionnaire (see AACAP Official Action, 1997).

Teachers' reports provide valuable information in the assessment of ADHD. To meet the DSM-IV criteria, symptoms of ADHD must be present in multiple settings and the classroom is often the setting in which attention deficits and hyperactivity are most evident. Teachers can help identify if a child's learning difficulties are caused by ADHD or by poor attitude, maturational delays, or poor-self image, as well as describe how the child handles problems and peer relationships (Kaplan et al., 1994). In their review of the longitudinal data on informants' ratings of ADHD, Klein and Mannuzza (1991) conclude that children rated as having symptoms of ADHD by their teachers are more likely to have persistent difficulties with attention and hyperactivity than children rated as having symptoms of ADHD by their parents alone.

Observational methods of assessment and solid state actigraphs have also been used to rate activity levels and the amount of time a child is on-task in the classroom and while completing laboratory tasks (Marks et al., 1999; Teicher, Ito, Glod, & Barber, 1996). Evidence of symptoms of ADHD may also be evident during the mental status exam or a neurological examination (Kaplan et al., 1994).

Neuropsychological Assessment.

Neuropsychological evaluations are used to assess and diagnose ADHD and provide a more comprehensive picture of a child's functioning than the assessment techniques discussed in the previous section. Diagnoses based solely on behavioral descriptions such as the DSM have been criticized for oversimplifying complex conditions by focusing on a single behavioral characteristic (e.g., impaired attention) and neglecting to address extensive neuropsychological deficits (Reitan & Wolfson, 1992). Reitan and Wolfson (1992) suggest that it is the use of behavioral diagnosis that leads to the high levels of overlapping neuropsychological deficits across children in different diagnostic categories.

Neuropsychological assessment typically involves a full battery of tests, including measures designed to assess attention, as well as other cognitive domains that may be affected by an attention deficit such as memory and executive functions. There are several advantages to using neuropsychological tests to assess attentional difficulties: 1) a more comprehensive understanding of a child's functioning in a variety of cognitive domains aids in differential diagnosis and in ruling out other explanations for a child's symptoms, 2) by using standardized procedures, an individual's performance may be compared to age-appropriate normative standards, and 3) using neuropsychological tests pre and post treatment provides an objective means of gauging change over time and assessing the effectiveness of interventions (Jenkins et al., 1998). The neuropsychological measures relevant to the present study are introduced below and their administration, scoring, reliability, validity, and normative data are discussed in more detail in the measures section of the methods chapter.

Continuous performance tests (CPTs) are frequently included in neuropsychological evaluations to assess attention and impulsivity in children. The first CPT was developed in the 1950's to detect attention deficits in individuals with petit mal epilepsy (see Conners, 1994). Since that time, several forms of computerized CPTs have been developed to assess attention. In most CPT tasks, the examinee is instructed to press a button whenever a target stimulus is presented on a computer screen (e.g., X, or A followed by X). The examinee must discriminate between the infrequently occurring target stimuli and the non-target stimuli and inhibit their responding until the appropriate time. CPTs are thought to involve several components of attention, including alertness, selective attention, and vigilance (see Seidel & Joschko, 1991).

Conners (1994) has developed a CPT in which the examinee responds to every stimulus except the target stimulus, X. Conners (1994) proposes several advantages to having the examinee respond continuously except to the rare target stimulus: 1) a larger sample of the examinee's response times, 2) more impulsive target errors, and 3) more variable foreperiod effects (i.e., the examinee is less able to predict when the next stimulus will occur).

CPT performance has been found to be affected by several factors including learning disorders, stimulant medication, CNS depressants, and aging (see Seidel & Joschko, 1991). CPT measures of inattention distinguish children with ADHD from controls (see Halperin et al., 1990) and children with DSM-III ADD+H from children with conduct disorder (O'Brien et al., 1992). Among adolescents, Fischer et al. (1990) found that youth with a history of ADHD made more errors of omission and commission on Gordon's (GDS; 1987) CPT of vigilance than normal controls.

Barkley (1998) states that CPTs are the only assessment instrument that directly measures inattention and impulsivity without contamination from other cognitive factors, and is the most reliable psychological test for discriminating children with ADHD from controls. However, despite good false positive rates, there is evidence that CPTs have an unacceptable rate of false negatives (children rated as having ADHD by their parents and teachers obtain normal CPT scores) and normal scores may be uninterpretable (see Barkley, 1998). Seidel and Joschko (1991) and Conners (1994) caution that despite the usefulness of the CPT for identifying attention problems, it should not be used in isolation as a diagnostic instrument for ADHD and is best included as part of a full evaluation.

Neuropsychological evaluations also typically include tests of learning and memory. Attention plays a key role in our ability to learn and form memories. If incoming information is inadequately registered or distorted by poor attention our ability to subsequently organize it, relate it to past experience, and remember it is severely limited (Reitan & Wolfson, 1992).

The California Verbal Learning Test – Children's Version (CVLT-C) is an assessment of verbal learning and memory that is used to diagnose and treat memory impairments secondary to learning disabilities, mental retardation, neurological disorder, psychiatric problems, and attention-deficit disorders (Delis, Kramer, Kaplan, & Ober, 1994). The CVLT-C entails the child learning a shopping list over several trials and then recalling it after an interference task and after a delay.

Neuropsychological tests of executive functions, such as the Wisconsin Card Sorting Test (WCST) may also be affected by deficits in attention. The WCST was originally developed by Grant and Berg (1948 as cited in Stuss & Benton, 1986) to assess abstraction abilities and flexibility of thinking in normal individuals, but it has since demonstrated sensitivity to cerebral damage and has become widely used as a neuropsychological instrument (see Heaton, 1981). The WCST is utilized to assess executive functions such as abstract reasoning, conceptualization, problem solving, the ability to maintain set, and the ability to shift cognitive strategies in response to changes in environmental contingencies (see Heaton, et al., 1993).

Research suggests that the WCST is particularly sensitive to dysfunction in the frontal lobes, but Heaton et al. (1993) caution that labeling the WCST a measure of "frontal" functioning oversimplifies the complexity of the frontal lobes and overlooks the other potential causes of impaired executive functioning. The similarity between the behaviors of individuals with frontal lobe damage and the symptoms of ADHD has led researchers to examine the performance of children with ADHD on the WCST.

Research suggests that children with ADHD demonstrate impaired performance on the WCST. Comparisons of the WCST performance of children with ADHD and age-matched normal controls have revealed that children with ADHD complete significantly fewer categories and make more perseverative errors and perseverative responses than control groups (see Heaton et al., 1993). The WCST manual (Heaton et al., 1993) suggests that the relative pattern of performance on the WCST and collateral instruments may be useful for assessing the impaired executive functions of youth with ADHD. However, studies utilizing adolescent ADHD samples have not revealed impairments in WCST performance (Barkley, Grodsinsky, & DuPaul, 1992; Fischer et al., 1990).

Boucugnani and Jones (1989 as cited in Heaton et al., 1993) and Chelune, Ferguson, Koon, and Dickey (1986) report that the WCST performance of children in their samples improved with age. Perhaps the ADHD deficits leading to the impaired performance on the WCST is outgrown by adolescence (Fischer et al. 1990). An improvement in executive functions over time is consistent with neuroanatomical development of the frontal lobes. The WCST is sensitive to frontal lobe functioning and the morphological maturation and myelination of the prefrontal cortex are not complete until puberty (see Stuss & Benson, 1986).

The Halstead-Reitan Neuropsychological Test Battery for Older Children (HRNB) is the most commonly used neuropsychological test battery and is frequently part of neuropsychological evaluation of ADHD (Bigler & Clement, 1997). Performance on two of the tests from this battery are thought to be indirectly affected by attention deficits: Category Test (CT) and Trail Making Test Part B (TMT-B).

Performance on the CT of the HRNB involves several forms of cognitive processing including attention, memory, and executive functions such as nonverbal abstraction, concept formation, and problem solving (Bigler & Clement, 1997; Reitan & Wolfson, 1992). The child must attend to a set of stimulus figures and discern similarities and differences to identify the underlying concept (Reitan & Wolfon, 1992).

Trommer, Hoeppner, Lorber, and Armstrong (1988) compared the CT performance of children with ADHD whose Gordon's CPT scores were in the abnormal range with those of children with ADHD but CPT scores in the borderline and normal range. Their results indicated that the CT performance of the children with abnormal CPT scores was significantly poorer than that of the children with borderline or normal scores. Trommer et al. (1988) utilized a different CPT than is being examined in the present study, but their results suggest a relationship between inattention as measured by a CPT task and performance on neuropsychological tests of higher level cognitive processes.

The TMT-B is considered a measure of prefrontal dysfunction and a general indicator of overall brain functioning. It assesses the susceptibility of children's cognitive processes to disruption by a competing response and is a good indicator of impulse control (see Gorenstein et al., 1989). An inability to inhibit competing responses is associated with damage to the prefrontal cortex in humans or to the frontal or limbic region in animal models (see Gorenstein et al., 1989).

Treatment of Attention Deficits

Once ADHD has been identified, early intervention should attempt to lessen its impact on a child's life. As previously discussed, ADHD is associated with academic problems, strained relationships with peers and family, and comorbid disorders in childhood and adulthood. Treatment for ADHD should strive to not only alleviate the acute symptoms of ADHD, but to address these associated difficulties as well. Pharmacological and psychosocial treatments for ADHD are discussed below.

Pharmacological Treatment.

The pharmacological treatment of ADHD has been a source of controversy. Critics have proposed that the use of drugs to treat ADHD stunts children's growth, causes aggressive behavior, and increases the likelihood that a child will later abuse drugs; however research has not supported these claims (see Garber et al., 1996; Hechtmen et al., 1984; Klein & Mannuzza, 1991). The media has also suggested that too many children are being placed on medication for ADHD. Nationally, the number of prescriptions does not outweigh the estimated number of cases of ADHD, but the percentage of children receiving drug treatment for ADHD varies by region and some areas appear to have unusually high rates of medication use (see Garber et al., 1996).

The use of pharmacotherapy for the treatment of ADHD also contributes to the complexity of diagnosing the disorder. Considerable caution must be used in diagnosing a disorder in which the treatment of choice is medication. A positive response to pharmacological intervention among individuals with ADHD includes decreased motor activity, slowed thinking, diminished talkativeness, and less subjective stress (see Bellak & Black, 1992). However, a positive response to medication is not a diagnostic litmus test for ADHD (see Garber et al., 1996). Normal children respond to ADHD medications with the same decreased motor activity, increased vigilance, and improved learning as children with ADHD, and 20% to 30% of children with ADHD do not respond positively to medications (see Garber et al., 1996; Rapoport et al., 1980).

