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COGNITIVE AND MEMORY PERFORMANCE PATTERNS ASSOCIATED WITH ADHD SUBTYPES

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COGNITIVE AND MEMORY PERFORMANCE PATTERNS ASSOCIATED WITH ADHD SUBTYPES

by

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Dedication

To Lamont Wood

Thank you for your encouragement, sense of humor, and love.

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COGNITIVE AND MEMORY PERFORMANCE PATTERNS ASSOCIATED WITH ADHD SUBTYPES

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This study investigated whether there were unique cognitive and memory patterns attributable to Attention Deficit Hyperactivity Disorder Combined or Inattentive subtypes (ADHD C or ADHD-I) or whether the patterns were common to ADHD regardless of subtype. Children ages 8-16 diagnosed with ADHD-C (n= 26) and children diagnosed with ADHD-I (n=30) formed the two clinical groups, and 31 non-clinical children served as control participants. The areas of neurocognitive functioning investigated included verbal working memory, verbal short-term memory, verbal organization and effort, sustained visual attention, and visual processing speed

This study did not find verbal working deficits in the ADHD-C group using the WISC-III Arithmetic and Digit Span backwards portion of Digit Span as a working memory task. As predicted, no differences in short-term verbal memory were found, suggesting that children with ADHD regardless of subtype do not have difficulties with encoding verbally presented material. Children with ADHD did not evidence difficulties relative to controls on a CVLT-C learning task. However because the construct validity

of the CVLT-C as a measure of executive function is unclear, the finding of no differences in verbal working memory performance across groups may reflect instrumentation error rather than reflect the true absence of group differences.

The hypothesis that children with ADHD-C would evidence significantly more errors of commission, have elevated response risk-taking and less perceptual sensitivity to the task on the CCPT than children with ADHD-I and controls was not confirmed. While children with ADHD-C did have significantly fewer correct hits when compared with controls, their performance did not differ significantly from children with ADHD-I. Children with ADHD-I evidenced significantly more errors of omission and had significantly fewer correct hits compared with controls. A unique finding of this study was that severity of inattentive symptoms was significantly related to a restricted risk taking on the CCPT and poorer performance on the WISC-III Coding subtest. These results suggest that when diagnosing ADHD using behavioral checklists, it is important to consider symptom severity as well as the presence or absence of the behavioral symptoms.

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CHAPTER I

INTRODUCTION

Imagine observing a class of 20-second graders during a math lesson. All eyes, save the one boy who is looking out the window, shifting uncomfortably in his seat, and humming, are focused on the teacher and appear to be attending to her. The task of listening and looking at the teacher appears to be a straightforward and simple one. But looks are deceiving. A closer analysis reveals a set of complex neurocognitive skills that must be coordinated successfully to accomplish this task. To focus on the verbally presented information requires the initial engagement of attention before actual hearing and auditory processing of the verbal information occurs. Once engaged or focused, the child must sustain this attention and inhibit external and internal distracters in order to allow for cognitive processing of information. Included in this cognitive processing is the interaction between the encoding of information (working memory and short-term memory) with long-term memory. When the teacher presents overhead materials, the child must shift attention to the visually presented information and again employ the focus-execute, sustain and encode attention elements. Thus one of the prerequisites for successful school learning is an intact attentional system that is as developmentally mature as those of same age or grade peers.

Mirsky (1996) has suggested that impaired or immature functioning in one or more of the components of attention (focus-execute, sustain, encode, and shift) can account for the behavioral symptoms of inattention, impulsivity, and hyperactivity associated with ADHD. On the other hand, Barkley (1997a, 1997b, 1997c, 1998) identifies difficulties with behavioral inhibition as the core deficit in his model of ADHD with secondary deficiencies occurring in four areas of executive function. These areas include nonverbal working memory, internalization of speech and verbal working memory, self-regulation of affect, motivation, and arousal, and the reconstitution of behavior. He suggests that his model applies to children diagnosed with ADHD-Combined (ADHD-C) type and ADHD-Hyperactive-Impulsive (ADHD-HI) type only and that the ADHD-Predominately Inattentive (ADHD-I) type may be a distinct disorder with slowed cognitive tempo as the primary feature.

ADHD is estimated to affect between three to five percent of school age children (APA, 1994). However, referral source (clinic versus epidemiological sample) and method of selection (single versus multiple raters and requirements for scale elevation) impact prevalence rates (Barkley, 1998; Carlson & Mann, 2000). Children with ADHD often also meet diagnostic criteria for learning, conduct, anxiety, major depressive, or oppositional defiant disorders (Pliska, 2000). (Tannock, 1998), in summarizing co-morbidity rates, reports a 40% to 90% co-occurrence between ADHD and conduct and oppositional disorders; a 25% co-occurrence between ADHD and anxiety disorders and a 20% overlap of ADHD and learning disorders. Thus in a classroom of 20 children, chances are that at least one child has ADHD and may have associated co-morbid areas of difficulty.

Given the relative frequency of the disorder and the two legislated avenues (section 504 of the Rehabilitation Act of 1973 and an Other Health Impairment special education category) by which parents can obtain educational services for their children, school psychologists are called upon to help address the academic needs of these children. Moreover as the fields of general education and school psychology begin to focus on response to invention, although now the primary focus is on children with reading difficulties, this focus may expand to include children with other, developmental disorders including ADHD. However, one of the essential prerequisites to successful academic intervention is the targeting of clearly delineated research-identified areas of impairment. Examination of cognitive and memory patterns associated with children with ADHD is one of the beginning steps in this validation process. That is, if unique theory driven neuropsychological performance patterns were found between the ADHD subtypes, support for ADHD etiology and the current DSM-IV classification system would be strengthened and could be used for generating tailored interventions.

This study had one overall goal, which was to determine if there were differential cognitive and memory patterns present within two ADHD subtypes (ADHD-C and ADHD-I) across five areas of neurocognitive functioning. The five areas investigated included verbal working memory, verbal short-term memory, verbal organization and effort; sustained visual attention; and visual processing speed. Additionally, the cognitive and memory performance of the two ADHD groups was compared with a group of non-clinic control participants. Results are interpreted within the context of Barkley's behavioral inhibition model of ADHD (Barkley, 1998) and Mirsky's model of attention (1996) and also discussed in terms of diagnostic utility of DSM-IV ADHD subtypes.

CHAPTER II

REVIEW OF THE LITERATURE

The literature review is divided into three general sections. Section A presents a summary of behavioral, socio-emotional, and neurocognitive differences associated with previous Attention Deficit Disorder (ADD) subtypes (APA, 1980) and provides a review of the diagnostic criteria utilized to form the current ADHD subtypes with the intended purpose of highlighting the changes in symptom emphasis over time. Next discussion in Section B focuses on theories regarding the etiology of ADHD, including a brief discussion of the biological mechanisms involved in ADHD. Also in this section, two general theoretical models are described: theories that conceptualize ADHD as reflecting deficits in self-regulation stemming from prefrontal lobe dysfunction (Douglas, 1983; Barkley, 1997a, 1997b, 1997c, 1998) and a multi-component theory of attention that suggests ADHD can stem from impairments in one or more of the anatomically distinct elements (Mirsky, 1996). A brief discussion of executive function and a model of working memory (Baddeley, 2000) is presented as contextual background from which to view Barkley's current theoretical model. Section C reviews the literature on cognitive and memory patterns associated with the ADHD subtypes and also includes the study rationale.

SECTION A:

Attention Deficit Disorder (ADD) subtypes

The term, "Hyperkinetic Reaction of Childhood" that appeared in the Diagnostic and Statistical Manual of Mental Disorders-Second Edition (DSM-II; APA, 1968) viewed excessive motor activity as the defining symptom of the disorder, though problems with attention, specifically short attention span, were also thought to be present in the disorder. Problems with impulsivity were not explicitly mentioned. According to DSM-II (1968), "the disorder is characterized by overactivity, restlessness, distractibility, and short attention span, especially in young children" (p.50). In contrast, the multi-dimensional diagnostic category of Attention Deficit Disorder (ADD) first appeared in the DSM-III (APA, 1980). ADD was used to describe children whose primary presenting symptoms included difficulties with the regulation of attention, impulse control, and activity level. Subtypes included children who evidenced problems with inattention, impulsivity, and hyperactivity (ADD+H) and those children with attention and impulse control problems who did not evidence hyperactivity (ADD-H).

Lahey, Schaughency, Hynd, Carlson, & Nieves (1987) examined the behavioral characteristics of ADD subtypes (41 ADD+H and 22 ADD-H). They found that ADD+H children were more impulsive and evidenced more severe conduct disordered behaviors (fighting and stealing) than did clinic-referred children with ADD-H. Parents and teachers saw children with ADD-H as having a slower cognitive tempo (drowsiness, lethargy, and hypoactivity) and were more likely to have co-existing internalizing disorders.

Barkley, DuPaul & McMurray (1990) compared the performances of children with ADD (ADD+H; N=42 and ADD-H; N = 48), LD children (N=16) and normal controls (N=34), on a test battery (parent interviews, parent and teacher behavior ratings, psychological tests), concluding that the two ADD subtypes could represent separate and unique types of attentional problems and not subtypes of a common attention disorder. While they found that behaviors of inattention in both ADD groups were associated with increased risk for behavioral, social, and emotional problems compared with LD and control children, behavioral differences across the ADD subtypes emerged as well. The presence of hyperactivity (ADD+H) was associated with less self-control, greater impulsivity, and more severe internalizing and externalizing problems, including an increased risk of co-morbid conduct disorder and oppositional defiant disorder. Children with ADD-H evidenced less overall aggression and impulsivity across home and school settings. Additionally, in an analysis of psychiatric disorders among relatives of ADD children, ADD+H was associated with aggression and substance abuse while ADD-H was associated with the presence of more anxiety and learning disorders. Significantly more children with ADD-H than with ADD+H had received educational services for learning disabilities.

Children with ADD+H had significantly fewer peer relationships compared with ADD-H children and were more likely to be described by teachers as “noisy, disruptive, messy, irresponsible and immature.” In contrast, the ADD-H children were seen as “confused, day dreamy or lost in thought.” The differences between the groups were attributed to differences in cognitive style with ADD+H associated with behavioral inhibition and organization problems while ADD-H were seen to reflect the presence of a slow cognitive tempo and inward directed attention.

A number of cognitive performance differences were found. ADD-H children evidenced fewer off task behaviors during a vigilance test, performed more poorly than did the other three groups (ADD+H, LD, and Controls) on the Coding subtest of the Wechsler Intelligence Test for Children-Revised (WISC-R; Wechsler, 1974) and had greater problems with consistent retrieval of verbal information on a memory task. No differences were found between children with ADD+H and controls on the memory and coding tasks. However, the ADD+H and LD group performed significantly worse on the Arithmetic subtest of the WISC-R than normal controls. The ADD—H did not differ from controls on the Arithmetic subtest. Finally, children with ADD regardless of subtype, performed more poorly than controls on a continuous performance measure, though the ADD+H children had more than twice number of commissions than did the ADD-H group. The attentional problems children with ADD+H demonstrated were interpreted to reflect a deficit in sustained attention and inhibition while the attention problems of ADD-H children were seen as reflecting problems with the focus component of attention (processing speed).

Lahey and Carlson (1991) in a review of the ADD literature concluded that factor analytic studies have identified two largely independent dimensions: 1) symptoms descriptive of motor hyperactivity and impulsive behavior and 2) symptoms of inattention, disorganization, and difficulty completing tasks. These two dimensions were present in both teacher and parent ratings of behaviors. Behavior differences between the two groups were present. Children with ADD-H evidenced fewer conduct problems and greater levels of anxiety and depression than ADD+H children. Although both groups of children with ADD were unpopular with peers, ADD-H children were seen as shy/withdrawn and were less likely to be actively rejected by peers.

Of the eight studies reviewed by Lahey and Carlson (1991), four studies found either minimal differences or no differences between the ADD subtypes on cognitive measures, although the ADD groups were impaired relative to normal controls. In the studies where cognitive differences were found, the results were interpreted as reflecting differing cognitive styles (Lahey, Schaughency, Frame, & Strauss 1985), and differences in resource allocation (Sergeant & Scholten, 1985). Children with ADD+H were less able to change strategies to meet task requirements. ADHD+H children were also found to show poorer performance on measures of visual-perception, visual sequential memory and writing performance than did children with ADD-H and both groups were impaired relative to controls on measures of visual perception and memory (Frank & Ben-Nun, 1988). The fourth study reviewed was the Barkley et al. (1990) study that was previously discussed above.

In a review of ADD subtypes, Goodyear and Hynd (1992) point out that children with ADD-H were slower than ADD+H children in responding to tasks requiring them to name familiar alternating stimuli. Differences were attributed to a slower rate of information processing. Deficits were seen as reflecting a sluggish cognitive tempo and were interpreted as a component of automaticity difficulties (e.g. impaired retrieval of long-term verbal information, math facts, slow writing speed). The review noted that problems with automaticity are often present in the neurocognitive profiles of LD children and also noted the high rate of co-morbid learning disorders found with ADD-H children.

Changes in ADHD Diagnostic Criteria

While the diagnosis of ADHD is based upon an observable set of behaviors, there is on-going debate concerning which behavioral deficits should be regarded as the hallmarks of the disorder and whether the symptom constellations associated with ADHD are best viewed as a single disorder or a multidimensional disorder with subtypes (Barkley, 1997a, 1997b, 1997c; Carlson, Shin & Booth, 1999). Since the DSM-III conceptualization, the ADD category has undergone two modifications. In DSM III-R (APA, 1987), the name of the disorder was changed from Attention Deficit Disorder (ADD) to Attention Deficit-Hyperactivity Disorder (ADHD) and the previous three core features (inattention, impulsivity and hyperactivity) were combined into one core symptom list. This was a change that essentially eliminated ADD without hyperactivity as a diagnostic entity and it also reflected a shift back to a uni-dimensional conceptualization. Additionally, it failed to take into account the research literature that documented numerous emotional/behavioral and cognitive differences between the ADHD subtypes of ADD+H and ADD-H (Barkley et al. 1990; Barkley, Grodzinsky & DuPaul, 1992; Goodyear & Hynd, 1992; Lahey & Carlson, 1991; Schaughency & Hynd, 1999).

The most recent edition, DSM IV (APA, 1994), returns to a multidimensional system of subtype classification utilizing the three DSM-III core features (inattention, impulsivity and hyperactivity). However, the three symptom clusters are reconfigured to form the following three subtypes: ADHD: Primarily Hyperactive -Impulsive Type (ADHD-HI), ADHD Primarily Inattentive Type (ADHD-I), and ADHD Combined Type (ADHD-C). Symptoms of impulsivity present in the DSM-III subtypes (ADD+H and ADD-H) are now placed within the ADHD-C subtype. They also are combined with symptoms of hyperactivity to form the new ADHD-HI subtype. The ADHD-I consists of a minimum of six symptoms of inattention, though subclinical (less than six) symptoms of hyperactivity-impulsivity can be present. The reverse is true for the ADHD-HI subtype. A minimum of six hyperactivity-impulsivity symptoms is needed, though again less than six symptoms of inattention may be present. Consequently, only the symptoms associated with the ADHD-C subtype remains unchanged from the previous (ADD+H) DSM-III subtype. Thus, the definition of ADHD terms has been revised three times over the past 21 years, complicating comparison of research results over time. See Appendix A for specific DSM-IV diagnostic criteria. Research on the cognitive and memory characteristics associated with the DSM-IV- ADHD subtypes will be reviewed in the Section C of the literature review.

SECTION B

Biological Mechanisms in ADHD

Just as the behaviorally based diagnostic formulation of ADHD has changed over the years, so has conceptualization regarding the mechanisms underlying ADHD. Beginning in the 1930's, researchers noted similarities between the behaviors of children with hyperactivity and the behaviors of individuals with acquired brain insult. They also noted similarities between the elevated activity levels shown in these children and the extreme restlessness found in monkeys with frontal lobe lesions and hypothesized that the excessive motor activity seen in these children was due to the presence of brain damage (Barkley, 1998; Kessler, 1980). The uniform attribution of brain damage as the causative agent for behavioral and learning difficulties came under fire when it was found that the majority of children with ADHD have no history of significant brain injuries (Barkley, 1998).

Diagnostically, the term minimal brain dysfunction (MBD) replaced the term brain damage, though an assumption, albeit unspecified, regarding brain-based etiology was still present. MBD was used to describe children of near average, or above average intelligence with certain learning or behavioral disabilities ranging from mild to severe which were associated with deviations of function of the central nervous system (Belmont, 1980). However the symptoms encompassing MBD were overly inclusive and had no clearly defined etiology, significantly reducing diagnostic utility and contributed to its discontinuance (Rie, 1980).

Today parallels continue to be made between the behaviors associated with ADHD and those produced by frontal lobe injuries, particularly in the prefrontal cortex, (Heilman, Voeller, & Nadeau, 1991). Current thinking reflects a shift away from focusing on gross insult to an examination of processes involved in neurodevelopment. Evidence from studies of neuroanatomy (Baumgardner et al., 1996; Hynd, Semrud-Clikeman, Lorys, Novey, & Eliopulos, 1990; Hynd, Semrud-Clikeman, Lorys, Novey, Eliopulos & Lyytinen, 1991), neurochemistry (Zametkin et al., 1993), genetic studies examining heritability (Biederman, Faraone, Keenan, Knee, &Tsuang, 1990; Gilger, Pennington, & DeFries, 1992; Gross-Tsur, Shalev, & Amir, 1991) along with impaired performance on neuropsychological measures purported to measure pre-frontal functioning (Barkley et al. 1992) suggest a neurological origin for ADHD.

Douglas' Model of ADHD

In the 1970's, Douglas and her colleagues at McGill University laid the groundwork for current theoretical models of ADHD (Barkley 1998; Quay, 1997). They proposed that a constellation of closely related deficits in attentional, inhibitory, arousal, and reinforcement mechanisms could not only account for the hyperactive behaviors seen in ADHD but also could explain problems with sustained attention (the maintenance of attention over time) and impulsivity (Barkley, 1998; Douglas, 1983). Problems with distractibility were seen as related to deficits in the investment, organization, and maintenance of attention and modulation of effort and arousal levels rather than as deficits related to filtering out extraneous stimuli or difficulties discriminating between relevant and irrelevant information (Douglas, 1983).

Douglas (1983) also identified two deficit areas generally present in the behaviors of ADHD children. These included a strong inclination to seek immediate gratification and difficulties with self-control or response inhibition. A number of researchers (Barkley, 1989, van der Meere & Sergeant, 1988) espoused the position that ADHD arose out of a neurologically based deficit in motivation. For example, Barkley (1989) asserted that deficits in rule-governed behavior (decreased control by partial reinforcement schedules, rapid habituation to behavioral consequences and diminished regulation of behavior by rules) rather than disordered attention were underlying etiological factors. Later however, Barkley (1997a, 1997b, 1997c) expanded his model.

Barkley's Model of ADHD

Barkley now proposes a hybrid theory of ADHD that views behavioral inhibition deficiencies or impulsiveness as the central impairment, with secondary deficiencies occurring in four areas of executive function (nonverbal working memory, internalization of speech and verbal working memory, self-regulation of affect, motivation, and arousal, and reconstitution of behavior). The secondary deficiencies are hypothesized to occur because faulty inhibition mechanisms disrupt functioning of these four areas that in turn contribute to reductions in motor control. See Figure 2.1 for depiction of model components. Thus regarding the etiology of ADHD, Barkley (1997a, 1997b, 1997c; 1998) continues to implicate the motor inhibition systems of the brain rather the sensory input systems involving the perception and processing of information.

Barkley (1997a) conceptualizes behavioral inhibition as consisting of three interrelated processes: " inhibiting the initial prepotent response to an event, stopping an ongoing response thereby permitting a delay in the decision to respond, and protecting this period of delay and the self-directed responses that occur within it from disruption by competing events and responses [interference control] (p.47)." A prepotent response is defined as a response for which immediate reinforcement is available or which has been previously associated with the response. The inhibition or stopping of this response is viewed as being the critical first step. Without it, the person cannot anticipate future rewards/punishments if they have already responded to the immediate environmental contingencies. Research has indeed found that children with ADHD have difficulty delaying immediate gratification for long-term rewards (Campbell, 1987; Rapport, 1986).

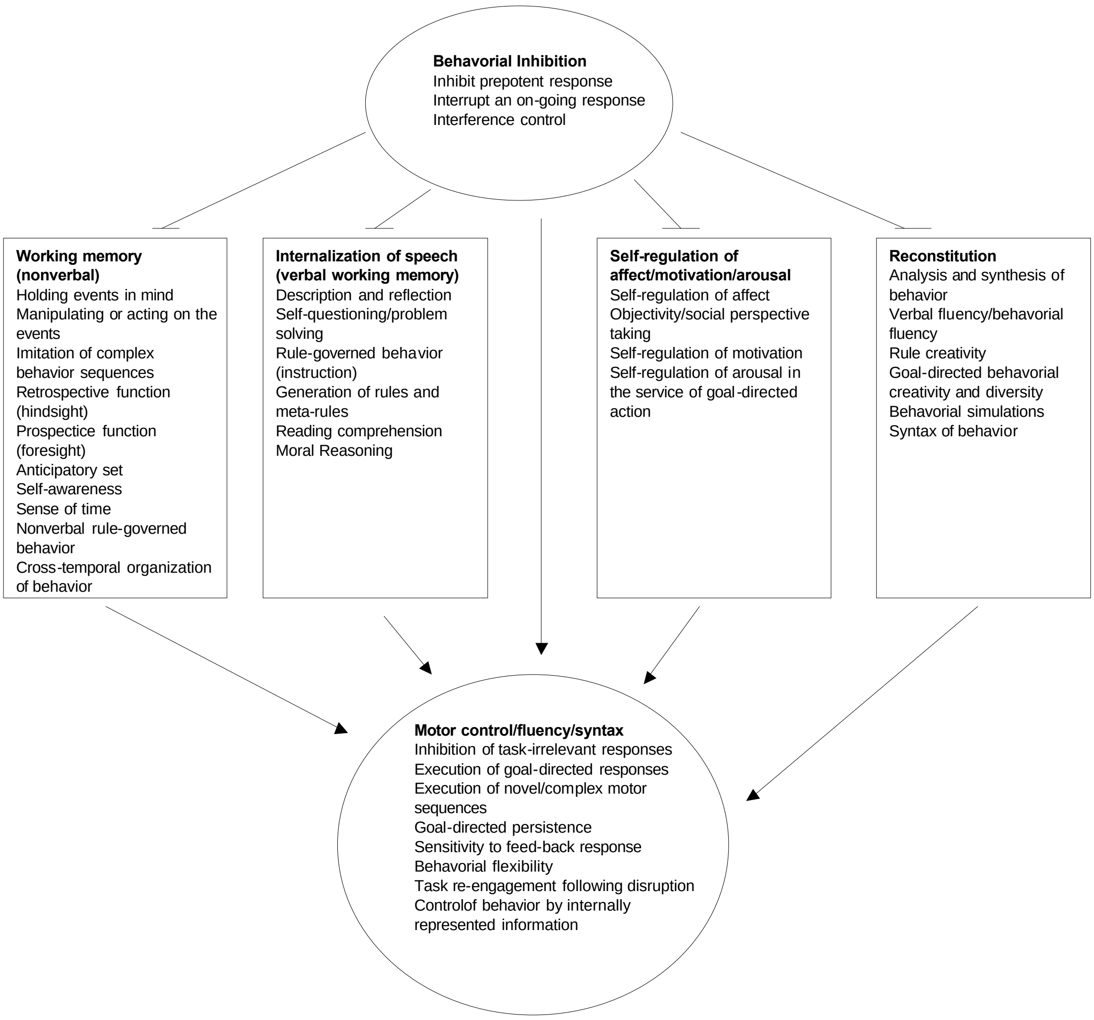

Figure 2.1 Diagram of Barkley Model of behavioral inhibition, executive function and motor control systems. Barkley (1997b).

According to Barkley, a second element in behavioral inhibition is the potential for self-monitoring and evaluation that is created once ongoing behavior patterns are interrupted. At this juncture, the individual draws upon working memory-an integrated system for holding and manipulating information, (Baddeley & Hitch, 1974)-to evaluate the immediate past performance results, modulate emotional responses and to plan the future responses. However, the difficulties with behavioral inhibition (immediate stimulus responding) in children with ADHD may significantly delay the development and/or refinement of the verbal and nonverbal working memory and emotional regulation systems. The third component is termed interference control and serves to protect the processing that is occurring from competing responses that are both internally and externally generated. Thus, poor interference control seen in children with ADHD also serves to disrupt employment of the working memory and emotional regulation systems.

Executive Functions

A brief discussion of the term "executive function"-(EF) and working memory as conceptualized by Baddeley and Hitch (1974) is provided as a contextual background from which to view Barkley's current theoretical model. The term executive function can be defined as a set of control processes that integrate, organize, and maintain other cognitive processes such as memory and attention (Denckla, 1996). These control processes include interference control (inhibition, delayed responding), use of effortful and flexible organization strategies, and strategic planning (planning of sequences of selected actions) (Denckla, 1994, 1996; Reader, Harris, Schuerholz & Denckla 1994). In a related vein, EF is thought to be involved with planning, decision-making, goal selection, behavior monitoring and utilization of feedback (Stuss, 1992). However the lack of definitional specificity reflects the gaps in knowledge that exist regarding the interaction of the specific neuroanatomical area (frontal lobes and/or associated brain areas) and the cognitive processes (executive functions) these areas control as well as the neuropsychological instruments used to measure these processes.

Anatomically, these executive control functions are hypothesized to be associated with frontal lobe functioning and frontally interconnected subcortical regions (Denckla & Reiss, 1997; Chelune, Ferguson, Koon, & Dickey, 1986). Pennington and Ozonoff (1996) in a review of literature on primate prefrontal cortex (PFC) and executive function (Fuster, 1989, Goldman-Rakic, 1987a, 1987b; Luria, 1966; Shallice & Burgess, 1988) assert that a common theme is present across studies. They point out that across studies "tasks or behaviors sensitive to PFC dysfunction require planning or programming future actions, holding those plans or programs on-line until executed, and inhibiting irrelevant actions."

Full frontal lobe (specifically prefrontal cortex) and EF maturation is not reached until late adolescence purportedly being due to the slow development of the cognitive functions, including human language that these areas support (Fuster, 1999). The cognitive and behavioral deficits stemming from executive function impairments (Barkley, 1997a, 1997b, 1997c, 1998) can be viewed as a significant delay or disruption of the normal developmental processes. Possible influences that should be considered when examining developmental disorders (ADHD included) are the severity of disruption, timing (when disruption occurs), location of disruption (within PFC, outside PFC but in a closely connected region, or both) and diffuse disruption (structural and/or metabolic) (Pennington & Ozonoff, 1996).

Baddeley's Model of Working Memory

In an effort to explain observed inconsistencies in long-term learning that arose using Atkinson and Shiffrin's (1968) modal model of memory (See Figure 2.2), Baddeley and Hitch, (1974), developed a multi-component model of working memory. It postulated an integrated system for holding and manipulating information during the performance of complex cognitive tasks. The working memory model consists of three interrelated systems. These systems include a central executive system that interacts with the phonological loop and visuo-spatial sketchpad sub-systems. See Figure 2.3.

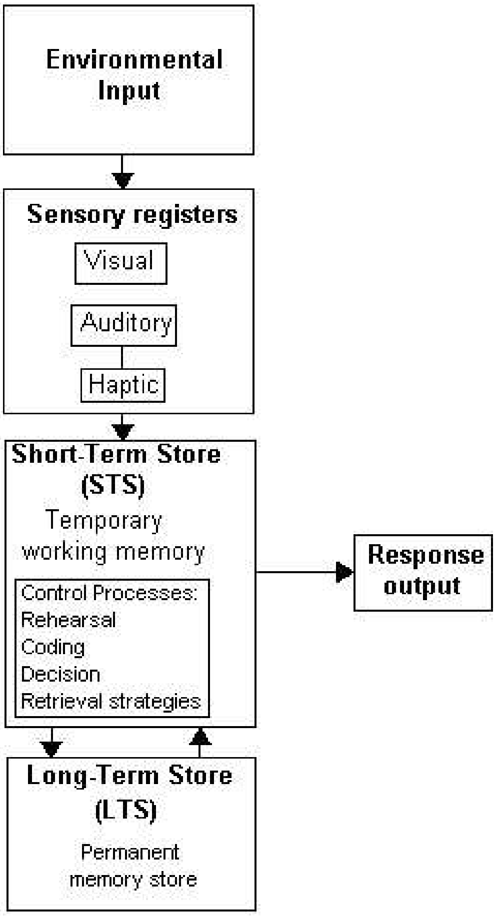

Figure 2.2 .Atkinson and Shiffrin Modal Model of Memory

According to Baddeley (2000), the phonological loop has two interactive components. The first is a temporary storage area where an acoustic or phonological memory trace is held for approximately two seconds. The second is a sub-vocal auditory rehearsal process that can refresh the memory trace and can also register

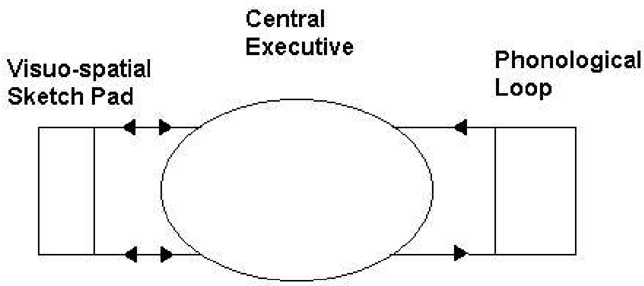

Figure 2.3: Baddeley and Hitch Multi-component Model of Working Memory.

visually presented nameable material. For example, when verbal information is placed in the phonological loop, it can be kept accessible by rehearsal, freeing the central executive to retrieve information from other parts of the memory system

As the name implies, the visuo-spatial sketchpad briefly stores visual-spatial information and assists with the generation and manipulation of images, though the sketchpad is thought to be composed two separable elements. These elements include visual features (what something looks like) and the spatial elements involving location or position (Baddeley, 2000). Both verbal and visual storage systems are in direct contact with the central executive. Although the central executive is the least elaborated of the three elements in the working memory model, the central executive is hypothesized to control information flow, retrieve knowledge from long-term memory and control multiple concurrent cognitive activities (Baddeley & Hitch, 1974; Baddeley, 1996, 2000).

Barkley's Executive Function Components

Barkley (1997a, 1997b, 1997c, 1998) defines the four executive functions in his hybrid theory as internalized self-directed actions that once were public or overt behaviors. The construct of verbal working memory and internalization of speech is loosely drawn from the articulatory or phonological loop component of Baddeley and Hitch's (1974) model of working memory. According to Barkley, self-directed speech allows for reflection, self-questioning, and problem-solving including the generation of rules and meta-rules. The development of self-directed speech is seen as a process occurring over time, proceeding from immediate verbalization of thought to increasing levels of covert or inner-directed thoughts (Barkley, 1997c). While Barkley does not specifically state that the central executive is involved in his model, it's presence is implied through his elaboration on the functions of self-directed speech and hypothesized interaction with other mental abilities (reading comprehension, moral reasoning).

Nonverbal working memory is defined as "the capacity to maintain internally represented information in mind or on line that will be used to control a subsequent response." (Barkley, 1997c, p. 235). Barkley asserts that the visual reconstruction of past behavioral sequences from both personal experience and vicarious learning provides an opportunity to evaluate behaviors independent or removed from the immediate situation. Although not specifically described as nonverbal working memory, a number of researchers including Denckla (1994) and Pennington and Ozonoff (1996) have defined working memory as the temporary holding of representations for the duration of a task. Working memory is viewed as the process that controls retrieval and utilization of acquired knowledge and allows the individual to act on the basis of represented rather than immediately presented information. These views of working memory are similar to that of Baddeley's (2000) conceptualization of the entire interactive working memory system.