Two main classes of medications are most commonly used to treat ADHD: psychostimulants and antidepressants. Stimulants include methylphenidate (Ritalin), dextroamphetamine (Dexedrine), and pemoline (Cylert) (Bellak & Black, 1992). Methylphenidate and dextroamphetamine begin to have an effect 30 minutes after administration and last four to six hours (see Bellak & Black, 1992). The usual dosage ranges from 0.3 to 0.7 mg/kg of methylphenidate and 0.15 to 0.5 mg/kg of dextroamphetamine (see Bellak & Black, 1992). The optimum dose is established by monitoring the effectiveness and side effects of the drug. Pemoline is thought to be less effective than methylphenidate, but have fewer side effects (Grilly, 1994).

Estimates suggest that 750,000 to 1.6 million American children are treated with methylphenidate. The United States uses ten times more Ritalin than England or Japan;

and in 1998, the US used 84% of the world's Ritalin (Diller, 1999). Since 1990, the production and use of methylphenidate has increased by 700% (Diller, 1999).

Methylphenidate has been shown to have a normalizing affect on areas of the brain that have been implicated in the etiology of ADHD. Methylphenidate increases the metabolism of glucose in rats' mesencephalic, diencephalic, and basal ganglia regions, and decreases the metabolic rate in the motor cortex (see Lou et al., 1989). In humans, methylphenidate had been shown to activate central brain regions, particularly the left striatum, and to tend to decrease activity in primary sensory regions in the occipital, temporal, and parietal lobes (Lou et al., 1989).

Treatment with stimulants has been found to affect children's performance on neuropsychological tests. Treatment with stimulants improves children's performance on measures of attention such as the CPT (see Halperin et al., 1990). Malone and Swanson (1993) found that compared to placebo, methylphenidate treatment significantly reduced impulsive responding and overall errors among children with ADHD on a task similar to the Matching Familiar Figures Test (MFFT). The reaction time for correct responses did not differ between the placebo and drug conditions. The authors suggest that stimulant treatment positively affects the efficiency of children's thinking, rather than merely slowing it down.

Some research suggests that treatment with psychostimulants in childhood may have positive effects on youth's adult outcome. Hechtman et al. (1984) compared young adults with childhood onset ADHD who had been treated with psychostimulants for at least 3 years with those who had not and with a matched normal control group. Overall, they found that that the young adults who had childhood ADHD experienced significantly more difficulties than normal controls in many areas (e.g., school, work, debt, personality disorders). There were also significant differences within the ADHD group; those who had been treated with psychostimulants in childhood had fewer car accidents, stole less while they were in elementary school, viewed their childhood more positively, were less aggressive, needed less current psychiatric treatment, and had better social skills and self-esteem than those who had not been treated with medication. The authors conclude that stimulant treatment may not eliminate educational and work difficulties, but many reduce social ostracism and result in a more positive view of self and others.

Gammon and Brown (1993) discuss the limitations of psychostimulants. These include their ineffectiveness in approximately 30% of individuals with ADD, their disruption of sleep and appetite, their short half life that can lead to mood swings throughout the day, their ineffectiveness in treating the comorbid conditions associated with ADHD, and their possible side effects of irritability and dysphoria.

As an alternative to psychostimulants, two classes of antidepressants are used to treat ADHD: tricyclic antidepressants (TCAs) and selective serotonin reuptake inhibitors (SSRIs). TCAs used to treat ADHD include imipramine (Tofanil) and desimipramine (Norpramine) (Bellak & Black, 1992). TCAs have been found less effective than stimulant treatment and have several limitations, including: a lack of improvement in concentration, sedation in some individuals, serious possible cardiovascular side effects, and toxicity in overdose (Gammon & Brown, 1993).

SSRIs such as fluoxetine (Prozac) and sertraline (Zoloft) have also been used to treat ADHD. There is limited support for the use of SSRIs alone to treat ADHD, but they may be used in combination with stimulants to treat children who do not respond to treatment with stimulants alone or children with comorbid mood disorders (see Barkley, 1998). Gammon and Brown (1993) examined the effectiveness of combining methylphenidate and fluoxetine with psychosocial treatment for the treatment of children with ADHD who had failed to improve with stimulant treated alone. Their results indicated that while receiving the combined drug therapy, the children's grades improved, they experienced improved concentration, had fewer mood swings, and experienced less irritability, oppositionality, anxiety, and depressive symptoms.

Psychosocial Treatments.

Psychosocial interventions for ADHD are used either alone or in conjunction with pharmacotherapy. The recent controversy surrounding the prescription of psychotropic medications to preschools has highlighted the importance of implementing behavioral, family, and school interventions before initiating drug treatment, as well as throughout treatment if medications are prescribed (Levant, 2000; Zito et al., 2000). In her review of adolescent outcomes of children with ADHD treated with stimulants in childhood, Hechtman (1985) observed that youth who participated in studies that combined stimulants with psychosocial interventions (e.g., individual, group, and/or family therapy; parent training) had more positive outcomes than those that received stimulants alone.

Psychosocial interventions can be tailored to target the needs of the individual child. An evaluation by a specialist in learning disabilities may identify ways to improve a child's study techniques and academic performance (see Bellak & Black, 1992). Behavioral techniques and modifications in the child's home and school environment can also help manage symptoms of ADHD (Garber et al., 1996). Psychotherapy and family therapy can address issues of self-esteem and relationships with peers and family. Many families of children with ADHD benefit from psychoeducational training on the disorder, referrals to organizations for ADHD, and bibliotherapy (Bellak & Black, 1992).

The Present Research

The literature reviewed thus far illustrates the complexity and importance of accurately diagnosing ADHD. A medical exam and full neuropsychological evaluation is the most thorough means of correctly diagnosing ADHD and identifying a child's needs. A comprehensive understanding of a child's strengths and weaknesses helps focus treatment interventions, thereby increases their effectiveness and efficiency.

The present research investigates how the results of children's neuropsychological evaluations can contribute to our understanding of their deficits by exploring the patterns of performance on measures of attention, learning, and executive functioning. Is the impact of attention deficits encapsulated in tests specifically designed to assess attention, or do they affect children's performance on other neuropsychological measures in predictable ways? Does a child's index score on Conners' CPT have implications for their performance on other tests? And are the suggested CPT cutoff scores useful for defining homogeneous groups of children? It is hypothesized that that they are, and that a relationship exists between children's performance on Conners' CPT, and their scores on the WCST, the CVLT-C, the CT and the TMT-B.

Specifically, it is hypothesized that children whose overall CPT index scores are outside the normal range (above the cutoff score of 11) will also exhibit greater impairment in performance on the other measures examined relative to children whose CPT index does not suggest attentional problems (index score below the cutoff of 8): 1) more errors, trials to complete first category, perseverative responses, perseverative errors, and failures to maintain set on the WCST; 2) poorer List-A Trial-1 free recall, List-A Trial-5 free recall, percentage of change from List-A Trial-5 to short-delay free recall and from short-delay free recall to long-delay free recall, semantic cluster ratio, and percent of recall consistency on the CVLT-C; 3) greater number of errors on the CT; and 4) greater number of errors and total time on the TMT-B. Furthermore, given the hypothesized relationship between CPT scores and performance on the other measures examined, it is expected that exploratory multivariate analyses will support the groups defined by the CPT cutoff scores as distinct homogeneous groups.

Conners' CPT is a widely used test in the assessment of ADHD and little is know about the relationship between children's index score on this measure and their performance on other instruments sensitive to attention deficits. Although Conners (1994) cautions that the CPT should not be used in isolation to diagnosis ADHD and warns that the overall index score is a simplification of a complex set of variables, the availability of a brief attention measure with cutoff scores designed to distinguish between children with ADHD and normals could easily be misused. A better understanding of the characteristics of the groups defined by these cutoff scores will help guide their interpretation and contribute to our understanding of the assessment of attention deficits and associated cognitive impairments.

Method

Participants

Participants were drawn from archival files of children seen for neuropsychological evaluation at Montana Neurobehavioral Specialists. These children were primarily Caucasian and from the Missoula, Montana area. They were referred for evaluation by their parents, schools, psychologists, and primary care physicians. The final sample was composed of 71 participants.

Inclusion and exclusion criteria were used to increase the homogeneity of the sample. The files of children 9 to 12 years of age who had completed the measures examined in this study were selected. This age range was chosen so that the participants would be an appropriate age for the measures examined, yet have not entered adolescence. Using the cutoffs recommended by Conners (1994) to identify attention deficits, the clinic referred children's performance on the CPT was used to define two groups: 1) children with overall index scores below 8, and 2) children with overall index scores greater than 11. Children with overall CPT index scores ranging from 8 to 11 were excluded to maximize group differences and examine the meaningfulness of these cutoffs.

Also excluded were children who had experienced a loss of consciousness of greater than 10 minutes, a seizure disorder, or who had a Full Scale IQ Score (FSIQ) of less than 85 on the Wechsler Intelligence Scale for Children, Third Edition (WISC-III).

These exclusion criteria were included to help minimize the potential impact of traumatic brain injury or low intellectual functioning on the dependent measures. ADHD may affect children's performance on standardized tests of intelligence. Research suggests that children with ADHD score an average of 7 to 15 points below control groups, so a cutoff of 85 (15 points below the mean) was used to exclude children whose below average performance on the WISC-III is likely to be due to more than attention deficits alone (see Barkley, 1998).

Many of the children seen for evaluation at Montana Neurobehavioral Specialists are being treated with psychotropic medications. At the time of testing, children in the present sample fell in one of five categories, taking: 1) no medications, 2) a CNS stimulant such as methylphenidate or dextroamphetamine, 3) a heterocyclic antidepressant such as bupropion or nefazodone, 4) an antidepressant from the class of selective serotonin reuptake inhibitors (SSRIs) such as fluoxetine or sertraline, or 5) taking both a stimulant and an antidepressant. Children on other classes of psychotropics were excluded from the study.

Procedures

The files of children that meet the inclusion criteria were assigned an identification number to ensure confidentiality, and the list of the children's names was kept in a locked drawer at the clinic at all times. The information collected from each selected file included demographic information (i.e., age, gender, race/ethnicity, WISC-III FSIQ score, education, handedness, medications, diagnoses), and test scores on the measures in question (i.e., CPT, CVLT-C, WCST, TMT-B, and CT).

All measures were individually administered and scored by trained psychometric technicians at Montana Neurobehavioral Specialists as part of a full neuropsychological assessment. The results of the children's testing were reviewed by a clinical neuropsychologist and diagnoses and recommendations have been made.

Measures

Conners' Continuous Performance Test (CPT).

The approximately 14 minute long "standard" mode of the Conners' CPT was used as a measure of attention. IBM compatible computers with 14-inch monitors and Windows 3.1 operating systems were used to administer the CPT. During the CPT, the child is instructed to watch the computer and press the space bar as soon as they see any letter except X flash on the screen. The accuracy of the keyboard as a response device in reaction time paradigms has been questioned (Segaloqitz & Graves, 1990). Nonetheless the space bar was used in the CPT standardization testing and was utilized as recommended by the CPT manual in the present study. Following the instructions, approximately 1 inch tall, bold-faced letters of the alphabet are presented for 250 milliseconds in six blocks. Within each block are three 20 trial sub-blocks with different inter-stimulus-intervals (ISIs) of 1, 2, or 4 seconds.

The Conners' CPT produces three types of basic measures. The first, omission errors, is the number of nontarget stimuli (i.e., letters other than X) to which the child did not respond. Omission errors may be the result of inattention or of slow responding. Comission errors are responding to the target stimulus, X, rather than inhibiting response until another letter is presented. The third measure is reaction time, particularly reaction time variability.

The results of the CPT are expressed in T-scores and percentiles relative to a general population sample and to a clinical sample of individuals with ADHD. Conners (1994) encourages the use of the general population norms in interpreting CPT results due to the smaller size of the clinical sample. The general population sample is 51.2% male and ranges in age from 4 to 70 (n = 520). The majority of the adult general sample is under 30 years of age (82.4%). The clinical sample is composed of 104 individuals diagnosed with ADD/ADHD alone and 134 individuals with ADD/ADHD and a comorbid disorder. The clinical sample ranges in age from 4 to 61, is 75.4% male, and was not on medication at the time of testing. The children's norms for both the clinical and general population samples are broken down by age into two year intervals (e.g., 4-5, 6-7, etc.). The T-scores produced by the CPT have an average of 50 and a standard deviation of 10. Isolated atypical scores should be interpreted with caution; two or more atypically high scores (i.e., percentile ≥ 90 or a T-score ≥ 60) suggest a possible attentional problem.

Impulsive and inattentive responding can produce different patterns of scores on the CPT. Attention problems are characterized by high scores of omission, a slow reaction time, inconsistent responding, and changes in response rate or hit rate over time. The pattern of CPT scores suggestive of impulsively include high commission error rate, and usually fast reaction time. The results of the CPT also indicate the child's attentiveness (d', ability to discriminate targets from non-targets), and degree of risk-taking (β, frequency of responses).

The CPT produces an overall index score based on a weighted sum of the scores that best distinguish 6 to 17 years old children who had been diagnosed with ADHD from general population cases among the normative sample. Conners (1994) has suggested cutoff points based on this overall index score. A score of less than eight on the overall index suggests that the child has no attentional problems. Scores ranging from 8 to 11 are considered “borderline” and Conners (1994) suggests further investigation of these individuals’ ability to attend. Scores greater than 11 are considered strong evidence of an attentional problem. It was these cutoff scores that were used to define the two groups in the present study.

Among the children 6 to 17 years old in the normative sample, these cutoff points yield a 9.6% false negative rate (clinical cases scoring < 8), and 5.9% false positive rate (general population cases scoring > 11); and 12.0% of individuals fall in the borderline range. The overall index score cutoffs have been cross-validated with an independent clinical sample and age and sex matched controls from the general population sample. Among 6 to 17 year olds in this second sample, the results indicated a false positive rate of 13.5% and a false negative rate of 26.1%.

<u>Wisconsin Card Sorting Test (WCST)</u>.

The WCST was used as a measure of executive function. The test consists of two decks of 64 response cards each depicting forms (triangles, stars, crosses, or circles) of varying color (red, green, yellow, or blue) and quantity (one, two, three, or four). The child is instructed to match each of the response cards to one of four key cards (a single red triangle, two green stars, three yellow crosses, or four blue circles). The child is not told how to match the cards, but is informed whether each card was correctly or incorrectly sorted after each response. The instructions indicate that there is no time limit on the WCST. The examiner records on which dimensions (color, form, number, or other) each match is made on a record form. Once the child has matched ten consecutive cards correctly, the sorting principle is changed without warning (e.g., sorting by color to sorting by form) until the child has successfully completed six categories (two of each sorting principle) or has finished both decks of cards.

Various forms of administration and scoring of the WCST have been used by different researchers. For the cases examined in the present study, the procedures outlined in the manual (Heaton, 1981; Heaton, et al., 1993) were used with one variation. The response cards were handed to the child one at a time rather than as an entire deck. This method was employed to avoid the child shuffling the deck or proceeding without feedback from the last response. Heaton has reportedly approved of this method of administration (personal communication of Montana Neurobehavioral Specialists' head psychometrician with Marshall Clinic, 1989).

WCST normative data from several samples are available for individuals 6 ½ to 89 years of age, and education-corrected norms are available for adults over 20 years of age (see Heaton et al., 1993). The original normative study described by Heaton (1981) suggests that the perseverative response score is the best predictor of brain damage, particularly focal frontal lobe involvement.

Five of the participants' scores on the WCST were collected for the present study: total numbers of errors, number of trials to complete the first category, perseverative responses, perseverative errors, and failure to maintain set. The scoring criteria for perseverative responses, perseverative errors, and failure to maintain set are complex and are discussed below.

There are several forms of perseverative responses. The most common form are responses that would have been correct by the previous sorting principle. For example, if the present category is form, matching to the previous category, color, would be perseverative. Since there is no previous principle during the first category (color), perseverative responses at this stage are defined as continuing to sort by an incorrect principle after the first incorrect response that matches the key card on only one dimension (either form or number). The final form of perseverative responses are those in which the child begins perseverating to a third principle that is neither the correct sorting principle nor the previous sorting principle. This change in the "perseverating-to" category is demarcated by three incorrect successive matches in which the response card matches the key card on only one dimension. For example, if the present category is form and the previous category is color, three unambiguous number responses in succession would redefine number responses as perseverative.

Both correct and incorrect responses may be perseverative. Responses that are correct, but also may have been sorted perseveratively (i.e., they match both the correct and "perseverating-to" category) are considered perseverative if they occur within a series of unambiguously perseverative responses. Perseverative errors are the perseverative responses that are also incorrect. The failure to maintain set score is the number of times that the child makes five to nine consecutive correct responses (suggesting insight into the sorting principle), but fails to make the full ten correct responses necessary to complete the category.

There is evidence of good interscorer and intrascorer reliability using the Heaton (1981) scoring system for the WCST with adults, children, and adolescents, as well as with experienced and novice scorers (see Heaton et al., 1993). However, others have suggested that the interscorer reliability of perseveration is low and have attempted to clarify the manual's scoring criteria (see Flashman, Horner, Freides, 1991). Heaton et al. (1993) review the evidence for the validity of the WCST in measuring executive functioning in a wide range of adult, child, and adolescent clinical groups including children with ADHD.

California Verbal Learning Test – Children's Version (CVLT-C).

The CVLT-C is an assessment of children's verbal learning and memory (see Delis et al., 1994). The normative sample for the CVLT-C is composed of 920 children, ages 8 to 16. It measures the quantity of verbal material the child learns as well as the strategies and processes involved in learning. The task involves the child listening to and recalling items from two hypothetical shopping lists, the Monday list and the Tuesday list.

Each list is composed of 15 items, with five items from each of three semantic categories (i.e., fruit, playthings, clothing). For all immediate recall trials, items are presented at the rate of approximately one word per second and each item follows an item from a different semantic category. For the first five trials, the child is presented with and asked to recall the Monday shopping list. Then the Tuesday list is presented and recalled for one trial as an interference task. The child is then asked to recall items from the Monday list only for a short-delay free-recall trial, and then asked to recall items from the Monday list by semantic category for a short-delay cued-recall trial.

After a 20-minute delay of other nonverbal tests, the child is asked to recall items from the Monday list for the long-delay free-recall trial, and to recall items from the Monday list by semantic category for the long-delay cued-recall trial. Finally, the child completes a recognition trial in which they are to identify items from the Monday list from of a long list of verbally presented shopping items.

The CVLT-C produces several measures, including: level of recall and recognition for all trials; use of learning strategies, such as semantic or serial clustering; serial-position effects; learning rate across trials; consistency of items recalled across trials; the effect of proactive and retroactive interference on recall; retention of learned material over a short and longer delay; effect of cueing and recognition on performance; discriminability, false positives, and response bias during a recognition task; and perseveration and intrusions.

Six scores of the CVLT-C related to attention, learning, and memory were examined in this study: 1) List-A Trial-1 free recall, 2) List-A Trial-5 free recall, 3) percentage of change from Trial-5 free recall to short-delay free recall, 4) the percentage of change from short-delay free recall to long-delay free recall, 5) the semantic cluster ratio, and 6) the percent of recall consistency.

List-A Trial-1 free recall is primarily a measure of auditory attention span and List-A Trial-5 reveals the effects of repeated trials on recall. The two percentage of change scores reflect the proportion of words that the examinee recalls at time 2 (either short-delay or long delay) that they also recalled at time 1 (either List-A Trial-5 or short delay free recall). Poor performance on these measures suggests unusually rapid forgetting during the delay interval or a high level of susceptibility to retroactive interference.

The last two measures of the CVLT-C examined gauge the child's use of active learning strategies. The semantic cluster ratio assesses the child's use of semantic clustering as a learning strategy. This score is calculated by dividing the observed degree of semantic clustering by the expected level. Low scores suggest that the child did not utilize semantic clustering strategies and either recalled the items in serial order or in no organized fashion. Children with ADHD often become inattentive or restless during the testing and abandon their learning strategies, leading to poor recall consistency (Delis et al., 1994). Among adults tested with the adult version of the CVLT, inconsistent recall is associated with frontal lobe involvement (see Delis et al., 1994).

Delis et al. (1994) discuss the reliability and validity of the CVLT-C. Trials 1 through 5 appear to have a high degree of internal consistency: the average across-trial coefficient alpha is .85, the average across-semantic-category reliability coefficient is .72, and the average coefficient alpha correlation across-word is .81. The test-retest correlations of CVLT-C scores differ by age of the child and range from .17 to .90. Delis et al. (1994) suggest that the theoretical and research foundations of the CVLT-C provide evidence of its content-related and criterion related validity. Factor analyses of the CVLT-C suggest that it has the same general six factor structure as the adult version. The correlation between the CVLT-C List-A Trials 1-5 raw score total and the WISC-R Vocabulary standard score ranges from .32 to .40, suggesting that these tests are mildly related (9% to 16% shared variance), but for the most part measure different cognitive domains.