Modality parallels between Baddeley's (2000) visuo-spatial sketchpad component of the working memory model and Barkley's (1997a, 1997b, 1997c, 1998) construct of nonverbal working memory are of limited utility for two reasons. The first reason is that Barkley's model of nonverbal working memory includes a mixture of nonverbal and verbal concepts. The presence of audition seems to relate more to the internalization of speech/verbal working memory than to nonverbal working memory. The Baddeley model has no such mixture of constructs. Secondly, the concepts of hindsight and foresight as well as the development of a sense of time, if interpreted within the context of Baddeley's model of working memory would require interaction with the central executive rather than being confined to a nonverbal arena only.

The third executive function component in Barkley's model involves self-regulation of affect, motivation, and arousal. Inhibition of responding coupled with the employment of the verbal and nonverbal working memory systems facilitates the regulation of emotion and arousal. The fourth element is defined as the ability to "take mentally represented information apart (analysis) and recombine it (synthesis) into novel sequences from which novel behavior structures can be generated" (Barkley, 1997c, p. 273).

Mirsky's Model of ADHD

Barkley's model of ADHD conceptualizes the behavioral/cognitive difficulties associated with the disorder as stemming from inhibition and executive function/working memory impairments. However, Mirsky (1996) has suggested that disordered attention in one or more of the components of attention (focus-execute, sustain, encode, shift and most recently response stability) can account for the difficulties associated with ADHD. Conversely un-impaired or “normal” attention results from the coordination of these linked components.

In an effort to better understand the construct of attention, Mirsky proposed a model that integrates a number of concepts of attention developed from information processing models (selectivity, vigilance, switching attention and encoding) and places them within a neuropsychological framework. The components in the Mirsky model are derived from two factor analytical (principal components) studies of neuropsychological test scores (Mirsky, 1996; Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991). The two samples included over 200 adult neuropsychiatric and control subjects and over 400 school-age children between the ages of seven and nine. In the child sample, four factors emerged: focus-execute, sustain, encode and shift. However, the four-factor structure was not replicated in a confirmatory factor analysis of the Mirsky et al. (1991) adult sample and a second sample of psychiatrically normal adults and adults with sleep disordered breathing. Findings included moderate correlations between factors (sustain-focus/execute, encode-focus/execute) suggesting the presence of common processes associated with both (Strauss, Thompson, Adams, Redline, & Burant, 2000). Differences in factor structure between adult and child samples suggest that processes involved in attention are not static and change with development/maturation.

According to Mirsky and colleagues (Mirsky, 1996; Mirsky, Pascualvaca, Duncan, & French, 1999), the “focus-execute” aspect of attention is defined as the capacity to focus or select some aspect of the environment while screening out irrelevant stimuli. Functionally, it also has an element of motor speed, as the tasks measuring this construct require a response under timed conditions. The specific instruments in the children’s sample employed to measure this construct included the Coding subtest of

Wechsler Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) and a Digit Cancellation task similar to the Symbol Search subtest of the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991). Hypothesized brain regions activated during execution of perceptual-motor tasks include the superior temporal cortex, inferior parietal cortex and corpus striatum structures (caudate, putamen and globus pallidus). The structures comprise the corticostriate pathway and are thought to be involved with the planning and execution of complex motor activities (Kandel, Schwartz & Jessell, 1995).

The "sustain" element refers to concept of vigilance or ability to maintain performance over time. To sustain "entails being able to stay on task in a vigilant manner for an appreciable interval-not missing designated targets, responding briskly to them, and inhibiting responses to nontargets" (Mirsky, 1996, p. 76-77). Performance (percentage correct, percentage of commissions and mean reaction time) on the Continuous Performance Test (CPT) (Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956) was used to form this element. Additionally, response stability was measured using the CPT reaction time variability. Hypothesized brain regions involved include rostral midline structures (Mirsky, 1996; Mirsky et al. 1999).

Although Mirsky has labeled a third element "encoding", the definition (the capacity to hold information briefly in mind while performing some action or cognitive operation upon it) is strikingly similar to those used to define "working memory" (Barkley, 1998; Denckla, 1994). Similarities are present between working memory conceptualizations and the "encode" attentional construct when it is defined as containing a "numerical-mnemonic "element that requires "serial incorporation, retention, cognitive manipulation, and ultimate recall of information" (Mirsky, Fantie, & Tatman, 1995, p.22). Hypothesized anatomical location is the hippocampus and amygdala. The "shift" component in the model refers to the ability to change focus and presumably is supported by the prefrontal cortex.

SECTION C

In the next section, discussion shifts from a delineation of theoretical models of ADHD to a review of the empirical literature regarding cognitive and memory patterns associated with ADHD. While the hallmark symptom dimensions of ADHD are difficulties with inattention and disinhibition, research has found that children with ADHD often have associated cognitive and memory problems. Children with ADHD have difficulties with tasks that require the use of verbal working memory for successful performance. In particular, tasks that require mental arithmetic are often very challenging for children with ADHD (Barkley, 1996; Mariani & Barkley, 1997). Also frequently present in the cognitive profiles of these children are problems with persistence or sustained effort and difficulties with task organization (August & Garfinkel, 1990; Hamlett, Pellegrini & Conners, 1987; Tannock, Martinussen & Frijters, 2000; Zentall 1988). A third area of difficulty involves visual motor coordination and sequencing (Barkley, 1996; Mariani & Barkley, 1997). Especially problematic for some children with ADHD is the fast and accurate execution of pencil and paper visual-motor tasks. The following sections will review the literature regarding verbal working memory and processing speed deficits and problems with sustained effort and organization in children with ADHD. First, however, a brief review of the intellectual or cognitive functioning of children with ADHD is provided.

Performance on Standardized Measures of Intellectual Functioning:

A number of studies (Faraone et al., 1993; Fischer, Barkley, Edelbrock, & Smallish, 1990; Mariani & Barkley, 1997; McGee, Williams, Moffitt, & Anderson, 1989) have reported that children with ADHD perform on average one half to 1 standard deviation below normal controls on standardized measures of intelligence, though it is unclear whether these differences reflect the presence of co-morbid learning difficulties, represent reductions caused by impulsive and/or inattentive responding or reflect true intellectual differences (Barkley, 1998; Teeter & Semrud-Clikeman, 1995). Recently, Barkley (1998) has asserted that the Intelligence Quotients (IQ) of children with ADHD span the entire intellectual spectrum. Using the vocabulary and block design subtests from the WISC-III, (Wechsler, 1991) and extrapolating a Full Scale Intelligence Quotient (FSIQ) based on 1974 normative information, Kaplan, Crawford, Dewey, and Fisher (2000) reported a roughly normal distribution of FSIQ scores for children with ADHD. Specifically, 60% of the sample had average IQ estimates, 13 % were below average and 27% were above average. However, this study provided no information on the subjects' ADHD subtype classification.

Verbal Working Memory/WISC-III Freedom from Distractibility Factor

The Wechsler Intelligence Scale for Children-Third Edition (WISC-III, Wechsler, 1991) is a standardized intelligence test consisting of 13 subtests which yields a Full Scale, Verbal, and Performance IQ score ranging from 40 to 160. Subtest standard scores form the basis for the four factor scores: verbal comprehension, perceptual organization, freedom from distractibility and speed of information processing. The freedom from distractibility (FD) consists of the arithmetic and digit span subtests. The other three factors include the processing speed factor (PS) made up of the coding and symbol search subtests, the verbal comprehension (VC) factor which includes the remaining WISC-III verbal subtests, and the perceptual organization (PO) factor which includes, with the exception of the mazes subtest, the remaining performance subtests.

The WISC-III Freedom from Distractibility factor is misnamed, as one of the elements thought to underlie performance on the Digit Span and Arithmetic subtests is working memory, rather than level of distractibility as the name erroneously implies (Prifitera, Weiss & Saklofske, 1998). “Working memory can be thought of as mental control involving reasonably higher order tasks (rather than rote tasks), and it presumes attention and concentration” (Prifitera et al., 1998, p.28). However, the two subtests are not “pure” measures of working memory as the Arithmetic subtest also requires knowledge and application of basic mathematical operations and the Digit Span subtest combines short verbal rote memory components (Digits Forward) with the working memory element (Digits Backward) for a summary score. A number of studies have found that children with ADHD and ADD+H do not have deficits with short-term verbal memory as measured by their performance on list learning or memory span tasks (Denckla, 1996; Fischer, et al., 1990; O’Donnell & Couvadelli, 1995; Pennington & Ozonoff, 1996; Plomin & Foch, 1981). Thus the working memory deficits hypothesized to be present in the cognitive profiles of children with ADHD when measured by the Digit Span subtest, could be attenuated or obscured by adequate or above average performance on the Digits Forward portion of the Digit Span subtest.

Mirsky (1996) has utilized the Digit Span and Arithmetic subtests of the WISC-R (Wechsler, 1974) as neuropsychological measures of attention that are hypothesized to capture the “encode” or working memory/numeric-mnemonic components in his model of attention, though his model does not predict differential performance of ADHD subtypes. As discussed previously, Barkley (1998) has asserted that ADHD-C children have verbal working memory deficits stemming from behavioral inhibition difficulties compared with normal controls while children with ADHD-I should not manifest these problems. Children whose sole problem is inattention (ADHD-I) are seen as representing a distinct disorder (Barkley, 1998; Barkley et al., 1992) and would not be expected to evidence verbal working memory difficulties.

In studies that utilized the entire WISC-III to compare the performance of ADHD subjects with controls, several patterns regarding the WISC-III factor scores emerged. Three studies compared the WISC-III performance of ADHD children with the WISC-III standardization sample. Prifitera and Dersh, (1993) found that ADHD children (N=65) had lower FD factor scores relative to their VC and PO scores. A similar pattern of significantly lower FD relative to norms and to PO scores was found in the Schwean, Saklofske, Yackulic, and Quinn (1993) study. In the Anastopoulos, Spisto, and Maher (1994) study, FD was also significantly lower than the VC and PO factor scores. However, in this study, the WISC-III coding subtest was included in calculation of the FD factor score and no PS factor was generated. A significant number of children in all three studies had secondary diagnoses of learning disabilities and behavioral/emotional disorders. Therefore it is not possible to conclude that lowered FD index scores were due to the presence of ADHD alone. In fact, when the WISC-III performance of children with ADHD is compared with LD children (Lazar & Frank, 1998) and with ADHD/LD children (Lazar & Frank, 1998; Mayes, Calhoun & Crowell, 1998b) children with LD perform significantly worse than do children with a sole diagnosis of ADHD.

Two studies have compared the WISC-III performance of children with ADHD and a clinical control group. Mayes, Calhoun, and Crowell, (1998a) found that the discrepancy between FSIQ and FD was significantly greater in the ADHD group and that in 87% of the ADHD sample, the FD factors score was significantly lower than the VC and PO indices. However, roughly 30 percent of the ADHD sample had a comorbid behavior or mood disorder. Mealer, Morgan and Luscomb, (1996) compared the WISC-III performance of children with ADHD only and clinic-control (non-ADHD) children finding that the ADHD group had significantly lower FD scores. Thus in both studies poorer FD scores were associated with a diagnosis of ADHD regardless of the presence or absence of a comorbid behavior or mood disorder.

Although impaired performance on the subtests comprising the FD factor score has been used as a diagnostic indicator of ADHD, additional research has strongly suggested that this practice is unfounded. For instance, Anastopoulos et al. (1994) found that over 78% of the children who met criteria for ADHD did not demonstrate significant discrepancies between the FD and other factor scores. Although Reinecke, Beebe & Stein (1999) in a large study of 200 children with ADHD found that the FD factor was low relative to the VC and PO factors, only 28% of FD scores were lower than VC scores and only 32% had significantly lower FD than PO scores. They suggest that among children with ADHD, poor performance on the FD factor is associated with a learning disability.

Riccio, Cohen, Hall, and Ross (1997) did not find significant differences between clinical groups (ADHD-C, ADHD-I and LD) on the WISC-III FD factor. They did however, report significant correlations between the FD factor, and to a lesser degree the PS factor, and measures of verbal and visual immediate working memory. In contrast, Lowther and Wasserman (1994) found differences in ADHD subtypes (N= 15, no co-morbid LD) on the WISC-III Arithmetic subtest and on a visual analog to the Digit Span subtest with the ADHD-I group performing significantly better than the ADHD-C group. However, the groups did not differ in their performance on the Digit Span subtest, though perhaps the small size of the sample contributed to this finding. Subtype differences were preliminarily attributed to working memory deficits in the ADHD-C group of children while the adequate performance of ADHD-I children was interpreted as consistent with previous research findings that ADHD-I children are able to transition from controlled to automatic processing (Braun, Kundert, Hess, & May, 1992).

To summarize, the presence of co-morbid learning and behavioral/mood disorders in the samples comparing the performance of ADHD children with normal controls have produced inconclusive results regarding the unique contribution of working memory difficulties as measured by the WISC-III FD factor score (Anastopoulos et al., 1994; Mealer et al., 1996; Prifitera & Dersh, 1993; Schwean et al., 1993). Reinecke et al. (1999) concluded that among children with ADHD, poor performance on the FD factor is associated with a learning disability. Conflicting results regarding ADHD subtype and the FD factor have also been found. For example, Riccio et al. (1997) did not find significant differences between ADHD subtypes on the FD factor while Lowther and Wasserman (1994) found that the ADHD-I group performed significantly better than the ADHD-C group on the Arithmetic subtest with no differences seen in Digit Span performance. Complicating these results is the fact that the Digit Span subtest combines a short-term verbal memory component (Digits Forward) and a working memory component (Digits Backward). Children with ADHD and ADD+H have performed similar to normal controls on short-term verbal memory tasks (Denckla, 1996; Fischer, et al., 1990; O'Donnell & Couvadelli, 1995; Pennington & Ozonoff, 1996; Plomin & Foch, 1981) raising the possibility that working memory difficulties could be attenuated or obscured by adequate or above average performance on the Digits Forward portion of the Digit Span subtest.

Problems with sustained effort and organizational deficits

Douglas (1983) found that in ADD children there was “no basic deficiency in the capacity to perceive visual or auditory stimuli accurately or to encode, store and retrieve such information. When deficits are found on memory tasks, they can be attributed to a failure to invest sufficient effort in activities such as processing visual or auditory information carefully and deeply, committing the information to memory and retrieving information that has been successfully processed and stored" (p. 297). In summary, while the sensory/perceptual or encoding systems of children with ADD are usually intact, difficulties with the organization and retrieval of information are often present.

A number of studies found that in comparison to normal controls, children with ADD+H have significant difficulties on tasks that require more effortful processing strategies. August and Garfinkel (1990) using subtests from the DTLA-2 and selected neuropsychological instruments examined the short term memory, conceptual reasoning and attentional functioning of children with ADHD, children with ADD+ RD and normal control group. Included in short term memory composite were two measures of short-term auditory memory (word strings and structured sentences) and two measures of visual sequential memory (object and letter sequences). Results found no significant differences between the two ADD groups on the auditory memory tasks though both groups performed less well than controls. A significant difference between the two ADD groups was found on one of the visual sequential memory measures (letter sequences). The performance of ADD+RD group was significantly more impaired than was the ADD+H group. The combined group of children also had more difficulty with a rapid naming test than did the other two groups. These findings were interpreted as reflecting differences in automatic vs. effortful levels of processing. Children with ADD+H were seen as having problems with cognitive processes which required deliberate effort and planning whereas the performance of the children with ADD+RD was further compromised by the presence of skill deficits in processes which in normal children become automatic.

Tannock, Martinussen & Frijters (2000) compared a group of ADHD (no subtyping noted) children, ADHD+RD children and normal control children on color and letter naming speed, phonologic decoding and arithmetic computation. They found that after controlling for general language ability, color naming was significantly more impaired in the ADHD only group and interpreted the results as reflecting specific difficulties with effortful semantic processing. The letter and color naming deficits seen in ADHD+RD group were seen as relating to general verbal processing difficulties.