Category Test of the HRNB for Older Children (CT).

The CT is a measure of executive functions including nonverbal abstraction, concept formation, and problem solving (Bigler & Clement, 1997; Reitian & Wolfson, 1992). The child is instructed to watch a 10" × 8" screen on which slides of different geometric figures and designs are projected. Something about the image on the screen suggests a number between 1 and 4. The child is to select which number they think the image suggests and pull down on the level on an answer panel corresponding to that number. The child immediately receives feedback on their answer, a bell if correct or a buzzer if incorrect. The child is allowed only one answer per image.

The entire test is composed of 168 visual images divided into six subtests. Each subtest has one idea or principle behind the correct answer. At the end of each subtest, the child is informed that the next subtest is about to begin and the idea may be the same as the last or it may be different. The final subtest is unique in that instead of having one idea or principle that runs through, it is composed of images from the previous subtests so the child must remember what the correct idea was for that image and use that idea again.

The first subtest is composed of Roman numerals (e.g., IV = 4). The principle behind the second subtest is the number of items in each image (e.g., two squares = 2). For the third subtest, the child must identify the one item out of four pictured that is different and respond with the ordinal position number of the unique item (e.g., one large triangle followed by three small triangles = 1). This subtest becomes progressively harder as the items begin to vary on multiple dimensions and the child must identify the one that is most different. The fourth and fifth subtests are both based on the principle of the fraction of the figure that is made of a solid line (e.g., a square with ¾ solid lines and

¼ dotted lines = 3). The sixth and final subtest is made up of items from the previous subtests and the child is to try to remember the correct answer.

Throughout the test, the examiner is to try to elicit the child's best performance and can encourage the child to look at each item carefully before responding, ask them to describe the image, and encourage them to note how the image changes from slide to slide. The examiner is not to reveal the principle behind the subtest. The CT produces only one score, total number of errors. Neuropsychologically, poor performance on the CT may indicated brain dysfunction in a wide range of areas and systems (Bigler & Clement, 1997).

Trommer et al., (1988) examined the performance of children with ADHD on Gordon's CPT and the CT. Their results revealed that the children with ADHD and abnormal CPT scores performed significantly poorer on the CT than children with ADHD but normal or borderline CPT scores. Trommer et al. (1988) utilized a different version of the CPT than the present study and their sample, methodology, and interpretation of their results have been criticized (Irwin & Mettelman, 1989); however their results do suggest a relationship between children's performance on measures of attention and of higher cognitive functions such as the CT.

Trail Making Test Part B of the HRNB for Older Children (TMT-B).

The TMT is composed of two parts, A and B. Only Part B was used in the present research. In TMT-B, the child must utilize visual-spatial searching abilities and simultaneously sequence both numbers and letters. The child is presented with a sheet of paper with circles containing numbers and letters. The front side of the paper is the sample and the child is instructed to connect the circles in sequence by drawing a line alternating between numbers and letters. The examiner instructs him/her to start at 1 and draw a line from 1 to A, A to 2, 2 to B, B to 3, 3 to C, and so on all the way to the end at D. The child is assisted in completing the sample if necessary.

After the sample, the paper is turned over and the child completes the timed test of connecting 15 circles numbered 1 to 8 and lettered A to G. S/he is instructed to again draw a line connecting the circles in order alternating between numbers and letters. The child is stopped after any errors and returned to the last correct circle (during which the stopwatch continues to run). The TMT-B produces two scores: the number of seconds to complete the test, and the number of errors.

Completion of the TMT-B involves several cognitive processes and multiple brain areas. It is thought of as a good general indicator of brain function. Validity studies of the HRNB for Older Children have demonstrated differential levels of performance among normal control children, children with brain damage, and children with learning disabilities (see Reitan & Wolfson, 1992 for a review).

Results

Several statistical techniques were used to analyze data in the present study. All analyses were conducted using SPSS for Windows Version 9. First the descriptive statistics of the sample will be reviewed, followed by the results of the cluster analyses and multiple discriminant analyses.

Descriptive Statistics

Data was collected on 71 children who met the criteria for inclusion in the present study. The majority of the sample was male (n = 49 [69%]), and all participants were either Caucasian or of unspecified race/ethnicity. The participants had a mean age of 10.37 years (SD = 1.17; range = 9 to 12), and a mean grade level of 4.80 (SD = 1.26; range = 3 to 7). The participants' mean WISC-III FSIQ score was 100.00 (SD = 10.07; range = 85 to 127). Most participants were right handed (n = 65 [92%]), and the majority were taking no medications at the time of testing (n = 48 [68%]). Of those taking psychotropic medication (n = 23), the most commonly taken class of drugs was stimulants (n = 12 [52%]), followed by a combination of stimulants and SSRIs (n = 5 [22%]), then SSRIs alone (n = 4 [17%]), and lastly by hetrocyclics (n = 2 [9%]).

Roughly half of the children in the sample had received multiple diagnoses (n = 36 [51%]). Most of the children had been diagnosed with ADHD (n = 55 [77%]). After ADHD, the most common class of diagnoses among the sample was mood disorders (n =

14 [20%]), followed by learning disabilities (n = 12 [17%]). Other less common diagnoses represented in the sample include: behavior disorders (n = 10 [14%]), anxiety disorders (n = 9 [13%]), cognitive disorders (n = 7 [10%]), and other diagnoses (e.g., communication disorders, adjustment disorders, and Aspergers) (n = 9 [13%]).

Preliminary comparisons were performed on the characteristics of the two groups defined by Conners' CPT cutoff scores. The mean CPT overall index score for the children with normal CPT performance (i.e., index scores < 8 [n = 40]), was 2.58 (SD = 2.54). The children with poor performance on the CPT (i.e., index scores > 11 [n = 31]) obtained an average overall index score of 17.84 (SD = 2.84). An analysis of variance (ANOVA) revealed no significant differences between the two groups on age, FSIQ score, or grade. A Chi-square of group by participants' gender indicated significant differences, X^2 (1, N = 71) = 5.680, $p < .05$. There were significantly more girls in the group with low CPT index scores (17 out of 40 [43%]) than in the group with high CPT indexes (5 out of 31 [16%]). Chi-square analyses revealed no significant differences between groups on race, handedness, medications, or frequency of ADHD diagnoses.

With the given sample size, it was decided to limit the number of variables in the cluster analyses and multiple discriminant analyses to five. This maintains a participant to variable ratio of approximately 14:1. An exploratory approach was taken towards selecting the variables to include by running oneway ANOVAs on all of the measures and selecting the variables that yielded the greatest differences between groups. This selection process increases the probability of finding differences between groups in subsequent analyses, but was deemed acceptable given the exploratory nature of this study and the goal of describing differences in the patterns of performance between groups.

The five measures selected for inclusion in the cluster analyses and multiple discriminant analyses were: 1) the Trials to 1st Category score of the WCST, 2) the Failure to Maintain Set score of the WCST, 3) the List-A Trial-5 Free Recall score of the CVLT-C, 4) the Long Delay vs. Short Delay score of the CVLT-C, and 5) the Semantic Cluster Ratio of the CVLT-C.

In the present sample, scores on Trials to 1st Category range from 10 to 44 with high scores indicating poor performance. Failure to Maintain set scores range from 0 to 3 and higher scores suggest greater difficulty maintaining response set on the WCST. The minimum number of items recalled on List-A Trial-5 of the CVLT-C in the present sample was 5 and the maximum was 14. The percentage of change from Short Delay to Long Delay of the CVLT-C ranges from –100% to +50%. Negative scores on this measure suggest that the child failed to remember items they had correctly recalled at Short Delay after 20-minutes of completing another task. The sample's performance on Semantic Cluster Ratio ranges from 0.6 to 2.2. Larger values suggest the child utilized active semantic clustering strategies while list learning.

Correlational analyses of age and these five neuropsychological measures indicated that age was significantly related only to scores on List-A Trial-5 Free Recall of the CVLT-C ($r = .31$, $p < .01$). Table 1 presents the Pearson correlations between the neuropsychological measures. As might be expected, there is a significant positive correlation between the use of semantic clustering strategies and the number of items recalled on List-A Trial-5 of the CVLT-C ($r = .37$, $p < .01$).

Table 1
Correlations between Neuropsychological Measures

Measure	WCST		CVLT-C		
	1	2	3	4	5
WCST					
1. Trials to 1st Category	--	.02	-.02	.07	-.07
2. Failure to Maintain Set		--	.19	.12	.14
CVLT-C					
3. List-A Trial-5 Free Recall			--	.03	.37**
4. Long Delay vs. Short Delay				--	.03
5. Semantic Cluster Ratio					--

Note. ** $p < .01$

Table 2 presents a summary of the primary findings of a group by neuropsychological measures ANOVA. The ANOVA indicated two scores from the CVLT-C differed significantly between groups at the $p < .05$ level. The children with low CPT index scores remembered significantly more items on Trial-5 of List-A of the CVLT-C than those with high CPT indexes, $F(1,69) = 4.00$, $p < .05$. The children with low CPT indexes also utilized semantic clustering learning strategies on the CVLT-C more frequently than the children with poor performance on the CPT, $F(1,69) = 6.09$, $p < .05$. The third score from the CLVT-C examined measures the percentage of change from Short Delay to Long Delay. Relative to the children with high CPT index scores, the children with lower CPT indexes demonstrated a trend towards recalling a greater proportion of items from short-delay again at the 20-minute long delay, $F(1,69) = 2.26$, $p < .14$.

Table 2
Means of Neuropsychological Measures by CPT Group

Measure	CPT index < 8 M	CPT index < 8 SD	CPT index > 11 M	CPT index > 11 SD
WCST				
Trials to 1st Category	15.38	08.27	12.48	03.94
Failure to Maintain Set	01.18	00.90	00.84	00.97
CVLT-C				
List-A Trial-5 Free Recall	11.73*	01.91	10.71*	02.37
Long Delay vs. Short Delay	04.62	13.79	-02.43	25.20
Semantic Cluster Ratio	01.53*	00.30	01.34*	00.33

Note. * Means in same row differ at $p < .05$

The two groups did not differ significantly at the $p < .05$ level on the measures of the WCST that were included in the multivariate analyses. There was, however, a trend for poorer performance on these two scores among the children in the low CPT index group. The children with normal CPT index scores took more trials to complete their first category than the poor CPT score group, F (1,69) = 2.27, $p < .08$; and also exhibited greater difficulty maintaining set, F (1,69) = 2.27, $p < .14$.

Cluster Analyses

Cluster analysis is a multivariate technique for identifying a structure within objects and classifying them into relatively homogenous groups (see Aldenderfer & Blashfield, 1984; Hair, Anderson, Tatham, & Black, 1995). There are a variety of approaches to cluster analysis. A combination of both hierarchical and nonhierarchical clustering methods was chosen for the present study. As outlined in Hair et al. (1995), the use of both of these methods capitalizes on the strength of each.

First a hierarchical cluster analysis was used to identify the appropriate number of clusters and likely cluster centers. The number of clusters and centroids suggested by the hierarchical cluster analysis were then used as the starting points for a nonhierarchical cluster analysis. This two step process avoids the arbitrariness of randomly selecting cluster seeds and the number of clusters to form associated with nonhierarchical methods, but allowing for the reassignment of cases throughout the clustering process. Prior to either clustering procedure, the scores on the neuropsychological measures examined were standardized to $\underline{z}$ scores to control for the implicit weighting of variables with larger dispersion (Aldenderfer & Blashfield, 1984; Hair et al., 1995).

Hierarchical Cluster Analysis.

Hierarchical cluster analysis begins with each case as its own cluster and proceeds to merge the two closest clusters until all cases form one large cluster. As recommended by Hair et al. (1995), the present study utilized the squared Euclidean distance as the distance measure of similarity, and Ward's method to derive hierarchical clusters.

Once the hierarchical cluster analysis was performed, the results were examined to determine the appropriate number of clusters. Two error variability measures were used to establish the cutoff point for the number of clusters (Aldenderfer & Blashfield, 1984; Hair et al., 1995). First, the percentage of change in the agglomeration coefficient for each of the last 10 cluster unions was examined for large increases. This coefficient represents the within-cluster sum of squares. As shown in Table 3, the largest increase in the percentage of change in the agglomeration coefficient (nearly 26%) appears to occur when three clusters are joined into two, suggesting that relatively heterogeneous clusters are being joined.

Table 3

Analysis of Agglomeration Coefficient for Hierarchical Cluster Analysis

Number of Clusters	Agglomeration Coefficient	% of Change in Coefficient
10	98.679	8.33
9	106.902	8.44
8	115.925	12.08
7	129.427	13.89
6	147.404	12.40
5	165.688	19.33
4	197.713	16.35
3	230.045	25.74
2	289.267	9.88
1	350.000	--

Second, the number of clusters was graphed against the corresponding agglomeration coefficients and the point at which the curve began to level off was identified (Figure 1). A flattening of the graph suggests that further merger of the clusters is providing no new information (Aldenderfer & Blashfield, 1984). This graphic portrayal of the results suggested a three-cluster solution as well.

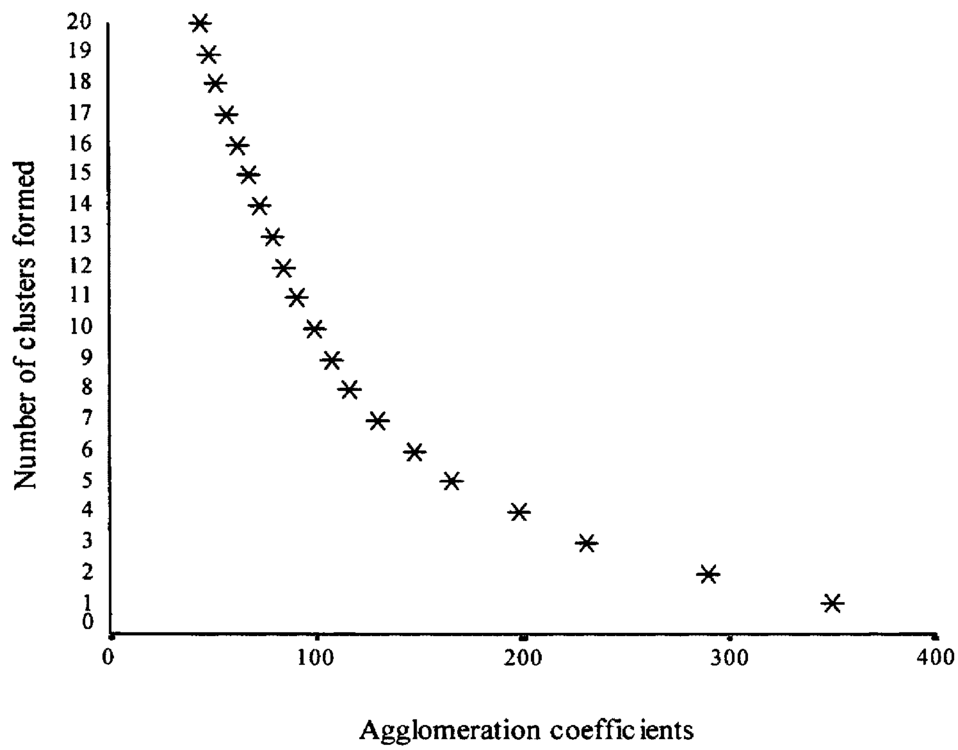

Figure 1. Plot of agglomeration coefficients vs. number of clusters formed for hierarchical cluster analysis using Ward's Method

Although both of these decision processes are heuristic and rather subjective, formal tests have not been widely accepted (Aldenderfer & Blashfield, 1994). Using these techniques, a three-cluster solution was chosen for this hierarchical cluster analysis. The cluster centroids generated by the three-cluster solution were then used as the starting points for the nonhierarchical cluster analysis.

Nonhierarchical Cluster Analysis.

In contrast to hierarchical cluster analysis, nonhierarchical methods allow for the reassignment of cases to clusters throughout the clustering process. This avoids the potential problem of poor cluster assignment early in the process negatively affecting the entire analysis. However, nonhierarchical procedures have their limitations; the number of clusters must be selected a priori, and unless the initial centroids are specified, the first full cases in the data set are used as cluster seeds and the order in which cases are listed can influence the results.

The present study utilized the centroids and number of clusters suggested by the hierarchical cluster analysis to run a K-means nonhierarchical cluster analysis. A summary of the results of the K-means cluster analysis is presented in Table 4. The K-means cluster analysis fine-tuned the results of the hierarchical cluster analysis by reassigning three cases from Cluster 1 to Cluster 2, resulting in minor adjustments in the final cluster centers.

Table 4
Results of Nonhierarchical K-Means Cluster Analysis with Initial Seed Points from Hierarchical Results

Cluster Variables	Cluster 1	Cluster 2	Cluster 3
Initial Cluster Centers	$n = 45$	$n = 19$	$n = 7$
Trials to 1st Category	-0.32471	-0.23932	2.73700
Failure to Maintain Set	-0.00632	-0.08589	0.27378
List-A Trial-5 Free Recall	0.40347	-1.02918	0.19973
Long Delay vs. Short Delay	-0.06501	0.08496	0.18729
Semantic Cluster Ratio	0.46483	-1.10000	-0.00246
Final Cluster Centers	$n = 42$	$n = 22$	$n = 7$
Trials to 1st Category	-0.34326	-0.21557	2.73703
Failure to Maintain Set	0.07130	-0.22323	0.27378
List-A Trial-5 Free Recall	0.48555	-0.99052	0.19973
Long Delay vs. Short Delay	0.00497	-0.06908	0.18729
Semantic Cluster Ratio	0.50757	-0.96822	-0.00246

Note. All scores standardized to z scores

Oneway ANOVA was used to compare the raw scores of the three clusters produced by the nonhierarchical cluster analysis. The ANOVA revealed significant differences between clusters on age, Trials to First Category scores of the WCST, and List-A Trial-5 Free Recall and Semantic Cluster Ratio scores from the CVLT-C. The mean raw scores and standard deviations of the three clusters may be seen in Table 5.

Table 5
Group Means for Three-Cluster Nonhierarchical Cluster Solution

	Cluster 1		Cluster 2		Cluster 3	
	M	SD	M	SD	M	SD
Clustering Variables						
Trials to 1st Category	11.76_a	1.94	12.64_a	2.95	32.86_b	5.87
Failure to Maintain Set	1.10_c	0.93	0.82_c	0.96	1.29_c	0.95
List-A Trial-5 Free Recall	12.33_d	1.16	9.14_e	1.93	$11.71_{d,f}$	2.75
Long Delay vs. Short Delay	1.64_g	13.13	0.18_g	29.01	5.24_g	20.22
Semantic Cluster Ratio	1.61_h	0.25	1.13_i	0.23	$1.44_{h,j}$	0.30
Other Variables of Interest						
Age	10.57_k	1.15	9.81_l	1.05	$10.86_{k,l}$	1.22
Grade	4.98_m	1.28	4.36_m	1.14	5.14_m	1.35

Note. Means in the same row not sharing subscripts differ at $p < .05$

Post hoc Bonferroni comparisons indicated: 1) relative to members of Cluster 2, children in Cluster 1 were significantly older, recalled more items on List-A Trial-5 of the CVLT-C, and utilized semantic clustering strategies more frequently; 2) children in Cluster 3 took significantly more trials to complete the first category of the WCST than members of Cluster 1 or 2; and 3) relative to Cluster 3, children in Cluster 2 took fewer trials to complete the first category of the WCST and recalled more items on List-A Trial-5 of the CVLT-C, but less frequently utilized semantic clustering strategies.

The positive correlation between age and scores on List-A Trial-5 Free Recall in conjunction with significant age difference between Clusters 1 and 2 raised concern that age might accounted for the different levels of performance observed between these two groups. To rule out this possibility, the mean raw scores of the three clusters were contrasted again using multivariate analysis of variance with and without age as a covariate (MANOVA and MANCOVA respectively). The results of these analyses did not differ substantially from one another, were consistent with the results of the oneway ANOVA, and yielded the same significant pairwise comparisons.

Profiles of the three clusters' mean $\underline{z}$ scores on the neuropsychological measures may be seen in Figure 2. For purposes of this graph, scores on Trials to 1st Category and Failure to Maintain Set were transformed so that negative values represent poor performance on all measures.