In a study which examined the rapid naming skills of children and adolescents with ADHD (no LD), reading disabilities (no ADHD) and normal controls, Semrud-Clikeman, Guy, Griffin & Hynd (2000) found that the children with ADHD had significantly poorer performance than controls on color and object naming tasks. Their performance on these tasks did not differ significantly from the group of children with reading disabilities. In contrast, on the letter and number naming tasks, children with ADHD performed similar to normal controls while the performance of children with reading disabilities was significantly slower and error prone. Additionally, children with ADHD did not differ from controls on tasks that required alternating between stimulus sets (letters and numbers, letters, numbers, and colors). Children with ADHD were seen as having achieved letter and number automaticity while problems with color and object naming were interpreted as reflecting the presence of a performance deficit. These results are consistent with Tannock et al. (2000) and further support the finding of difficulties with effortful semantic processing in children with ADHD.

Borcherding et al. (1988) also examined the degree to which children with ADD+H employ effortful processing strategies. Borcherding et al. (1988) used free recall performance on related and un-related word lists as measures of effortful processing and recognition performance on the word lists as measures of automatic processing. Effortful processing tasks distinguished the children with ADD+H from a group of same-age and gender control children while the recognition performance did not. The children with ADD+H had significantly poorer free recall performance on both related and un-related word lists in comparison to controls. Results were interpreted as supporting the importance of effort-related variables such as affect, self-regulation and motivation in the examination of cognitive functioning of children with ADD+H.

Zentall (1988) found that ADD+H children have more difficulty than controls with verbal tasks that either requires internal processing or re-organization of information. Using four tasks (making up a story, generating a story from four words, generating a story from pictures and a story retell condition), she examined both the quality and quantity of on and off task verbalizations. She found that children with ADD+H talked more during transitions and asked more non-task questions than did the controls. The pattern of performance was reversed during two of the story telling tasks. Children with ADD+H talked less often than peers on tasks that required internal processing or re-organization of information (making up a story and story retell). These results were interpreted as being consistent with the presence of language production deficiencies that were situation and task specific.

Children with ADD+H are also less likely to spontaneously generate and effectively use semantic problem solving strategies (August, 1987; Denckla, 1994, 1996; Douglas & Benezra, 1990; Hamlett, Pellegrini & Conners, 1987). Hamlett, et al. (1987) asserted that deficits in attentional and inhibitory mechanisms interfere with cognitive performance on complex problem solving tasks that require organization or deliberate planning. Non-hyperactive children were expected to demonstrate more efficient use of problem-solving strategies than children with hyperactivity because attention and inhibition problems in the later group would have disrupted the developmental mastery of these strategies.

Using a sort recall task, children with ADD+H and a normal control group of children were required to sort cards into at least two but not more than seven groups or categories. They were encouraged to sort in a way that would help them remember each one. All 20 cards were visible at the end of the game and the children had 5 seconds to examine them after which they were asked to recall the items. Additionally, they were asked to provide verbal instructions to a younger child regarding how to play the game. Results indicated that children with ADD+H had significantly lower overall instruction scores, strategy scores and communication effectiveness scores when compared with the control group. The authors suggest that children with ADD+H are less likely to spontaneously generate and effectively use semantic problem solving strategies.

August (1987) investigated whether children with ADD+H would show recall and organizational deficits in comparison to normal peers and an age-matched group of children with reading disability. An additional research question examined the impact of instruction on the organizational performance of children with ADD+H. The procedures consisted of a single trial free recall task and a multi-trial free recall sort presentation. In the single trial free recall task the subjects were asked to recall a total of 24 words presented visually in six groups with four weakly categorizable nouns. In the sort presentation, the subjects were handed cards with the target words written on them and asked to sort them into groups that would help them remember the words. However, no specific examples of sorting strategies were provided. The subjects were then asked to recall the word lists. This sorting procedure occurred across five trials. Dependent measures included the number of items recalled, recall organization (category clustering), and sorting time prior to recall. Clustering scores included the total number of observed category repetitions, the maximum possible category repetitions and the expected or chance number of category repetitions.

Results indicated that children with ADD+H recalled fewer words and employed clustering less often on the baseline trial than did the children in the other two groups. Group means and clustering scores on trials 1 and 2 were not significantly different and were interpreted as evidence that the sorting task provided an organizing strategy for the ADD+H group of children. On trials 3-5, the recall and clustering performance of children with ADD+H was once again significantly lower than both groups. These results were interpreted in terms of deficits in the spontaneous and sustained use of an organizational strategy. Additionally, Voelker, Carter, Sprague, Gdowski and Lachar, 1989) found that children with ADD+H use a semantic clustering strategy (grouping by meaning) only when task demand is obvious and requires little mental effort.

Denckla (1996) asserts that the critical cognitive elements to examine in the search for processes gone awry in ADHD and learning disabilities are those which fall under the constructs of working memory and executive function rather than attention and long-term memory. Key in her discussion is the idea that working memory is the process that controls retrieval and utilization of acquired knowledge and allows the individual to act on the basis of represented rather than immediately presented information. She concludes that there is no evidence that children with ADHD have problems with consolidation or storage but rather they appear to have problems with the process of encoding or acquisition of information. She hypothesizes that these difficulties may be related to deficient application of proactive strategies and finds that children with ADHD (no subtyping noted) obtain normal scores (recall and recognition) but fail to apply strategy of organizing named items into meaningful groups that could facilitate learning.

In summary, children with ADD+H have significantly more difficulty with tasks that require sustained effort than do non-ADHD control children (August & Garfinkel, 1990, Borcherding et. al., 1988). Zentall (1988) found that, in comparison with normal control children, ADD+H children have marked difficulty with verbal tasks that require re-organization of information. Children with ADD+H are also less likely to spontaneously generate and effectively use semantic problem solving strategies (August, 1987; Denckla, 1994, 1996; Douglas & Benezra, 1990; Hamlett et al., 1987). Tannock et al. (2000) also found more difficulties with effortful semantic processing in a group of ADHD children compared with non-ADHD control children.

Problems with sustained attention and Continuous Performance Tests

The Continuous Performance Test (CPT) paradigm has been used to measure processes related to sustained attention or vigilance. Originally designed to measure the signal detection accuracy of radar operators over time (Mackworth, 1970), most of the current CPT measures follow or are some variant of the procedures set forth by Rosvold, Mirsky, Sarason, Bransome, & Beck, (1956). These procedures have a subject watch a computer screen and continuously react to the presence or absence of a specific stimulus with distracters present. The Conners' CPT (Conners, 1995), used in this research study, is a commercially available instrument that provides a standardized computer administration (pre-programmed) and generates a norm-referenced clinical report. The Conners' CPT employs continuous responding with inhibition required when the target letter (X) appears with no alerting stimulus occurring before the target letter is presented.

A number of key elements are common across CPTs. These include measures associated with vigilance or the ability to identify targets correctly across the duration of the task, error measures and signal detection measures (d'-discrimination of targets from non-targets and beta-a measure of risk-taking). Initial theoretical application of error type with attentional difficulty associated omission errors with inattentiveness and errors of commission with impulse control problems (Barkley, 1990; Corkum & Siegel, 1993). Specifically the more omission errors (target letters presented but no response) a person made, the more inattentive he or she was thought to be and a high number of commission errors (failure to inhibit responding) supposedly reflected elevated impulsivity. However, research application of error type to performance in clinical groups has produced mixed and inconclusive results. These studies are reviewed later in this section.

In evaluating the literature regarding the use of CPTs with children with ADHD, it is important to consider two general categories of variables that can impact results and complicate interpretation; those variables related to the design of the instrument (type and duration of task and inter-stimulus interval differences-ISI) and subject specific variables (age, gender, and impact of stimulant medication on performance and the presence or absence of the examiner during administration). In a review of the literature (N= 13 studies), Corkum and Siegel (1993) examined the visual CPT performance of children with ADHD children compared with normal controls on variables related to instrument design. They compared subject performance across three task types; successive task (A then X, n= 7); simultaneous task (X, n=3); and tasks that had a combination of both (n=3) and found that all task types were likely to find performance differences between children with ADHD and controls. They also identified some common patterns across both groups. Specifically, the hyperactive and normal control group had more correct responding and fewer commissions (false alarms) when ISI (time allowed to respond) was than longer 1.5 seconds regardless of task type. They also found that as overall time on task increased perceptual sensitivity or d’ decreased. They concluded that the task variables that best differentiate children with ADHD from normal children are those that require the subject to attend consistently, react quickly with relatively short time between images along with a high percentage of presented targets.

The Corkum and Siegel (1993) review also examined the impact of subject specific variables (age, gender, presence/absence of medication and examiner during testing) on CPT performance. In the eight reviewed studies, the use of stimulant medication improved performance. That is, the children on medication were able to detect more targets and made fewer commission errors. They also found that no difference in performance was obtained between children with ADHD and controls when the examiner was present during computer administration and in studies where the examiner was not present during testing, the performance of the children with ADHD deteriorated more rapidly over time than did the performance of controls. While the Corkum and Siegel review did not find significant differential performance between males and females, they did find a significant effect for age with younger children performing significantly more poorly than older children and recommend controlling for age. More recently and using a non-referred population, Conners, Epstein, Angold and Klaric (2003) in a normative epidemiological sample found significant age and gender effects with CPT performance improving with age and boys evidencing more errors and risk-taking.

An examination of the studies reviewed by Corkum and Siegel (1993) regarding ADHD performance patterns on specific CPT variables (types of errors and signal detection indices) finds that, of the ten studies looking at types of errors (omissions and commissions) five found that the ADHD group made more omission errors than did normal controls. One study found errors of omission correlated with the inattention scale of the DSM—III rating scale and inattention passivity scale of a teacher rating scale and in four of the studies no differences in error type were found across children with ADHD and controls. In four studies, children with ADHD evidenced more commission errors than controls and in five studies differential performance was not found. While signal detection indices were used as variables for comparison less frequently, of the five studies reviewed, two of them found differences in risk-taking and all found that the ADHD group had significantly lower levels of perceptual sensitivity than the control group. Perceptual sensitivity (d') is assumed to be an index of arousal and beta or decision making hypothesized to reflect changes in both effort and activation (Hooks, Milich & Lorch, 1994)

Both Barkley (1998) and Mirsky (1996) assert that the number of errors (commissions and omissions) provide a measure of sustained attention. Mirsky et al (1999) report that compared with normal controls, ADHD children (no subtyping noted) evidenced difficulties in sustained visual and auditory attention as measured by the CPT. The authors report that children with ADHD made more errors of commission. Additionally, when the CPT performances of ADHD, ADHD+LD and normal control children were examined, the ADHD children made significantly more errors of omission and commission than did the combined ADHD+LD group.

Mirsky (1996) reports that aggressiveness and shyness are associated with different patterns of attentional impairment. According to Mirsky, children who were rated by teachers as shy and having poor concentration had deficits in the sustain/detect component of the CPT (number of omission errors). In contrast, children who were seen as abnormally aggressive and having poor concentration performed poorly on the sustain/inhibit component of the CPT (number of commissions).

Willcutt, Chhabildas and Pennington (2001) provide preliminary results of a study conducted by Chhabildas, Pennington, and Willcutt (under review) where they compared the performance of ADHD subtypes on the CPT, predicting that significant CPT commissions would be associated with ADHD-C children and significant CPT omissions would be seen with ADHD-I children. The results found that both ADHD groups were impaired relative to controls but did not differ significantly from each other on these measures. In contrast, Lowther and Wasserman (1994) found that ADHD-I children made fewer commission errors relative to the ADHD-C children and that their commission errors decreased over time while the commission error rate for ADHD-C children did not decrease.

In summary, research has suggested that the performance of children with ADHD is significantly worse than normal control children on continuous performance measures (Corkum & Siegel, 1993; Mirsky et al., 1999; Pennington & Ozonoff, 1996; Willcutt et. al., 2001). A number of researchers (Barkley, 1998; Mirsky, 1996; Mirsky et al. 1999) have interpreted these findings as indicating a deficit in sustained attention. In studies examining the CPT performance of ADHD subtypes no clear patterns have emerged. In two studies, children diagnosed with ADHD-I made fewer commission errors relative to ADHD-C children (Lowther & Wasserman, 1994) and more omission errors (Mirsky, 1996), while one study (Willcutt et al., 2001) found no differences in performance among the ADHD subtypes.

Problems with processing speed

Processing speed (PS) is defined as an indication of the rapidity with which a person can process simple or routine information without making errors (Prifitera, et. al, 1998). Prifitera & Dersh (1993) and Schwean et al., (1993) found that ADHD children had lower PS factor scores relative to their VC and PO scores. However as previously mentioned, a significant number of children in these two samples had learning disabilities and behavioral/emotional disorders which prevents the attribution of unique cognitive deficits associated with ADHD. Mayes et al. (1998a) found that in 87% of the ADHD sample, the PS factor score was significantly lower than the VC and PO indices. However, again roughly 30 percent of the ADHD sample had a comorbid behavior or mood disorder. Riccio et al. (1997) did not find significant differences between clinical groups (ADHD-C, ADHD-I and LD) on the WISC-III PS factor.

Mirsky, et al. (1999) found that children with ADHD (no sub-typing specified) were impaired relative to controls on the focus-execute tasks and Pennington and Ozonoff (1996) found that relative to controls, children with ADHD performed significantly worse on measures of perceptual speed (Coding and Symbol Digit). Barkley (1997a) asserts that the deficits involved with ADHD-I reflect problems with focused or selective attention and memory retrieval problems. Willcutt et al. (2001), using the trail-making test, reported that children with ADHD-I evidenced a marginally significant deficit in processing speed compared with ADHD-C children.

To summarize, a number of studies have found that children with ADHD perform significantly worse than normal controls (Pennington & Ozonoff, 1996: Prifitera & Dersh, 1993; Schwean et al., 1993) on measures of perceptual speed (Coding and Symbol Search). However the presence of co-morbid learning and behavioral/emotional disorders limits conclusions regarding the uniqueness of PS deficits found. Few studies have examined processing speed differences associated with ADHD subtypes. Willcutt et al. (2001) reported that children with ADHD-I evidenced a marginally significant deficit in processing speed compared with ADHD-C children

STUDY HYPOTHESES

This study examined five areas of neurocognitive functioning in a group of children diagnosed with either ADHD-C or ADHD-I and a group of control participants. The following hypotheses were investigated:

1. Children with ADHD-C would perform significantly worse than ADHD-I children and controls on two verbal working memory tasks. No performance differences were predicted between ADHD-I and normal controls.
2. Short-term verbal memory performance on two verbal span tasks across the three groups was predicted to yield no significant performance differences.
3. Children with ADHD-C would evidence difficulties relative to ADHD-I and controls on a task that require sustained cognitive effort and verbal organization. No performance differences were predicted between ADHD-I and normal controls.
4. The sustained visual attention of children diagnosed with ADHD-C or ADHD-I on a continuous performance task would differ significantly from normal control participants and from each other.
5. Children with ADHD-I would evidence significantly slower visual processing speed across two measures compared with normal control children and children with ADHD-C. No performance differences were predicted between ADHD-C and normal controls.

CHAPTER III

METHOD

PARTICIPANTS

Fifty-six study participants between the ages of 8 and 16 were selected from the archival records of a group of children diagnosed with Attention Deficit Hyperactivity Disorder referred to the Austin Neurological Clinic (ANC) in Austin, Texas. Thirty-one volunteer (non-clinical) control participants, also between the ages of 8 and 16, were recruited from the community of San Antonio, Texas. The University of Texas at Austin Institutional Review Board approved this study.

The majority of referrals to ANC were for evaluation of attention and academic difficulties and came from a wide referral base (family members, physicians, psychologists, and school personnel). The fifty-six archival sample participants included in this study were a subset of the larger clinic population. Study inclusion criteria for the two clinical groups included:

1. Meeting the DSM-IV (APA, 1994) diagnostic criteria for attention deficit hyperactivity disorder in one of two subtypes: ADHD-combined type (ADHD-CT) and ADHD-inattentive type (ADHD-I). The DSM-IV diagnostic criteria are listed in Appendix A.
2. Having a complete set of assessment data present. This data included the Wechsler Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991), excluding the Mazes subtest, the California Verbal Learning Test-Children's Edition (CVLT-C; Delis, Kramer, Kaplan & Ober, 1994), and the Conners' Continuous Performance Test (CCPT; Conners, 1995.

3. Attaining a WISC-III Full Scale IQ score of 80 or above.
4. Being off stimulant medication (e.g., Ritalin) during the assessment process.

Children who met criteria for the ADHD-hyperactive-impulsive type (ADHD-HI) or who had a co-morbid diagnosis of learning disability, including a diagnosis of nonverbal learning disability were not included in the study. Additionally, children who met criteria for other childhood disorders or had, by history, a significant medical disorder (cerebral palsy, epilepsy, head injury) were also excluded from the study.

Thirty-One non-referred children served as control participants. The inclusion and exclusion criteria for this group were identical to those of the two clinical groups with two exceptions. The control participants could not meet diagnostic criteria for the two subtypes of ADHD and parental checklist ratings of behavior needed to be within normal limits. All control participants received a cash payment of $25.00 for their 2-hour participation.

PROCEDURES

Determination of the ADHD diagnosis

The following ANC procedures were employed for all clinical group participants chosen for inclusion in this study. As part of a comprehensive neuropsychological evaluation, parents completed a family data questionnaire that sought information regarding the mother's pregnancy history, and the child's birth, developmental, medical, and school history. School records and any previous evaluations were requested. Information regarding family history was also solicited. Parents and teachers were asked to rate the referred child's behavior, using either the Child Behavior Checklist (CBCL; Achenbach, 1991) or the Child Behavior Checklist-Teacher Report Form (CBCL-TRF;

Achenbach& Edelbrock, 1986). Parents were also asked to complete the SNAP DSM-IV ADHD/ODD Checklist (SNAP-IV; Swanson & Carlson, 1994). Additionally, each family met with the licensed psychologist for a clinical interview. Neuropsychological assessment was conducted by doctoral students enrolled in the School Psychology and Clinical Psychology programs at the University of Texas at Austin under the supervision of the licensed clinical psychologists at ANC and the University of Texas. The licensed ANC psychologists conducted a comprehensive feedback session for all parents. The diagnosis of ADHD was made on the basis of meeting DSM-IV criteria, (See Appendix A for a listing of criteria), significant elevations on the behavioral rating scales (T scores above 70 on the CBCL forms), the results of the clinical interview with parent and child, behavioral observations of the child during assessment, and the neuropsychological assessment results. Thus the diagnosis of ADHD was based upon information gathered from multiple respondents and multiple sources and reflects best practice procedure.

Clinical groups selection and data collection procedures

Of the approximately 250 archival assessment files reviewed, twenty-six children who were diagnosed with ADHD-C and thirty children who were diagnosed with ADHD-I met the study inclusion criteria. Reasons for exclusion of children diagnosed with ADHD included the presence of co-morbid learning disabilities, being on stimulant medication during the assessment process, or incomplete assessment records. The presence of a co-morbid learning disability in reading was the most common occurrence followed by combinations of reading and writing disabilities, reading, writing and math disabilities, math disability alone or the presence of a nonverbal learning disability. This pattern was especially pronounced with girls who were diagnosed with ADHD-C and resulted in the removal of seven potential ADHD-C participants. Additionally, a small number of participants were excluded because of a diagnosis of mental retardation, co-morbid emotional disturbance, and history of Traumatic Brain Injury or epilepsy.

The following information was coded for each clinical group member: Id number, ADHD subtype group membership, gender, and age. Race/ethnicity information was not available on the assessment protocols and was therefore not coded. Information from the two parent completed checklists (CBCL and the SNAP-IV), the WISC-III summary information and information from the CCPT computer scored report was also coded. All CVLT-C written responses from the protocols were scored using the CVLT-C Scoring Assistant software (Fridlund & Delis, 1994). See Appendix E for a sample of the CVLT-C Scoring report.

Control group selection and data collection procedures

Thirty-one children were recruited through the professional and social contacts of the principal investigator in San Antonio, Texas to serve as control participants. Parents of the children participating in the control group provided signed informed consent and the children gave their consent (ages 13-16) or assent (ages 8-12). See Appendices B and C respectively for a copy of the consent and assent forms employed in the study. As part of the pre-testing process, participants were told that they could withdraw from participation at any point during the assessment without penalty. All control participants completed the assessment process.

Parents of control participants completed the CBCL and the SNAP-IV checklists. None of the control participants had significant elevations on the CBCL or the SNAP-IV that necessitated exclusion from the study. All control participants were administered (in the following order) the WISC-III, the CVLT-C (List A and B trials and Short Delay Free-Recall and Short Delay Cued Recall trials) followed by the CPT and the CVLT-C

Long Delay Free Recall, Long Delay Cued Recall and Recognition trials. All instruments were administered in a manner consistent with the standardization procedures and conditions set forth in the respective test manuals. Additionally, all instruments were scored consistent with criteria outlined in their respective test manuals. Data taken from categories identical to that of the clinical groups' demographic information (ID number, gender and age) was coded. Checklist information (CBCL and SNAP-IV) and dependent variable information from the WISC-III and the CCPT was also entered into the database. The written CVLT-C responses for the control group were scored using the CVLT-C Scoring Assistant software (Fridlund & Delis, 1994). Appendix D contains a sample CVLT-C Scoring report.

MEASURES

Child Behavior Checklist (CBCL; Achenbach, 1991)

The CBCL is a broadband behavior rating scale that provides information grouped into eight factor analytic derived domains (anxiety, depression, somatic complaints, social problems, thought problems, attention problems, rule breaking behavior and aggressive behavior). Parents of children between the ages 4 and 18, using a three point scale (0=Not true as far as you know; 1=Somewhat true or sometimes true; 2=Very true or often true), indicate the degree to which each statement reflects current behavior or behavior within the last 6 months. Raw score totals are summed and, using separate norms for males and females, are converted to T-scores for the eight domains. T-score elevations above 70 are considered clinically significant. Using the standardization sample, Achenbach (1991) reports good test-retest reliabilities (average r=.90 for boys and average r=.88 for girls over a one week interval) and adequate evidence of concurrent validity.

SNAP DSM-IV ADHD/ODD Checklist (SNAP-IV; Swanson & Carlson, 1994)

The SNAP is a 26-item diagnostic checklist based on DSM-IV ADHD and ODD (Oppositional Defiant Disorder) symptoms. The instrument incorporates the Swanson, Nolan, and Pelham Checklist IV and the DSM-III-R Disruptive Behavior Disorder Rating Scale (Pelham, Gnagy, Greenslade, & Milich, 1992). Respondents indicate the extent to which a particular symptom is present (Not at all; just a little; pretty much; and very much). Of the 26 items, 18 are used to determine one of the three possible ADHD subtype diagnoses: ADHD, Predominately Inattentive Type, ADHD, Predominately Hyperactive-Impulsive Type and ADHD, Combined Type. There are nine questions that parallel the inattentive symptoms from the DSM-IV and nine questions which tap the hyperactive/impulsive symptoms from the DSM-IV. The remaining eight items mirror symptoms associated with the DSM-IV Oppositional Defiant Disorder (ODD).

Wechsler Intelligence Scale for Children-Third Edition (WISC-III, Wechsler, 1991)

The WISC-III is an individually administered intelligence test consisting of 13 subtests which yields a Full Scale, Verbal, and Performance IQ score ranging from 40 to 160. Subtest standard scores form the basis for the four factor scores: verbal comprehension, perceptual organization, freedom from distractibility and speed of information processing. The WISC-III was used to determine study eligibility (FSIQ $\geq$ 70). The Digit Span and Arithmetic subtests comprise the Freedom from Distractibility factor and the Coding, and Symbol Search subtests form the Speed of Information Processing factor. Performance on these four subtests was examined in this study.

WISC-III Digit Span (Wechsler, 1991)

Digit Span consists of two parts: Digits Forward and Digits Backwards. On Digits Forward, the child is asked to repeat a sequence of orally presented numbers and on

Digits Backward, the child, after hearing a set of orally presented numbers, is asked to repeat them in reverse order. On both parts of the subtest, the sequences become progressively longer as the subtest progresses. To obtain credit the child must recall the correct number in the correct sequence. Average split-half reliability of this subtest is .85 with a coefficient range of .79 to .91.

WISC-III Arithmetic (Wechsler, 1991)

The Arithmetic subtest consists of a series of oral word problems that the child must solve mentally. Also included are easier counting items and for more difficult items, a written prompt is provided. Average split-half reliability is .78 with a coefficient range of .71 to .82.

WISC-III Coding (Wechsler, 1991)

Under timed conditions (2 minutes), and using a visual template, the child is required to correctly match either a symbol (Coding A-ages 6-7) or number (Coding B-ages 8-16) with the template and then write the corresponding symbol. All study participants were administered Coding B. Because measures of internal consistency such as split-half coefficients are inappropriate for speeded tests, stability coefficients derived from the WISC-III standardization test-retest sample are reported. Based on the Coding performances of children ages 6, 7, 10-11 and 14-15, the average stability coefficient is .79 with a range of .72 to .84.

WISC-III Symbol Search (Wechsler, 1991)

Under timed conditions (2 minutes), the child is asked to scan a series of target and search groups of symbols and indicate whether or not a target symbol appears in the search group by marking a yes or no column. The average stability coefficient is .76 with a range of .69 to .82.

California Verbal Learning Test-Children's Version (CVLT-C; Delis, Kramer, Kaplan, & Ober, 1994)

The CVLT-C is an individually administered test of verbal learning and memory. Given to children ages 5-0 to 16-11, CVLT-C is a downward extension of the California Verbal Learning Test (CVLT; Delis, Kramer, Kaplan, & Ober, 1987).

The CVLT-C consists of the following administration steps:

1. A 15-word target list (List A) is read to the child at a rate of one word per second over five immediate free recall trials. The List A-target list is composed of five words from each of three semantic categories (things to wear, things to play with, fruits) and the child verbally recalls the words in any order. On these trials as well as all that follow, the exact order the child recalls the words is recorded along with any errors.
2. Immediately after the fifth learning trial, an interference list (List B) is presented for a single, immediate free-recall trial. List B is also composed of five words from each of three semantic categories (furniture, sweets and fruits). The fruits contained on List B are different from the fruits on List A.
3. Next the child is asked to spontaneously recall the words from List A without having the word list read first (short-delay free recall trial).
4. Then the child is asked to recall words from each of the three List A categories (short delay cued recall trial).
5. A 20-minute delay interval occurs during which no verbal tasks should be administered.
6. After the delay, the child is asked to spontaneously recall words from List A (Long delay free recall trial).

7. Next the child is asked to recall words from each of the three List A categories (long delay cued recall trial).
8. The final step is a recognition task. The child is asked to indicate (yes/no) if a particular word was on List A. Item foils include words from List B, words that are semantically related to the category types, words that are phonemically similar, and unrelated words.

Scoring information for the CVLT-C can be grouped into four general areas:

1. Level of recall or number of words correctly recalled on each of the trials as well as the total number of words recalled across the learning trials (Trials 1-5);
2. Learning characteristics across List A-trials 1-5,
3. Recall errors such as perseverations (repetition of a response word on the list) and intrusions (reported word that is not on the target list),
4. Recognition measures.

A subset of the level of recall and learning characteristics were examined across the five learning trials. These indices include the total number of correctly recalled words on List A trial 1, the semantic cluster ratio across trials 1-5, and the recall consistency across trials 1-5.

The determination of the global or total semantic cluster score on List A trials 1-5 is a multi-step process and is briefly described below. This variable consists of two components: the observed semantic cluster score and the expected semantic cluster score. A response is scored as belonging to an observed semantic cluster whenever a correct response immediately follows a correct response from the same category. There are three semantic categories for List A: things to wear, things to play with and fruits. Within each category, the possible total observed semantic cluster is four and the maximum observed semantic cluster score possible on a particular trial is twelve. Across trials 1-5 the maximum semantic score possible is 60.

Calculation of the expected semantic cluster score on List A trials 1-5 takes into consideration the total number of words recalled on a particular trial, including errors such as perseverations and intrusions as well as the number of correct words recalled within each category type. The total semantic cluster score then is the total number of observed semantic clusters across the five trials divided by the total expected semantic cluster across the five trials. The calculation of the remaining CVLT-C variables (total number of correctly recalled words on List A trial 1 and the recall consistency across trials 1-5) is straightforward.

On the CVLT-C there is item interdependence within and across trials that complicates the usage of traditional reliability measurements. Item interdependence is present because the recall of any one word, out of the 15-item word list, on a trial decreases the likelihood that the other 14 items will be recalled on that same trial. Item interdependence is also present across trials because the recall of a particular word increases the probability that the same word will be recalled on subsequent trials. CVLT-C reliability estimates are based upon the List A-learning trials 1-5. The average across trial consistency alpha estimate is .85; the average across semantic category consistency alpha estimate is .72 and the average across word consistency alpha estimate is .81

Conners' Continuous Performance Test (CCPT; Conners, 1995)

The CCPT is a computer-administered instrument designed to assess sustained attention or vigilance in persons aged 4-61. The CCPT is based upon the continuous performance task (CPT) first developed by Rosvold, Mirsky, Sarason, Brasome, & Beck in 1956 to detect attention lapses in patients with petit mal (absence) epilepsy. The standard CCPT requires the child to press the spacebar for all letters except the letter X. The 14-minute administration is divided into six block intervals, each with three trial sub-blocks. The inter-stimulus intervals vary (1, 2, or 4 seconds) for the blocks with each letter displayed for a quarter of a second (250 milliseconds).

A computer generated report presents score information in four forms: raw scores, standard T-Score (M = 50, SD =10), percentiles and range categories (average, mildly or markedly atypical). Performance variables include the number and percentage of correct responses (hits), omissions (misses) and commissions (pressing space bar when the letter X was present on screen). Additional performance variables include the mean response time (hit RT), consistency of response time to targets (hit RT standard error), perceptual sensivity (how well the child discriminates between targets and non-targets), risk taking, hit rate and standard error across the six time blocks and hit rate and standard error of reaction time. An overall index is the weighted sum of the eleven measures (Conners, 1995).

CHAPTER IV

RESULTS

This study included 87 participants divided into three groups: children who were diagnosed with Attention Deficit Hyperactivity Disorder Combined Type (ADHD-C), children who were diagnosed with Attention Deficit Hyperactivity Disorder Primarily Inattentive Type (ADHD-I), and children who served as control participants.

EXAMINATION OF SAMPLE DEMOGRAPHICS

One of the first steps in the data analysis process was to determine possible significant age or intellectual differences among the ADHD subgroups and the control group that necessitated the use of a covariate during data analysis. A one-way analysis of variance (ANOVA) revealed no significant mean difference in age between the three groups, $\underline{F}$ (2, 84) =.86, $\underline{p}$= .43). Table 4.1 presents the mean age and standard deviation for each of the three study groups.

Table 4.1
Mean Age and Standard Deviation by Group

Group	Mean Age	SD	Min. Age	Max. Age
ADHD-C (n=26)	11.45	2.41	8.00	15.8
ADHD-I (n=30)	11.53	2.01	8.00	15.0
Control (n=31)	12.16	2.40	8.00	16.9

To determine if there were statistically significant differences in intellectual functioning across the three groups (independent variables), a repeated measures multivariate analysis of variance (MANOVA) was conducted using performance on the WISC-III Verbal Comprehension (VC) and Perceptual Organization (PO) factors as dependent variables. These two factor scores were chosen for comparison for two reasons. The first reason is because the WISC-III subtests contributing to the VC and PO factor scores are different from those used to generate the Freedom from Distractibility (FD-Digit Span and Arithmetic subtests) and Processing Speed (PS-Coding and Symbol Search subtests) factors examined in Hypotheses 1 and 5 respectively. The Full Scale IQ score was not used as it includes scores from the Arithmetic and Coding subtests. Second, the factor analytic and intercorrelation information (WISC-III; Wechsler 1991) suggest that these four factors are measuring distinct aspects of neurocognitive development. As expected no statistically significant overall group differences were found [Wilks' Lambda =.959, $F(4,166) = .885$, $p=.47$]. Consequently, no covariate for differential intellectual performance was employed when examining the study hypotheses. Table 4.2 presents the means, standard deviations and results of the univariate analysis of variance for the dependent measures.