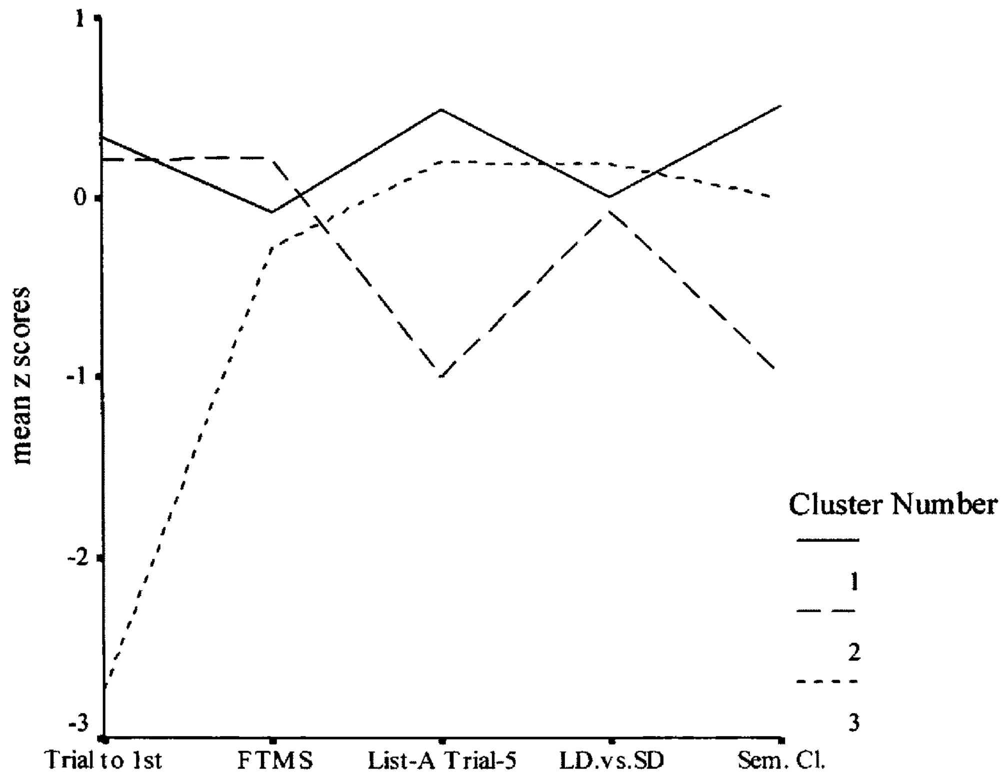

Figure 2. Plot of each cluster's mean z scores on five neuropsychological measures
Trials to 1st = trials to 1st category on WCST
FTMS = failure to maintain set score of WCST
List-A Trial-5 = list-A trial-5 free recall of CVLT-C
LD.vs.SD = long delay vs. short delay free recall of CVLT-C
Sem. Cl. = semantic cluster ratio of CVLT-C

Chi-square analyses of participants' cluster assignment by frequency of ADHD diagnosis and by gender yielded no significant results. ANOVA indicated that the clusters do not differ significantly on WISC-III FSIQ scores. A Chi-square of CPT group by participants' cluster assignment revealed significant differences, X^2 (2, N = 71) = 8.91, $p < .05$. The majority of the children in the low CPT index group were assigned to Cluster 1 (27 out of 40 [68%]). The remaining children in the low CPT index group were relatively evenly split between Clusters 2 and 3 (7 out of 40 [18%], and 6 out of 40 [15%], respectively). Only one child in the high CPT group was assigned to Cluster 3, and the remaining members of the high CPT index group were evenly split between Clusters 1 and 2 (15 out of 71 [21%] for both Clusters 1 and 2).

Oneway ANOVA was also used to compare the three clusters' raw scores on the nine variables that were not used to derive the cluster solution. The results revealed significant differences between the clusters on several scores from the WCST (i.e., total Errors, Perseverative Responses, and Perseverative Errors), as well as from the CVLT-C (i.e., List-A Trial-1 Free Recall, Short Delay vs. Trial-5 Free Recall, and Percent of Recall Consistency). The mean raw scores and standard deviations of the variables that differed significantly between the three clusters may be seen in Table 6.

Table 6
Clusters' Mean Scores on Measures Not Used to Derive Cluster Solution

	Cluster 1		Cluster 2		Cluster 3	
	M	SD	M	SD	M	SD
WCST						
Errors	35.43_{a}	18.35	$35.27_{a,b}$	18.36	54.71_{b}	21.66
Perseverative Responses	17.90_{c}	10.50	18.00_{c}	8.37	31.86_{d}	23.15
Perseverative Errors	16.12_{e}	8.82	16.27_{e}	7.28	27.57_{f}	18.60
CVLT-C						
List-A Trial-1 Free Recall	6.93_{g}	1.57	5.36_{h}	1.47	$7.14_{g,h}$	2.03
Short-Delay vs. List-A Trial 5	-10.12_{i}	15.08	-24.01_{j}	21.84	$-15.50_{i,j}$	7.78
% Recall Consistency	84.02_{k}	7.91	77.00_{l}	7.60	$83.43_{k,l}$	7.14

Note. Post hoc Bonferroni comparisons indicate means in the same row not sharing subscripts differ at $p < .05$

Figure 3 depicts the three clusters' mean z scores on these six measures. Scores on the three WCST indices have been transformed so that negative z score values reflect poor performance on all measures.

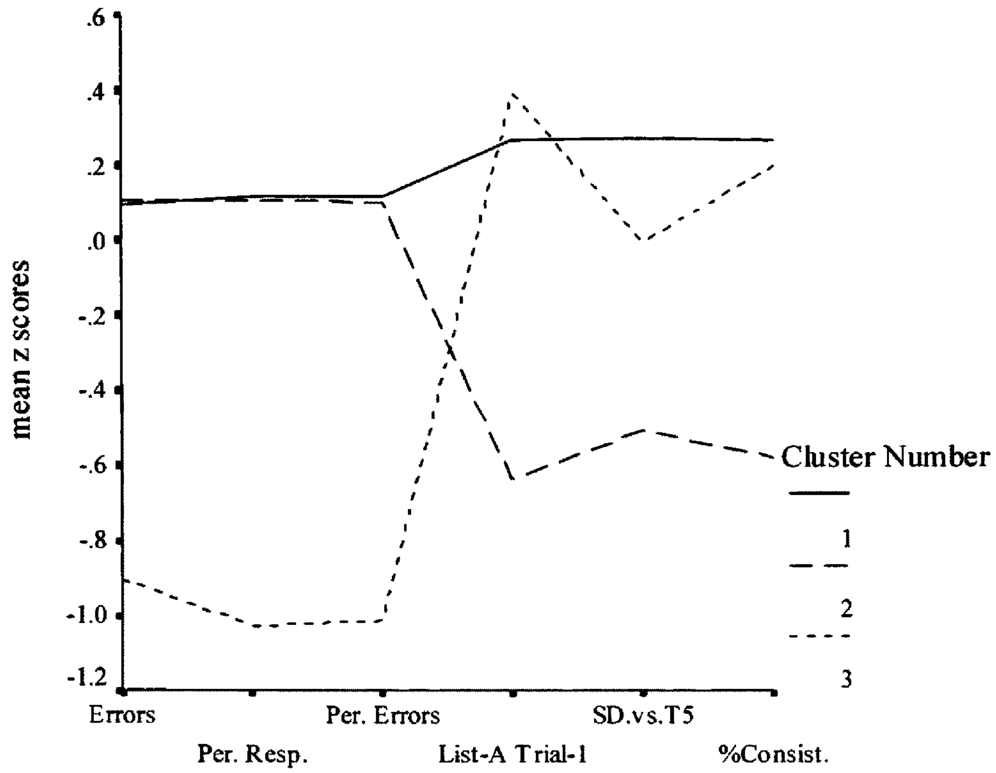

Figure 3. Plot of each clusters' mean z scores on neuropsychological measures not used to derive cluster solution
Errors = total number of errors on WCST
Per. Resp. = perseverative responses on WCST
Per. Errors = perseverative errors on WCST
List-A Trial-1 = list-A trial-1 free recall of CVLT-C
SD.vs.T5 = short delay vs. trial-5 of CVLT-C
%Consist. = % recall consistency on CVLT-C

The CVLT-C and WCST scores that differed significantly between the three clusters were compared to each measure's age-matched normative sample. The percentile ranks of the three clusters' scores are presented in Table 7.

Table 7
Clusters' Percentile Ranks on Scores of CVLT-C and WCST Relative to Normative Samples

	Cluster		
	1	2	3
CVLT-C			
List-A Trial-1	70	30	70
List-A Trial-5	70	16	70
Semantic Cluster Ratio	70	30	50
% Recall Consistency	70	50	70
WCST			
Perseverative Responses	45	47	16
Perseverative Errors	47	50	16
Total Errors	42	45	14
Trials to 1st Category	>16	>16	2-5
Failure to Maintain Set	>16	>16	>16

Multiple Discriminant Analyses

Multiple discriminant analyses served several purposes in the present study: 1) to describe differences between groups based on their multivariate profiles of neuropsychological test scores, 2) to derive a classification rule based on these differences and assess its predictive accuracy, and 3) to further delineate the profiles of the three clusters produced by the nonhierarchical cluster analysis. To achieve these goals, two discriminant analyses were conducted.

The independent variables for these two analyses were the participants' five neuropsychological test scores, and the dependent measure was group membership (i.e., CPT group for the first analysis, and cluster group for the second). Before conducting the multiple discriminant analyses, the normality of the five independent variables was examined using Kolmogorov-Smirnov's test of normality with Lilliefors significance correction. The results indicated that Semantic Cluster Ratio was the only normally distributed variable. Transformations of the data for the other four variables did not significantly improve normality.

Discriminant Analysis for Group.

Using a stepwise computational method to compute the discriminant function, the independent variables were entered into the function one at a time by sequentially adding the variable that contributed the most discriminating power (see Grimm & Yarnold, 1995; Hair et al., 1995). Variables that were not useful in discriminating between the groups were not included in the discriminant function. A maximum $\underline{F}$ significance value of .05 was required for entry into the function and a minimum significance level of .10 was required for removal.

The total value analysis method was used to specify the probabilities of classification. This method computes the probability of membership based on the group sizes to determine a weighted optimal cutting score. Mahalanobis $\underline{D}^2$ was chosen as the measure of statistical significance for the discriminatory power of the resulting function. This measure adjusts for unequal variance and is appropriate for use with the stepwise method (see Hair et al., 1995).