Table 4.2
Means, Standard Deviations, and Univariate Results for WISC-III VC and PO Factors

	Group								
	ADHD-C n=26		ADHD-I n= 30		Control n=31		F	p*	η^2
	M^4	SD	M^4	SD	M^4	SD			
VQ	109.46	12.74	108.53	13.24	109.48	10.08	0.06	0.94	0.01
PO	107.85	13.52	106.63	13.58	112.06	10.57	1.56	0.23	0.04

Note: Standard Scores (M=100, SD=15)
*p=NS

A second step was to determine if there was equal gender distribution across the groups that allowed for gender based variable comparisons. Table 4.3 presents the frequency of males and females in each of the three study groups. There was a high male to female ratio within the ADHD-C group (22 males to 4 females). This finding is not unexpected given that the research on gender-based prevalence rates has indicated that males are 4 times more likely to be diagnosed with ADHD-C than are females (Barkley, 1996).

A Chi-Square analysis comparing the gender frequency differences across the groups revealed, as expected given the extremely small number of ADHD-C females, a significantly higher frequency of male participants (p =0.02) compared to female participants. Therefore it was not possible to examine dependent variable performance of gender and all subsequent analyses were conducted using the performance scores of males and females combined within each of the three groups.

Table 4.3
Gender Frequencies by Group

	Frequency (%)		
	ADHD-C (n=26)	ADHD-I (n=30)	Control (n=31)
Male	22 (85%)	17 (57%)	15 (48%)
Female	4 (15%)	13 (43%)	16 (52%)

EVALUATION OF ADHD SYMPTOM SEVERITY

The purpose of the next set of analyses was two fold. The first was to confirm that the ADHD and control participants were correctly placed within their respective groups. The second was to determine ADHD symptom severity within the three groups and to code the data so that analyses could be conducted, when warranted, examining the impact of symptom (inattention, hyperactivity-impulsivity and oppositionality) severity on dependent variable performance.

Eighty-three out of the total of eighty-seven study participant parents rated their child's behavior using the SNAP-ODD. In four of the clinical cases the SNAP-ODD parental rating scale was unavailable from the archival file. The SNAP-ODD is a 26-item diagnostic checklist based on DSM-IV ADHD and ODD (Oppositional Defiant Disorder) symptoms and was one of the instruments used by the ANC in the determination of an ADHD diagnosis. Difficulties with inattention are suspected when at least 6 of the 9 inattentive behaviors are checked as being present and difficulties with hyperactivity-impulsivity are suspected when at least 6 of the 9 hyperactive-impulsive behaviors are present. Although using only the presence or absence of the behavior is consistent with

DSM-IV diagnostic guidelines, this method does not provide useful information regarding severity of the rated behavior.

To obtain a measurement of behavioral severity for each of the three SNAP-ODD dimensions (hyperactive-impulsive, inattentive, and oppositional behavior) for the sample and to code the data so that further analyses could be conducted, parental ratings of the SNAP-ODD items were generated using the following 4-point scale (0= not at all; 1= just a little; 2= pretty much; and 3= very much). Appendix D contains a copy of the SNAP-ODD instrument. The SNAP-ODD inattentive and hyperactive impulsive items have a possible score range of 0-27 and oppositional defiant items have a possible score range of 0-24.

A multivariate analysis of variance (MANOVA) was performed with the independent variable being group (children with ADHD-C; ADHD-I and control subjects). The three dependent variables were total score on each of the SNAP-ODD symptom clusters (hyperactive-impulsive, inattentiveness and oppositional). The overall multivariate test was statistically significant [Wilks' lambda = .207, $F = (6, 156) = 31.11$, $p < .01$].

Three univariate tests revealed significant group differences on all dependent variables. See Table 4.4 for the means, standard deviations and univariate analysis of variance results. Comparison of the mean inattentiveness symptom cluster rating score across the three groups revealed significant mean difference, $F(2,80) = 77.17$, $p = <.01$ with a large effect size of .66. The determination of the effect size magnitude is based on the Grimm & Yarnold (1995) effect size metric where the eta-square values (.01-.08) are considered small; (.09-.24) are medium and ($\geq .25$) are large. Pairwise comparisons using the Bonferroni adjustment for multiple comparisons indicated that the children in the ADHD-C group were rated as significantly more inattentive by their parents then were children in the control group. Children in the ADHD-I group were also rated as significantly more inattentive by their parents than were children in the control group. Comparison within the two clinical groups found that children in the ADHD-C group were rated as more inattentive by their parents than were children in the ADHD-I group.

Table 4.4

Means, Standard Deviations, and Univariate Analysis of Variance Results with Bonferroni adjustment for multiple comparisons for SNAP-ODD Symptom Clusters

	Group							
Symptom Cluster	ADHD-C N=26		ADHD-I N=26		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
Inattentiveness	20.23[a]	5.21	15.27[a]	5.30	4.96[a]	3.78	77.17*	0.66
Hyperactive-Impulsive	14.29[a]	5.61	4.92[ab]	4.04	2.29[ab]	1.90	65.61*	0.62
Oppositional	10.23[a]	6.16	5.53[a]	5.81	2.61[a]	2.87	16.18*	0.28

Note: MANOVA: η= .207, F = (6, 156) =31.11, p<.01. *= p<.01.
Means with different superscripts, differ significantly ([a]= p<.01; [b]= p <.05).

Hyperactive-impulsive symptom cluster ratings also differed significantly across the three groups, F(2,80) = 65.61, p = <.01 with a large effect size of 0.62. Pairwise comparisons revealed that the ADHD-C group displayed a significant difference in their mean parental hyperactive impulsive rating score (M = 14.29, SD = 5.61, p<.01) from the children in the control group (M=2.29, SD=1.90, p<.01) and from the children in ADHD-I group (M=4.92, SD=4.04, p<.01). This finding is expected given that the diagnostic criteria of ADHD-C require the presence of hyperactive-impulsive behaviors. Children in the ADHD-I group also displayed a significant difference in their mean hyperactive impulsive score (M=4.92, SD=4.04, p<.05) compared with the control group (M=2.29, SD=1.90, p<.05) that suggested the presence of sub-clinical hyperactive-impulsive symptoms.

Comparison of mean ratings across groups on the oppositional defiant symptom cluster was also significant, $F(2,80) = 16.17$, $p = <.01$ with a large effect size of .28. Pairwise comparison of means indicated that children in the ADHD-C group were rated by their parents as displaying significantly more oppositional behaviors (M = 10.23, SD = 6.16, p<.01) when compared with the parental ratings of children in the control group (M=2.61, SD=2.87, p<.01) and with the children in ADHD-I group (M=5.53, SD=5.81, p<.01). Parental ratings of children in the ADHD-I group did not differ significantly from parental ratings of control children.

Seventy-two parents out of the total of eighty-seven study participant parents rated their child's behavior using the Child Behavior Checklist (CBCL; Achenbach, 1991). In five of the clinical cases, the CBCL was unavailable from the archival file. The CBCL is a behavior rating scale that provides information grouped into eight problem domains and was one of the instruments used by the ANC to gather a profile of the child's emotional and behavioral functioning. Raw score totals were summed and were converted to T-scores. Table 4.5 presents the mean T-score rating of relevant CBCL problem domain by group. Inspection of table reveals ratings on the Attention problem domain were within the clinically elevated range (T-Score of 70 or greater) for the ADHD-C group and within the Borderline clinical range (T-Score between 65-69) for the ADHD-I group. As noted in Table 4.5, parents of the children with ADHD-C also reported sub-clinical difficulties with defiance and aggression on this instrument. This finding is consistent with the SNAP-ODD oppositional defiant symptom ratings.

Additionally parents of both the ADHD-C and ADHD-I reported somewhat elevated (although again sub-clinical) difficulties with anxiety.

Table 4.5
Mean T-score parental rating on the CBCL relevant symptom by group

	Symptom Cluster							
Group	Anxiety		Attention		Defiant		Aggressive	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
ADHD-C	61.00	8.26	72.77	9.21	63.00	7.60	63.68	8.62
ADHD-I	61.63	6.80	65.58	9.53	54.95	5.72	54.52	4.49
Control	51.48	3.21	52.19	3.80	54.12	5.19	53.36	4.30

In summary, these analyses confirmed that the ADHD and control participants are placed correctly within their respective diagnostic groups. The results also suggest that, on average, the group of children diagnosed with ADHD-C were demonstrating more severe difficulties with inattention, hyperactivity-impulsivity and oppositionality than were the children diagnosed with ADHD-I. Additionally both clinical groups were rated as having moderate problems with anxiety.

STUDY HYPOTHESES

Hypothesis 1 asserted that children with ADHD-C would perform significantly worse than ADHD-I children and controls on two verbal working memory tasks. No performance differences were predicted between ADHD-I and normal controls. Before hypothesis 1 could be examined, it was necessary to transform the dependent variables of WISC-III Digit Span backwards and the WISC-III Arithmetic subtest to a comparable score metric. Although the typical method of standard score generation for the WISC-III Digit Span subtest, combines the digits forward and digits backwards sections into a single standard score, to test hypotheses 1, performance on digits backwards and digits forward needed to be examined individually. This procedure was done because the two Digit Span sections were hypothesized to measure two differing elements of memory as discussed in the literature review. Digit Span backwards was hypothesized to provide a measurement of verbal working memory and Digit Span forward a measurement of verbal memory span.

Performance on Digit Span backwards was calculated by finding the longest correct digit span (0-9 digits) completed by each child. The score was then converted to a *z* score by using the mean and standard deviations by age group provided in the WISC-III supplemental table B. 6 entitled "Cumulative percentages of longest digit span forward and backward by age group" p. 267. The conversion to the *z*-score metric allowed for direct comparisons between the two measures (Digit Span backward and Arithmetic) and controls for the impact of developmental differences due to age on the score values. The raw scores from the Arithmetic subtest were also transformed into standard scores (*M* =100; *SD* =15) and then to allow a direct comparison of performance with the Digit Span backward *z*-score information, the WISC-III Arithmetic standard scores were also converted to a *z*-score metric. A final conversion to a T-score metric (*M*= 50, SD =10) was done to remove the negative values (scores below average) from the data and did not change the shape of the original distribution.

To test hypothesis 1, a multivariate analysis of variance (MANOVA) was conducted. The independent variables were the three groups (ADHD-C, ADHD-I and control) and the dependent variables were Digit Span Backward and Arithmetic scores. No statistically significant overall main effect was found among the groups on the two dependent variables (η =.951, F (4,166) = 1.06, p=0.37. Likewise, univariate analyses found no significant differences in group performance on these two measures. Table 4.6 presents the means, standard deviations and results of the univariate analysis of variance for the two dependent measures. Thus the hypothesis that children with ADHD-C would perform significantly worse than children with ADHD-I and control participants on two working memory tasks was not confirmed and the prediction that there would be no difference in performance between children with ADHD-I and control participants on these tasks was confirmed.

Table 4.6
Means, Standard Deviations, and Univariate Analysis of Variance Results with Bonferroni adjustment for multiple comparisons for Hypothesis 1(Verbal Working Memory Measures)

	Group							
Verbal WM Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
DS Backwards	48.37	10.74	52.51	9.89	51.73	9.08	1.36	0.03
Arithmetic	52.95	10.26	52.56	11.03	55.27	8.16	0.67	0.02

Note: Repeated Measures MANOVA: η= .951, F = (4, 166) =1.06, p=.37.
Verbal WM Measures = Verbal Working Memory Measures
DS Backwards= Digit Span Backwards
M= Means are based on a T-Score metric (M= 50; SD =10).

Hypothesis 2 predicted that no difference in short-term verbal memory performance on two verbal span tasks across the three groups would be obtained. This hypothesis was examined using verbal span performance on the WISC-III Digit Span Forward and the CVLT-C List A-Trial One. Again it was necessary to transform scores into comparable metrics. Raw scores from the CVLT-C list A Trial 1 were transformed into standard scores (Mean =0; SD =1) to reduce the impact of developmental age on the score values. The Digit Span forward score was calculated by finding the longest correct digit span (0-9 digits) completed by each child. This score was then translated into a standard z-score by using the mean and standard deviations by age group provided in the WISC-III supplemental table (B.6) entitled "Cumulative percentages of longest digit span forward and backward by age group" p.267. A final conversion to a T-score metric (mean= 50, SD =10) for both dependent variables was done to remove the negative values (scores below average) from the data and did not change the shape of the original distribution.

A MANOVA with group as the independent variable and mean CVLT-C trial 1 and digit span forward T-scores as the dependent variables was conducted. As expected, no overall significant difference was found [η= .945, F = (4, 166) =1.91, p=.32]. Univariate analysis also revealed no significant differences across the groups on the two measures. Table 4.7 presents the means, standard deviations and results of the univariate analysis for Digit Span Forward and CVLT-C Trial One.

Table 4.7
Means, Standard Deviations, and Univariate Analysis of Variance Results with Bonferroni adjustment for multiple comparisons for Hypothesis 2(Supra Span Measures)

	Group							
Supra Span Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
DS Forward	48.67	9.54	51.20	9.90	53.25	8.27	1.74	0.02
CVLT-C Trial One	55.19	10.03	52.00	9.15	54.03	10.83	0.73	0.04

Note: Repeated Measures MANOVA: [η= .945, F = (4, 166) =1.91, p=.32.]
DS Forwards= Digit Span Forward
M= Means are based on a T-Score metric (M= 50; SD =10).

To evaluate if group differences were present using the combination of the Digit Span standard score (combination of both digits forward and backwards) and the Arithmetic standard score as dependent variables, a MANOVA was conducted. While the overall multivariate F was non-significant (η =.928, F (4,166) = 1.57, p=.19), a trend towards significant difference was obtained on the Digit Span variable [F (2,84) = 3.03, p = .053] but post hoc comparisons, with Bonferroni correction for multiple comparisons detected no significant differences. See Table 4.8. Thus, Hypothesis 2 was confirmed.

Table 4.8
Means, Standard Deviations, and Univariate Analysis of Variance Results with Bonferroni adjustment for multiple comparisons for Digit Span and Arithmetic

	Group							
WISC-III Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
Digit Span	9.88	2.29	10.50	2.86	11.58	2.71	3.03*	0.07
Arithmetic	10.88	3.08	10.77	3.31	11.58	2.45	0.67	0.02

Note: Repeated Measures MANOVA: (η = .928, F (4,166) = 1.57, p=.18). * p =.053
M= Means are based on a scaled score metric (M= 10; SD =3).

Hypothesis 3 predicted that children with ADHD-C would evidence difficulties relative to ADHD-I and controls on a task that required sustained cognitive effort and verbal organization. No performance differences were predicted between ADHD-I and normal controls. Cognitive effort and organization was measured using the CVLT-C semantic cluster index and the CVLT-C recall consistency score. A repeated measures MANOVA was conducted with no significant differences found among the groups on the two dependent variables (η =.982, F (4,166) = 3.83, p=.82). Thus hypothesis 3 was not confirmed. Table 4.9 presents the means, standard deviations and results of the univariate analysis for CVLT-C semantic cluster index and the recall consistency score.

Table 4.9
Means, Standard Deviations, and Univariate Analysis of Variance Results with for Hypothesis 3 (CVLT-C task)

	Group							
CVLT-C Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
Semantic cluster score	0.77	1.05	0.05	0.88	-0.06	1.15	0.13	0.01
Recall Consistency	0.23	0.53	0.12	0.67	0.27	0.63	0.53	0.01

Note: Repeated Measures MANOVA: (η =.982, F (4,166) = 3.83, p=.82).
M= Means are based on a Z-score metric (M= 0; SD =±1).

Hypothesis 4 asserted that the sustained visual attention (as measured by performance on a continuous performance task) of children diagnosed with ADHD-C and ADHD-I would differ significantly from normal control participants and from each other. The continuous performance variables examined include the hit-rate (number of correct responses) commission rate (number of false responses); omission rate (number of missed responses); d prime (a measure of perceptual sensitivity) and beta (a measure of risk taking). The study hypothesized the following performance patterns:

1. Children with ADHD-C will evidence significantly more errors of commission and significantly fewer hits than normal controls and children with ADHD-I due to inhibition problems. They will also be significantly less attentive and engage in more response-risk-taking than children in the ADHD-I and control groups.
2. Children with ADHD-I will evidence significantly more errors of omission than will children with ADHD-C and normal controls.

Because a number of studies (Conners, Epstein, Angold & Klaric, 2003; Corkum & Siegel, 1993) have found an age effect to be present on CPT measures, all MANOVA's used to test hypothesis four included an age covariate. However, in the first MANOVA that compared the hit rate and commission error rate performances across the three groups, age was not significant and a covariate was not employed. This comparison detected an overall significant difference [η =.885, F (4,166) = 2.62, p= .04) with significance found with the univariate ANOVA difference in hit-rate performance [F (2,84) = 3.93, p =.02]. Specifically, the hit rate performance of children with ADHD-C and ADHD-I was poorer than control children (p= .055 for both clinical groups compared with controls). Differences in hit rate performance between the two clinical groups were not significant. The three groups did not differ in the number of commission errors obtained. See Table 4.10.

Table 4.10

Means, Standard Deviations, and Univariate Analysis of Variance Results for Hypothesis 4 (CPT Hit rate and Commission errors)

	Group							
CPT Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
Hit rate	38.92	14.06	39.31	18.67	49.03	14.00	3.93*	0.36
Commissions	47.25	10.55	50.57	12.22	51.85	10.08	1.29	0.17

Note: Repeated Measures MANOVA: [η =.885, F (4,166) = 2.62, p=.04 . * p =.02.
M= Means are based on a T-score metric (M= 50; SD =10).

The second MANCOVA compared the hit rate and omission error rate performances across the three groups with age as a covariate. This comparison detected an overall significant difference [η =.827, F (4,164) = 4.08, p =.00]. Results of a univariate ANOVA found a significant difference in hit-rate performance [F (2,83) = 4.60, p =.013] with the hit rate performance of children with ADHD-C and ADHD-I significantly poorer than control children (p= .03 for both clinical groups compared with controls). Univariate ANOVA results for number of omission errors was significant [F (2,83) = 3.51, p =.03] with the children with ADHD-I making significantly more errors than control participants. No significant difference in omission error rate performance was obtained between the two clinical groups (p=.80). See Table 4.11.

Table 4.11
Means, Standard Deviations, and Univariate Analysis of Variance Results for Hypothesis 4 (CPT Hit rate and Omission Errors) continued

	Group							
CPT Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
Hit rate	38.92[a]	14.06	39.31[a]	18.67	49.03[a]	14.00	4.60*	0.11
Omissions	58.69	11.66	61.20[b]	08.86	53.98[b]	09.11	3.51*	0.27

Note: Repeated Measures MANCOVA: [η =.827, F (4,164) = 4.08, $p \leq .01$] * $p \leq .05$.
[a] = $p<.05$; [b] =$p<.05$
M= Means are based on a T-score metric (M= 50; SD =10).

The third repeated measures MANCOVA compared the perceptual sensitivity and risk-taking performances across the three groups with age as a covariate. This comparison also detected an overall significant difference [η =.889, F (4,164) = 2.48, p =.05]. Results of a univariate ANOVA found a significant difference in risk-taking performance [F (2,83) = 3.05, p =.05] with the ADHD-I group evidencing significantly more conservative risk-taking than the control participants (p= .03) while comparison of performance with the ADHD-C group was non-significant. Univariate ANOVA results examining perceptual sensitivity across groups was not significant [F (2,83) = .72, p =.43]. See Table 4.12.

Table 4.12
Means, Standard Deviations, and Univariate Analysis of Variance Results for Hypothesis 4 (CPT d' and beta variables)

	Group							
CPT Signal Detection Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
d'- perceptual sensitivity	54.15	13.22	57.70	12.07	54.05	09.87	0.72	0.36
Beta Risk-taking	68.05	23.52	70.67[a]	19.47	56.92[a]	17.17	3.05*	0.17

Note: Repeated Measures MANCOVA: [η =.889, F (4,164) = 2.48, p=.05 . * p =.05.
[a] = p= .03.
M= Means are based on a T-score metric (M= 50; SD =10).

In summary, the hypothesis that children with ADHD-C would evidence significantly more errors of commission than children with ADHD-I and controls was not confirmed as no significant differences between the groups was obtained. Also the performance of children with ADHD-C did not differ significantly from controls and children with ADHD-I on the risk-taking and perceptual sensitivity indices. Although children with ADHD-C did have significantly fewer correct hits when compared with controls, their performance did not differ significantly from children with ADHD-I. The hypothesis that children with ADHD-I would evidence significantly more errors of omission than controls was confirmed though the assertion that children with ADHD-I would evidence more errors of omission than children with ADHD-C was not confirmed. Additionally counter to predictions, children with ADHD-I had significantly fewer correct hits and evidenced a conservative risk-taking response pattern significantly more often than did controls.

Hypothesis 5 predicted that children with ADHD-I would evidence significantly slower visual processing speed performance when compared with the children in the control and ADHD-C groups. This hypothesis was examined using performance on the WISC-III Coding and Symbol Search subtests. All raw scores were transformed to standard scores and the mean standard score was the metric used for comparison in the MANOVA (independent variable was group and the dependent variables were performance on Coding and Symbol Search). The overall multivariate F was significant [η =.839, $F(4,166) = 3.80$, $p=.01$] and an examination of the univariate analyses found that coding performance differed significantly across the three groups ($F(2,84) = 5.50$, $p=.01$) while symbol search performance did not ($F(2,84) = .82$, $p=.44$). Pairwise comparison of means found that the ADHD-C and ADHD-I groups performed significantly more poorly on these tasks than did the normal control participants (ADHD-C and control $p= .014$ and ADHD-I and control $p= .003$). The ADHD-I group did not perform significantly poorer on these tasks when compared with the ADHD-C children ($p= .63$). Table 4.13 presents the means, standard deviations and univariate analysis results.

Table 4.13

Means, Standard Deviations, and Univariate Analysis of Variance Results for Hypothesis 5 (Processing Speed Tasks)

Processing Speed Measures	ADHD-C N=26		ADHD-I N=30		Control N=31		F	η^2
	M	SD	M	SD	M	SD		
Coding	09.50[a]	2.83	09.17[b]	2.34	11.12[ab]	2.45	5.50*	0.12
Symbol Search	12.23	3.48	11.17	3.62	11.29	2.95	0.82	0.02

Note: Repeated Measures MANOVA: (η =.839, F (4,166) = 3.80, p=.01). * p=.01
Means with different superscripts, differ significantly ([a]= p<.05; [b]= p <.01).
M= Means are based on a standrd score metric (M= 10; SD =3).

Three subsequent MANOVA's were run to determine if symptom severity could account for Coding and Symbol Search performance differences across the three groups. Repeated measures MANOVA comparisons using hyperactive-impulsive symptom severity [η =0.936, F (4,158) = 1.33, p =0.26] and oppositional symptom severity [η = 0.980, F (4,158) = 0.39, p =0.81] as independent variables were non-significant. However, a repeated measures MANOVA using inattentive symptom severity as the independent variable found a multivariate trend towards significance [η =0.900, F (4,158) = 2.13, p =0.07] on these measures. Examination of the univariate analyses found that coding performance differed significantly across the three groups [F (2,80) = 4.08, p =.02] while symbol search performance did not [F (2,80) = .04, p =0.96]. Coding performance of the children evidencing severe inattentive problems was significantly poorer than those children with mild inattention problems. See Table 4.14 for results. Additionally, a correlation analysis comparing coding score and level of inattentive symptoms was statistically significant (-.34, p=.001) finding that poor Coding performance was associated with elevated levels of inattention.

In summary, the coding performance of both clinical groups differed significantly from control participants but not differently from each other. An additional analysis found that children whose parents reported severe inattentive problems on the SNAP-ODD performed significantly more poorly on the coding task. No differences in performance across the three groups were found on the Symbol Search task. Thus Hypothesis 5 was partially confirmed.

Table 4.14
Means, Standard Deviations, and Univariate Analysis of Variance Results for the Processing Speed Tasks based on Inattentive Symptom Severity

	Degree of Inattention							
Processing Speed Measures	Mild N=32		Moderate N=25		Severe N=26		F	η^2
	M	SD	M	SD	M	SD		
Coding	11.03[a]	2.72	9.40	2.35	9.31[a]	2.71	4.08*	0.09
Symbol Search	11.69	3.40	11.44	3.08	11.62	3.51	0.04	0.01

Note: Repeated Measures MANOVA: (η = .900, F (4,158) = 2.13, p =.07, *p=.02).
[a] =p=.04.
M= Means are based on a standard score metric (M= 10; SD =3).

CHAPTER 5

DISCUSSION

The purpose of the present study was to investigate whether there were unique cognitive and memory patterns that could be attributed to specific ADHD subtypes (ADHD-C and ADHD-I) or, when using a non-clinic control comparison group, could be attributed to ADHD regardless of subtype. The five areas of neurocognitive functioning investigated included verbal working memory, verbal short-term memory, verbal organization and effort; sustained visual attention; and visual processing speed. Discussion of results from each of the five areas of neurocognitive functioning is interpreted the within the context of Barkley's behavioral inhibition model of ADHD (Barkley, 1998) and Mirsky's model of attention (1996). Results are also discussed the results in terms of diagnostic utility of DSM-IV ADHD subtypes.

HYPOTHESIS 1: VERBAL WORKING MEMORY

The hypothesis that children with ADHD-C would perform significantly worse than ADHD-I children and controls was examined using the WISC-III Arithmetic subtest and the Digits Backward portion of the Digit Span subtest. No significant differences in performance were found on these measures among the three groups. This finding is inconsistent with Barkley's model of behavioral inhibition that defines verbal working memory impairment as one of the key deficit areas for children with ADHD-C. No specific ADHD subtype predictions in attentional impairment were made using Mirsky's model, though the Mirsky "encode" construct is roughly the theoretical equivalent of verbal working memory in Barkley's model of behavioral inhibition and Mirsky has employed the Wechsler subtests of Digit Span and Arithmetic to provide a measurement of the encode construct.

Previous research utilizing the Digit Span and Arithmetic subtests of the WISC-III have found differences in performance between children with ADHD and control participants (Anastopoulou s, Spisto, & Maher, 1994; Mayes, Calhoun, & Crowell, 1998a; Prifitera & Dersh, 1993; Schwean, Saklofske, Yackulic, & Quinn, 1993). However these studies did not control for co-occurring learning disabilities in the clinical groups so differential group performance cannot be attributed solely to the presence of ADHD. Because none of children in the two ADHD groups in the current study met criteria for a co-morbid learning disability diagnosis, the finding of roughly equal performance among the three groups on the Digit Span and Arithmetic tasks strengthens the interpretation that previous research findings of differential performance were due to the influence of learning difficulties. These results are also consistent with the Riccio et al. (1997) finding of no significant differences between ADHD subtypes on these subtests and support the conclusion that poor performance on Digit Span and Arithmetic is associated with a learning disability (Krane & Tannock; 2001; Reinecke, Beebe & Stein; 1999).

It is also important however to examine the degree to which these two subtests provide measurement of verbal working memory. The WISC-III Arithmetic subtest does not provide a unidimensional measurement of verbal working memory, as successful performance on this subtest requires, knowledge of mathematical operations, in addition to the working memory task demand, and is facilitated by the automatic retrieval of math facts. Thus in the current study where none of the children with ADHD had identified difficulties with mathematics, the absence of differences between the ADHD groups and control participants is not surprising.

Reynolds (1997) has advocated the separation of forward and backward memory span tasks with generation of separate scaled scores. He bases his argument on a series of factor analyses conducted with the standardization sample of the Test of Memory and Learning (TOMAL; Reynolds & Bigler, 1994) that found that Letters Forward (similar to the WISC-III Digit Span Forward task) and Digits Backward and Letter Backward (tasks similar to WISC-III Digit Span Backwards) strongly loaded on two distinct factors. This study, working within the confines of the methodology possible with the WISC-III, separated the two Digit Span elements and found no differential performance among ADHD groups or across the three groups on the Digits Backwards.

However, rather than conclude that the absence of difference between groups suggests intact verbal working memory functioning for children with ADHD, a second explanation for these results must be entertained; possibly the Digit Span Backwards task did not provide a sufficient (reliable and valid) measurement of verbal working memory functioning. Pickering and Gathercole (2001) provide support for this possibility. They assert that the use of Digit Span forward and backwards tasks as sole measures of working memory are problematic for two reasons. The first is that using digit names that have highly familiar (over learned) forms reduces sensitivity to phonological storage capacity differences (Gathercole, Willis, Baddeley, & Emslie, 1994). The second reason is that the usage of a single task to measure working memory constructs (forward recall of digits taps the phonological loop; digits backward involves the phonological loop and central executive) increases measurement error and reduces the probability of detecting differences in performance. In their Working Memory Test Battery for Children (Pickering & Gathercole; 2001) they include three tasks [Backward Digit Recall, Listening Recall-evaluating short sentences) and Counting Recall (counting dots across multiple sheets) designed to measure interaction between the phonological loop and central executive working memory systems. While they provide norm-based information (British norms), there are no published studies to date evaluating the performance of children with ADHD using this set of theory-based working memory measures. An analysis to examine whether there were significant differences using the combined Digit Span score revealed a trend towards significance with the ADHD-C group having somewhat lower mean Digit Span scores compared with controls. However, when controlling for multiple comparisons this trend turned into non-significance.

HYPOTHESIS 2: SHORT-TERM VERBAL MEMORY

Hypothesis 2 predicted that no difference in short-term verbal memory performance on two verbal span tasks (WISC-III Digit Span Forward and the CVLT-C List A-Trial One) across the three groups would be obtained. Results confirmed this prediction. These results are logically consistent with Barkley's behavioral inhibition model that predicts deficits in working memory tasks as opposed to verbal span tasks. Mirsky's attentional model uses the combined Digit Span subtest to assess working memory functioning and makes no predictions regarding differential performance on two subparts. The current study results are also consistent with previous research findings that children with ADHD and ADD+H do not have deficits with short-term verbal memory as measured by their performance on memory span tasks (Denckla, 1996; Fischer, et al., 1990; Pennington & Ozonoff, 1996; Plomin & Foch, 1981) or as measured by their initial performance on a list learning task (O'Donnell & Couvadelli, 1995).

Regarding the use of Digit Span forward, Pickering and Gathercole (2001) include this task as part of a group of four measures assessing functioning of the phonological loop portion of the Baddeley's working memory model. Studies examining developmental dyslexia in children have found evidence of working memory deficits along with phonological core deficits (problems with understanding the phonological word form and efficiency of phonological decoding) [Berninger, Abbott, Thomson, Wagner, Swanson, & Raskind, (submitted); Swanson and Siegel (2001]. Thus poor performance on Digit Span Forward due to problems with phonological loop working memory could partially explain the impaired Digit Span performance obtained by ADHD samples co-morbid for learning disability (dyslexic) samples (Anastopoulous, Spisto, & Maher, 1994; (Krane & Tannock; 2001; Mayes, Calhoun, & Crowell, 1998a; Prifitera & Dersh, 1993; Reinecke, Beebe & Stein; 1999).