The results of the stepwise statistics generated a two-variable function. The variables included in the function are children's Semantic Cluster Ratio scores from the CVLT-C and their scores on Trials to 1st Category from the WCST (standardized discriminant function coefficients of .847 and .667, respectively). Discriminant loading values are the simple linear correlation between each variable and the discriminant function, and are considered valid means of assessing the relative importance of each variable in discriminating between groups (Hair et al., 1995). For this function, the discriminant loadings are .751 for Semantic Cluster Ratio, and .546 for Trials to 1st Category scores.

The centroid of the canonical discriminant function for the low CPT group was .343, and -.443 for the high CPT group. The canonical correlation suggests that this model accounts for 14% of the variance in the dependent variable, and the Chi-square statistic indicates that the discriminant function is significant at $p < .05$ level (Table 8).

Table 8
Results of Two-Group Discriminant Analysis

	% of Variance	Canonical Correlation	Wilks' Lambda	Chi-square	df	p
Function 1	100	0.368	0.865	9.873	2	.007

Using the discriminant function and the weighted cutting scores determined by the total value analysis, each case was classified to one of the two groups on the basis of its discriminant score. Table 9 presents the classification matrices for the two-group discriminant analyses for both the original analysis sample and for a cross-validated sample. The results of the discriminant analysis conducted with the original sample were cross-validated using the *U*-method. The *U*-method is a form of the "leave-one-out" estimator of classification accuracy. In this procedure, each observation was eliminated in turn from the sample and then classified by the classification rule generated with the remaining sample. The proportion of observations removed and then correctly classified produces a valid and consistent estimate of the classification accuracy rate (Hair et al., 1995). The classification results of the cross-validation sample support the results of the analysis sample.

Table 9

Classification Matrices for Two-group Discriminant Analysis for Analysis and Cross-Validated Samples

	Predicted Group Membership	
True Group Membership	CPT < 8	CPT >11
Analysis Sample		
< 8	31 [77.5%]	9 [22.5%]
>11	14 [45.2%]	17 [54.8%]
Cross-validated Sample		
< 8	31 [77.5%]	9 [22.5%]
>11	14 [45.2%]	17 [54.8%]

Note. 67% of both samples correctly classified

The proportional chance criterion was used as a measure of predictive accuracy (see Hair et al., 1995). Based on the size of the two groups in the sample, this criterion suggests that a function should demonstrate a hit rate greater than 51% to exceed the odds of correctly classifying cases to the smaller group by chance. An acceptable level of predictive accuracy is generally considered to be at least one-fourth greater than chance, or in this case at least 64%. The 67.6% hit rate obtained with this discriminant function exceeds this value but should be interpreted with caution; an internal classification analysis such as this with no hold-out sample can bias the prediction accuracy upward.

Multiple Discriminant Analysis for Cluster.

Multiple discriminant analysis techniques were repeated with cluster membership from the nonhierarchical K-means cluster analysis as the dependent variable. The stepwise procedure was used in the same manner as with the discriminant analysis for group; however, when distinguishing between three groups, two canonical discriminant functions are calculated.

The discriminant analysis yielded two three-variable functions. The three variables entered into the functions included: the Semantic Cluster Ratio of the CVLT-C, the Trials to 1st Category score of the WCST, and the List-A Trial-5 Free Recall of the CVLT-C. For the first function, the variables' discriminant loadings are .964 for Trials to 1st Category, .078 for List-A Trial-5 Free Recall, and .038 for Semantic Cluster Ratio. For the second function, the discriminant loadings are .656 for Semantic Cluster Ratio, .652 for List-A Trial-5 Free Recall, and -.264 for Trials to 1st Category. The cluster centroids and the standardized canonical discriminant function coefficients of each of the three variables may be seen in Table 10.

Table 10
Standardized Canonical Discriminant Function Coefficients and Functions at Cluster Centroids for Three-Cluster Discriminant Analysis

	Standardized Canonical Discriminant Function Coefficients			Functions at Cluster Centroids		
	Trials to 1st Cat.	List-A Trial-5	Sem. Cluster Ratio	1	2	3
Function 1	1.012	0.226	0.183	-0.572	-1.062	6.769
Function 2	-0.090	0.744	0.748	1.061	-1.898	-0.399

Note. Trials to 1st Cat. = Trials to 1st Category on WCST
List-A Trial-5 = List-A Trial-5 Free Recall of CVLT-C
Sem. Cluster Ratio = Semantic Cluster Ratio of CVLT-C

Table 11 depicts the multivariate results of the three-cluster discriminant analysis. Each function is statistically significant as measures by the Chi-square statistic, and each contributes to the variance accounted for by the model.

Table 11
Results of Three-Cluster Discriminant Analysis

	% of Variance	Canonical Correlation	Wilks' Lambda	Chi-square	df	p
Function 1	73.8	0.917	0.055	193.940	6	.000
Function 2	26.2	0.808	0.348	70.801	2	.000

The cutting scores generated by these two discriminant functions achieve a high degree of classification accuracy (Table 12). The proportional chance criterion based on the square proportion of each group suggests that a classification rate of 46% could be achieved by chance alone with these group sizes. An acceptable classification rate would need to exceed a rate one fourth greater than chance (in this case 58%). The classification rate achieved with these functions (98.6%) does exceed this value, but again must be viewed with caution unless validated with an independent sample.

Table 12
Classification Matrices for Three-Cluster Discriminant Analysis for Analysis and Cross-validated Samples

	Predicted Cluster Membership		
True Cluster Membership	1	2	3
Analysis Sample			
1	42 [100%]	0 [0%]	0 [0%]
2	1 [4.5%]	21 [95.5%]	0 [0%]
3	0 [0%]	0 [0%]	7 [100%]
Cross-validated Sample			
1	42 [100%]	0 [0%]	0 [0%]
2	1 [4.5%]	21 [95.5%]	0 [0%]
3	0 [0%]	0 [0%]	7 [100%]

Note. 98.6% of both samples correctly classified

As is evident in the scatterplot of the three clusters' two discriminant function values (Figure 4), Function 1 distinguishes Cluster 3 from Clusters 1 and 2, and Function 2 distinguishes Cluster 2 from Clusters 1 and 3. No one variable discriminates well between all three clusters, but two discriminant functions can be used to define regions containing each cluster in two-dimensional space (Hair et al., 1995).

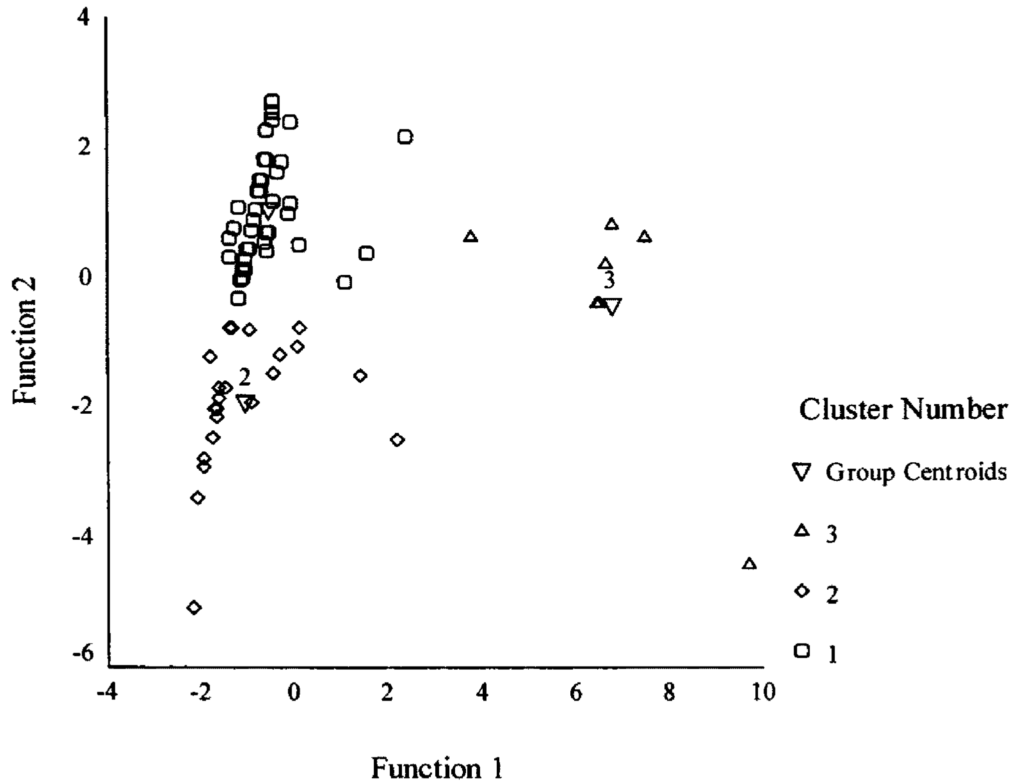

Figure 4. Scatterplot of three clusters' values on discriminant functions 1 and 2

Discussion

The results did not strongly support the primary hypothesis, that children with impaired attention as defined by poor performance on the CPT would also demonstrate deficits on measures of learning, memory, and executive function relative to children with CPT index scores within the normal range. The results indicated that the two groups differed significantly on only 2 of the 14 scores examined: List-A Trial-5 Free Recall and Semantic Cluster Ratio of the CLVT-C. For both of these scores, the children with normal CPT indexes scored an average of one-half a standard deviation greater than the mean of the normative sample, and the children with poor CPT index scores obtained average scores equal to those of the normative sample. The scores of neither group were outside of the normal range of performance on this measure.

The two groups did not differ significantly on scores from any of the other measures examined (i.e., WCST, CT, TMT-B). There was, however, a trend for poorer performance by the group with normal CPT indexes on two scores of the WCST: number of Trials to Complete 1st Category, and Failure to Maintain Set. On both of these WCST indices, the children with poor CPT indexes obtained average scores at least one standard deviation below the mean for their age, but nonetheless superior scores to those of the children who had normal CPT scores. Although nonsignificant, this trend is interesting in that it is in the opposite direction predicted by the hypotheses. Given the literature discussed in the introduction regarding deficits on the WCST among children with ADHD (see Heaton et al., 1993), it was expected that the children with impaired attention as measured by the CPT would also exhibit poorer performance on the WCST.

The secondary hypothesis, that exploratory analyses would support the groups defined by the Conners' CPT cutoffs as distinct and homogeneous in their neuropsychological performance, was also not supported by the results of the present study. The results of the cluster analyses yielded three clusters. The first was characterized by being older, utilizing active learning strategies more frequently, and successfully recalling more items on a repeated trial learning task. The second cluster was characterized by being younger, using fewer active learning strategies, and recalling fewer items after five trials of list learning. The third and final cluster was characterized by a moderate position between Clusters 1 and 2 on the use of active learning strategies and the number of items recalled on a repeated trial list learning task, and by greater difficulty conceptually matching nonverbal stimuli early in a novel task than either Clusters 1 or 2.

The performance of these three clusters can be described in reference to the normative samples for the WCST and the CVLT-C. The mean WCST Trial to 1st Category scores of Clusters 1 and 2 were within the normal range, but Cluster 3's mean score was in the 2nd to 5th percentile range. All three clusters obtained mean WCST Failure to Maintain Set scores that were within normal limits. On the CLVT-C, Cluster 2's mean score on List-A Trial-5 Free Recall was mildly impaired (i.e., one standard deviation below the mean), and Clusters 1 and 3's scores were each one half a standard deviation above the mean. On average, none of the three clusters significantly failed to retain items remembered at short-delay recall after a 20-minute long-delay. For mean scores on Semantic Cluster Ratio, Cluster 1 was one half a standard deviation above the mean, Cluster 2 was one half a standard deviation below the mean, and Cluster 3 was at the mean for the normative sample.

For each of the three clusters, the cluster variate was examined and a name was assigned to describe its characteristics. The first cluster was labeled "effective learners" due to their above average use of active learning strategies and their normal performance on a repeated trial list learning task. The second cluster was named "passive learners" to describe their low average use of active learning strategies and their mildly impaired performance on repeated trial list learning. The third cluster was termed the "poor problem solvers"; this group's performance on learning measures was within normal limits, but they exhibited impaired performance on a measure of early conceptualization during a novel problem-solving task.

A comparison of the three clusters' performance on variables not used to derive the cluster solution indicated that they differ significantly on six of the nine indices that did not distinguish between CPT groups. Profiles of the three clusters' mean z scores were remarkably similar to that of their performance on the five variables used to form the clusters. The effective learners (Cluster 1) obtained WCST scores (i.e., Errors, and Perseverative Errors and Responses) within normal limits relative to age appropriate norms and scores roughly half a standard deviation above average on the CVLT-C (i.e., List-A Trial-1 Free Recall, and Percent Recall Consistency). The passive learners (Cluster 2) exhibited normal WCST performance, but scored a half a standard deviation below average on the first trial of the CVLT-C. They did, however, maintain an average level of recall consistency across trials of the CVLT-C. The poor problem solvers

(Cluster 3) again displayed a very different pattern than the other two clusters. These children obtained high average scores on the CVLT-C (one half a standard deviation above the norm), but their performance on several of the WCST scores (i.e., Total Errors, Perseverative Errors and Responses) was roughly one standard deviation below the normative mean for their age.

Overall, the different patterns of performance on the WCST and CVLT-C observed between the three clusters may reflect individual variation in their rates of cognitive maturation. Research suggests that as children age they increasingly develop competency in the use of strategies to encode and retrieve information from memory (see Boyd, 1988; Delis et al., 1994). Children eight and under rarely approach learning and memory tasks with an organized strategy. Between the ages of nine and twelve, children begin to use mnemonic strategies with increasing frequency, and continue to develop use of these skills into adolescence. Likewise, studies with normal children have observed a developmental improvement in children's perseverative response scores of the WCST (Welsh, Pennington, & Groisser, 1991). Children begin to show improved performance from seven to eight years of age, but do not attain an adult level of performance until approximately age ten or older.

Children in the present sample fall in the transitional age range when strategic learning and adult-level conceptualization and problem-solving skills are still emerging. This developmental transition may not occur at the same rate for all children. Furthermore, functions within the larger domain of executive functions have been shown to develop at different times (Welsh et al., 1991). The clusters may reflect differential rate of development in this age range's use of active learning strategies and problem solving techniques.

Both the organization of information for the purpose of encoding it and retrieving it from memory and conceptual problem solving may been seen as executive functions dependent on attention for optimal performance. As discussed in the introduction, it has been proposed that delayed maturation of the frontal lobes may play a role in the neurobiology of ADHD. The majority of children in the sample have been diagnosed ADHD and such a delay may contribute to the below average performance on learning and concept formation tasks observed among the passive learners and poor problem solvers. This would be consistent with research suggesting damage in the prefrontal cortex is associated with deficits in judgements of the order of events, suppressing irrelevant stimuli, and organizing the use of strategy (see Cohen, 1997).

The results of the cluster analyses did not provide strong support for the hypothesis that the groups defined by the Conners' CPT cutoff scores would form distinct homogeneous groups. In grouping cases by multivariate similarity, the cluster analysis split the children in the poor CPT index score group almost evenly between Clusters 1 (effective learners) and 2 (passive learners). The children in the normal CPT index group demonstrated a greater degree of homogeneity; 68% of children with normal CPT scores were grouped into Cluster 1 (effective learners).

The results of the multiple discriminant analyses also indicated that the groups defined by the Conners' cutoff scores did not demonstrate distinctly different patterns of scores on the neuropsychological measures. The results of the multiple discriminant analysis generated a two-variable function with the degree to which the child utilized active learning strategies contributing the greatest relative discriminating power, followed by their performance at the initial stages of a concept formation task. This two-variable function classified 67% of the cases correctly to the two groups. This hit rate exceeds the acceptable level of predictive accuracy (64%), but one would hope for a more accurate classification rate in an internal classification analysis such as the present study. The usefulness of this function should be viewed with caution unless validated with an independent sample.

In contrast, the multiple discriminant analysis for cluster membership generated a 98.6% classification rate. This value far exceeds the acceptable classification rate of 58% for these size groups. A failure to find such a high classification rate for the cluster solutions would call their validity in to question. Given that the clusters were formed by grouping together similar cases, one would expect them to be distinct based on the test scores used in their development. The high level of classification accuracy observed supports the validity of these discriminant functions.

The discriminant loadings of the variables entered into the two three-variable functions can also further delineate the clusters' profiles. The loadings for the first function suggest that children's early performance on a concept formation task best differentiates between the poor problem solvers (Cluster 3), and the effective and passive learners (Clusters 1 and 2 respectively). The discriminant loadings of variables in the second function suggest that the use of active learning strategies and performance over a repeated list learning task contribute almost equally to the discrimination between passive learners (Cluster 2), and effective learners and poor problem solvers (Clusters 1 and 3 respectively); and early conceptualization abilities contribute to this distinction to a lesser extent.

Although not a primary hypothesis of this study, it was expected that the CPT groups would differ in their frequency of ADHD diagnoses. This expectation was not supported by the results. The children with poor CPT performance were diagnosed with ADHD more frequently than the children with normal CPT scores (84% and 73% respectively), but this difference was not statistically significant. These results may be due in part to the sample of the study. Given that all of the children were referred for neuropsychological evaluation and that selection criteria excluded many other reasons for referral, the vast majority of the children (77%) included in the study were diagnosed ADHD. Although unexpected, these results are consistent with those discussed in the introduction that suggest although abnormal scores do suggest ADHD, ADHD can not be ruled out by normal performance on a CPT (see Barkely, 1998; Golden, 1996). As one would hope, these diagnoses must be based on more than CPT performance alone.

Overall, the results of the present study do not support the use of Conners' CPT cutoff scores for defining unique subgroups of children referred for neuropsychological evaluation in this clinic setting. The two groups differ significantly on very few measures and the results of exploratory multivariate analyses suggest different, more homogeneous subgroups exist within the data (e.g., the effective learners, passive learners, and poor problem solvers). The neuropsychological deficits associated with ADHD discussed in the introduction do not appear to hold true for attention deficits as measured by Conners' CPT in this sample. Perhaps this is the result of comparing two clinic-referred groups. One would expect greater differences between children with poor

CPT index scores and normal controls from the community, but pragmatically this means little when evaluating children in a clinic setting who have all been referred for evaluation as a result of some form of difficulty.

The limitations of this study must be noted. As mentioned previously, statistical analyses indicated that the data from most of the measures examined was not normally distributed, and efforts to correct for nonnormality did not lead to significant improvements. Of the statistics used in the present study, normality is primarily a concern in ANOVA and multiple discriminant analysis. ANOVA can accommodate a modest degree of skewness with a moderate sample size and there is mixed evidence regarding the results of violating the assumption of normality with multiple discriminant analysis (Hair et al., 1995).

The degree of normality in the data may be a more common difficulty in neuropsychological research than in other areas of psychology. Although many brain functions are represented by a normal probability distribution in the population, others are not (Dodrill, 1997). Most neuropsychological instruments are designed to distinguish normal from abnormal, not make fine-grain distinctions between normal cases as in intelligence assessment (Melamed & Wozniak, 1998). It is not entirely uncommon with neuropsychological measures to find a highly skewed dichotomous distribution with the majority of individuals obtaining scores within the normal range and far fewer individuals exhibiting deficits (Reitan, 1984).

A second methodological issue of the present study is the relatively limited sample size. Due to the number of cases available, an exploratory approach was taken to selecting the variables to be examined in the multivariate analyses. This choice was not theoretically driven and increased the likelihood of observing differences between groups in later analyses. The number of participants also prohibited the use of a holdout sample to validate the cluster analyses and multiple discriminant analyses, and their results should be interpreted with caution until externally validated. The present study did not control for comorbid diagnoses and psychotropic medication use among the sample.

Future research may improve upon the generalizability of this study by replicating with a larger sample and with children from different settings. The stability and validity of the clusters and discriminant functions suggested by the results are uncertain until examined with an independent sample. Other potential areas of investigation include examining a larger age range, utilizing different neuropsychological measures, including a normal control group for comparison, contrasting the neuropsychological performance of children exhibiting impulsive versus inattentive styles of responding on the CPT, and examining the performance of children whose CPT index scores fall in the "borderline" range.

The odds in the present study were stacked in favor of observing differences between the two CPT groups. Only children with extremely good or poor scores were included in the study, and only those variables that distinguished best between the two groups were utilized in the multivariate analyses. Cluster analysis was included in the present study primarily for the purpose of determining if the scores of the two CPT groups on measures of learning, memory, and executive function support these two groups as distinct and homogeneous. However in the process of disconfirming this hypothesis, the clusters that emerged raised further questions of their own. Their profiles appear interpretable, but it remains unclear whether they would remain stable if children whose CPT scores fall in the middle range had been included in the sample.

Given the level of complexity and importance involved in the assessment and diagnosis of ADHD, this issue is likely to continue to arouse interest and public controversy. Psychologists, educators, and the medical community each play a role in serving these children, but too often function independently and fail to integrate their unique perspectives on this disorders. Future research should aim to increase our understanding of these children's performance on neuropsychological measures, as well as the implications of their performance for treatment and academic remediation.

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