HYPOTHESIS 3: VERBAL ORGANIZATION AND EFFORT

Hypothesis 3 predicted that children with ADHD-C would evidence difficulties relative to ADHD-I and controls on a learning task that required sustained cognitive effort and verbal organization. The CVLT-C semantic cluster index and recall consistency scores were used as dependent measures. Barkley's behavioral inhibition deficit model of ADHD predicts executive functioning problems for children with ADHD-C. It has been proposed that the use of the CVLT-C process indices (semantic clustering strategies among others) reflect both executive function and working memory processes (Denckla, 1996; Cutting, Koth, Mahone, & Denckla, 2003). In this study, no significant differences were found among the groups on the two dependent variables. The absence of differences across the three groups suggests that children with ADHD are able to semantically encode and recall the same words consistently across trials as well as peers. This unexpected result is consistent with the Cutting et al. study that found that the ADHD group (Mixed subtypes; N= 18) did not differ significantly from controls (N =20) on their semantic clustering strategy usage. However, they did find that girls regardless of group employed semantic clustering strategies more frequently than did boys; a finding consistent with the Kramer, Delis, Kaplan, O'Donnell, & Prifitera (1997) study that examined among other variables, strategy use in the CVLT-C normative sample. Although gender comparisons within the three groups on semantic clustering strategy usage was not possible, (limited sample size of the female ADHD-C group), a univariate ANOVA (gender by semantic clustering score) run on this sample was non-significant [F (1,86) =.92, p=.34].

The negative findings of this study coupled with those of Cutting, et al. (2003) can be interpreted a number of ways. The first requires an assumption that the CVLT-C process identified measures provide adequate measurement of executive functioning, in order to conclude that no differences in executive functioning exist among ADHD subtypes and across ADHD clinical and control groups. However, this assumption cannot be fully endorsed, as the Beebe, Ris, & Dietrich (2000) results raise questions regarding the construct validity of the CVLT-C process variables as an executive function measure. Beebe, et. al (2000) predicted that better performance on the CVLT-C process measures would be related to better performance on two executive functioning measures and found that only the process measures of consistency of word recall and serial cluster strategy use were associated with better problem solving/mental flexibility performance on the Wisconsin Card Sort Test (WCST). That is, the consistency of recalling the same subset of words across the five trials (consistency of word recall) and recalling the word in the same order as it was given by the examiner (serial cluster strategy) was associated with better problem solving and mental flexibility as measured by the WCST. However, because the participants in the Beebe et al. (2000) study were non-diagnosed adolescent participants in a longitudinal study, these results must be interpreted with caution when applied to children with ADHD. Future research using multiple measures of executive functioning should evaluate the construct validity of the CVLT-C in a study that evaluates functioning of both non-referred and clinical populations (ADHD included).

The second interpretation of these findings is that the CVLT-C variables (semantic clustering and recall consistency) employed in this study were not the most appropriate ones to employ when examining memory or learning patterns in children with ADHD. This interpretation is consistent with the Cutting, et al. (2003) finding that children with ADHD (no subtyping noted) recalled fewer words after a short delay than did control participants. However, this is interpretation is not couched in terms of executive functioning difficulties but rather as evidence of learning inefficiencies.

HYPOTHESIS 4: SUSTAINED VISUAL ATTENTION

Hypothesis 4 predicted that children with ADHD-C would evidence difficulties relative to ADHD-I and controls on a computer task that required sustained visual attention using the CPT variables of commission errors (false alarms) and correct responses. This prediction was made in order to test the link between impulsive responding and diagnostic category. Barkley's behavioral inhibition/executive function deficit model of ADHD predicts impulsive responding problems for children with ADHD-C while Mirsky's attentional model does not differentiate among subtypes, though Mirsky et al (1999) does report that children with ADHD made more errors of commission than controls. In this study there were no significant differences between the groups on the number of commission errors and this finding does not support Barkley's nor Mirsky's predictions of erroneous responding. Corkum and Siegel (1993) have identified a potential confound of examiner presence during testing. That is, examiner presence can improve the performance of ADHD children. In this study, the examiner was not present during the CPT testing for control participants but because the records of archival ADHD participants were used, it was not possible to verify that all subjects took the CPT without examiner presence. Consequently, the magnitude of differences in commission errors could have been reduced.

Hypothesis 4 also predicted that children with ADHD-I would evidence difficulties relative to ADHD-C and controls using the CPT variables of omission (missed responses). This prediction was made in order to test the link between missed responses and diagnostic category. Barkley's behavioral inhibition/executive function deficit model of ADHD does not predict problems for children with ADHD-C. In this study, after controlling age differences, children who were diagnosed with ADHD-I missed significantly more targets than children diagnosed with ADHD-C and control participants. To examine whether severity of inattention could account for these significant results, a univariate ANOVA was conducted. The results [F (2,82) = 1.95, p =.15] however did not support a conclusion that symptom severity was associated with missed CPT targets. Carlson and Mann (2002), identify a sub-group of children within the diagnostic category of ADHD-I who are characterized as having a set of behaviors (slow retrieval and information processing, sluggishness, drowsiness and constant daydreaming) consistent with sluggish cognitive temp (SCT). They have suggested that the SCT symptoms represent a set of unique inattentive behaviors; different from those found in inattention symptoms common to both ADHD-C and ADHD-I groups. The possibility that children with SCT were present in this sample and given their hypothesized slower rate of responding, contributed to the significant omission differences cannot be ruled out. There was also a significant difference between the groups on the risk-taking variable (children with ADHD-I compared with controls) and severe inattentive symptoms, (independent of group placement) were associated with significantly higher rates of conservative risk-taking [F (3,82) = 4.26, p <.05] suggesting that degree of inattention rather than placement in an ADHD group was more predictive of risk-taking.

HYPOTHESIS 5: VISUAL PROCESSING SPEED

Hypothesis 5 predicted that children with ADHD-I would evidence significantly slower visual processing speed performance as measured by performance on the WISC-III Coding and Symbol Search subtests when compared with the children in the control and ADHD-C groups. According to Mirsky and colleagues (Mirsky, 1996; Mirsky, Pascualvaca, Duncan, & French, 1999), the "focus-execute" aspect of attention is defined as the capacity to focus or select some aspect of the environment while screening out irrelevant stimuli. Functionally, it also has an element of motor speed, as the tasks measuring this construct require a response under timed conditions. The finding in this study that children with ADHD regardless of subtest performed significantly worse on the coding subtest than did control participants is consistent with the Mirsky, et. al (1999) and Pennington and Ozonoff (1996) results. The finding that the ADHD-I group did not perform significantly more poorly on the Coding task when compared with the ADHD-C children could be explained by the finding that a high degree of inattentive behaviors is significantly associated with worse Coding performance. That is the presence or absence of inattentive behaviors better explains Coding performance than does ADHD subtype.

DISCUSSION SUMMARY

This study did not find verbal working deficits in the ADHD-C group as predicted by Barkley (1998) using the WISC-III Arithmetic and Digit Span backwards portion of Digit Span as a working memory task. No differences across the three groups were found using the WISC-III Arithmetic and entire Digit Span subtest. Additionally, the usage of Digit Span Backwards as a measure of verbal working memory was not supported. As predicted, no differences in short-term verbal memory were found, suggesting that children with ADHD regardless of subtype do not have difficulties with encoding verbally presented material. Children with ADHD-C and ADHD-I did not evidence difficulties relative to controls on a learning task that required sustained cognitive effort and verbal organization skills. Further research is required to evaluate the construct validity of the CVLT-C as a measure of executive function and utility of the instrument with children with ADHD.

Using the CCPT as a measure of sustained visual attention, the two clinical groups differed from the normal control participants on a number of indices but not in the same manner. The performance pattern of children with ADHD-C was not consistent with Barkley's behavioral inhibition/executive function deficit model of ADHD that predicts impulsive responding problems for children with ADHD-C. With the exception of significantly fewer correct hits than controls, the performance of ADHD-C children did not differ from controls. Children with ADHD-I evidenced significantly more errors of omission and had significantly fewer correct hits compared with controls but did not differ significantly from children with ADHD-C in the number of correct target hits made. They also evidenced a significantly elevated conservative risk-taking response pattern compared to control participants.

An additional analyses also found that severe inattentive symptoms, (independent of group placement) was associated with significantly higher conservative rates of risk-taking suggesting that degree of inattention rather than placement in an ADHD group was more predictive of risk-taking response on the CCPT. The presence of severe inattention behaviors also appears to impact WISC-III Coding subtest performance. Children with ADHD regardless of subtype performed significantly worse on the coding subtest than control participants and the presence of severe inattentive behaviors was significantly associated with worse Coding performance.

SCHOOL PSYCHOLOGY IMPLICATIONS:

Verbal Working Memory: These results suggest that the WISC-III subtests have limited utility in assessing whether children diagnosed with ADHD have verbal working memory difficulties and should not be used in any differential subtype ADHD diagnosis process. In order to adequately evaluate verbal working memory functioning, school psychologists should employ multiple measures of verbal working memory and avoid multi-dimensional working memory tasks (WISC-III Arithmetic) that confound interpretation. Results also suggest that if WISC-III performance is significantly lower on these subtests, the possibility of learning difficulties needs to be investigated by examining academic achievement.

Verbal Short-Term Memory: The finding that children with ADHD on average do not have difficulty with encoding verbally presented information does not mean that all children with ADHD are able to do so. It is important to assess an individual child's performance on list learning measures. Additionally, if the child performs similar to age peers or performs well, instructional materials should be tailored to utilize this cognitive strength.

Verbal Organization and Effort: Although school psychologists may want to use the CVLT-C to obtain information regarding level of recall, error information and recognition performance, the use of the two learning indices (semantic cluster index and recall consistency) as a measure of executive functioning was not supported in this study. Measures specifically designed to evaluate executive functioning in children such as the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001) or the

NEPSY (Korkman, Kirk, & Kemp; 1997) could also be employed. In addition to assessment results, it is also important to gather behavioral data such as classroom behavior during structured and unstructured tasks to better understand how the child sustains cognitive effort in his or her daily classroom activities.

Sustained Visual Attention and Visual Processing Speed: A unique finding of this study was that severity of inattentive symptoms was significantly related to increased risk taking on the CCPT and poorer performance on the WISC-III Coding subtest. This finding suggests that when diagnosing ADHD using behavioral checklists such as the SNAP-ODD, it is important to consider symptom severity as well as the presence or absence of the behavioral symptoms. These findings also serve as potential “red flag” indicators for school psychologists, as slower than average processing speed has learning implications. For example, taking notes from information displayed on an overhead projector is similar to the task demands of the Coding subtest, though the classroom note taking activity has the added cognitive demand of language processing. Thus knowing level of inattention symptoms and Coding performance can assist with development of suitable intervention strategies.

STUDY LIMITATIONS

Study limitations are grouped into two areas: limitations relating to the independent variables (gender composition and diagnostic group) and limitations pertaining to the dependent variables (instrumentation). Given the relatively few females diagnosed with ADHD (n=17) compared with males diagnosed with ADHD (n=39), generalization of these results to females with ADHD is not recommended. Secondly, although the purpose of the study was to evaluate whether unique patterns of neurocognitive functioning were present in children only diagnosed with ADHD, this limited scope restricts application of these results to children with ADHD who have a co-morbid diagnosis of learning disability (LD) and who make up a substantial portion of the ADHD population. Subsequent studies need to include groups of children with ADHD only, ADHD and LD and LD only. Instrumentation limitations are related to difficulties with the assessment measures chosen to reflect functioning in the verbal working memory and verbal organization and effort areas. Because the construct validity of the CVLT-C as a measure of executive function and criterion validity with children with ADHD has not been established, extension of study results relating to the presence or absence of executive functioning deficits in children with ADHD or subtypes of ADHD cannot be made. Similarly, the verbal working memory measures chosen were problematic for two reasons: one measure (Arithmetic) did not provide a pure test of verbal working memory and the second measure may not have has enough discriminative power to detect differences. Therefore, the finding of no differences in verbal working memory performance across groups may reflect instrumentation error rather than reflect the true absence of differences.

FUTURE RESEARCH

It is suggested that future research employ multiple measures to assess the three areas of possible working memory dysfunction. That is, those areas related to phonological loop problems, those involving the visual spatial sketchpad and those tapping an interaction between the phonological loop and central executive. Future studies examining possible working memory difficulties in ADHD should also include a group of children with dyslexia. However, instead of relying on ability-achievement discrepancies as the criteria for whether one has dyslexia, all groups should be determined on the basis of meeting or not meeting specific research-validated inclusionary criteria for dyslexia (Berninger & O'Donnell; manuscript submitted for publication)

The current study also found that, contrary to prediction, semantic clustering strategy usage on the CVLT-C did not differ within and across the study groups. More research is needed using the learning strategy variables (including the semantic clustering and serial clustering) and level of recall variables to more adequately identify differential performance by the ADHD group of children. More research is also needed to provide construct validity evidence. Included in this validity research should be comparisons between non-clinical and clinical children (those with ADHD and learning disability) on multiple measures of executive function.

This study also found that on two measures requiring a combination of sustained visual attention (CPT-risk-taking) and visual processing speed (WISC-III Coding), severity of inattention problems (not ADHD diagnostic category) was associated with impaired performance. Finally, the finding that significantly elevated CPT omission errors in the ADHD-I group were not attributable to severity of inattentive ratings raises the question of what else, if not inattention could contribute to missing CPT targets? In order to begin to answer this question, future research should include behavioral ratings of sluggish cognitive tempo in their ADHD diagnostic criteria.

APPENDICES

APPENDIX A.

<u>DSM-IV Diagnostic Criteria for Attention Deficit Hyperactivity Disorder</u>

Attention Deficit Hyperactivity Disorder

A. Either 1 or 2:or both

1. Inattention: At least six of the following symptoms of inattention have persisted for at least six months to a degree that is maladaptive and inconsistent with developmental level.

Inattention

a. often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities
b. often has difficulty sustaining attention in tasks or play activities
c. often does not seem to listen when spoken to directly
d. often does not follow through on instructions and fails to finish schoolwork, chores or duties in the workplace (not due to oppositional behavior or failure to understand instructions
e. often has difficulty organizing tasks and activities
f. often avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)
g. often loses things necessary for tasks or activities (e.g., toys, school assignments, pencils, books or tools)
h. is often easily distracted by extraneous stimuli
i. is often forgetful in daily activities

2. Hyperactivity-Impulsivity: At least six of the following symptoms of hyperactivity-impulsivity have persisted for at least six months to a degree that is maladaptive and inconsistent with development.

Hyperactivity

a. often fidgets with hands or feet or squirms in seat
b. often leaves seat in classroom or in other situations in which remaining seated is expected
c. often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)
d. often has difficulty playing or engaging in leisure activities quietly
e. is often on the go or often acts as if driven by a motor
f. often talks excessively

DSM-IV Diagnostic Criteria for Attention Deficit Hyperactivity Disorder
(continued)

Impulsivity

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

B. Some hyper-active-impulsive or inattentive symptoms that caused impairment were present before age 7 years.
C. Some impairment from the symptoms is present in two or more settings (e.g., at school [or work] and at home).
D. There must be clear evidence of clinically significant impairment in social, academic, or occupational functioning
E. The symptoms do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia or other Psychotic Disorder, and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Disassociative Disorder or a Personality Disorder).

APPENDIX B

Subject Consent to Take Part in a Study of Cognitive and Memory Performance Patterns Associated with ADHD Subtypes

Conducted by Louise O'Donnell, Graduate Student at The University of Texas at Austin, Department of Educational Psychology in partial Fulfillment of the requirements for the Degree of Doctor of Philosophy

I am asking you to take part and to allow your child to take part in a research study that examines the thinking and memory skills of children and adolescents who have been diagnosed with Attention Deficit Hyperactivity Disorder (ADHD). I am examining how children and adolescents with ADHD organize and remember spoken information and how quickly and accurately they handle information that is shown visually. I am asking you and your child to take part in this study because he/she has not been diagnosed with ADHD. I would like your child to participate as "control subject." I expect to have 30 control participants in the study.

If you decide to allow your child to take part, you and your child will be asked to participate in a number of activities. You will be asked to complete a brief checklist concerning your child's behavior. You will also be asked to complete a 26-item checklist of attentional symptoms and will be asked to provide brief background information regarding your child's medical and educational history. Children between the ages of 11 and 18 will be asked to complete a brief checklist of their behavior. All children will be asked to remember words and numbers, provide word definitions, answer questions tapping understanding of everyday events and information, tell how two things could be alike, build some things with blocks, look at pictures to find what is missing in each one, solve arithmetic problems and copy designs. All children will also sit in front of a computer screen and be asked to press the spacebar when certain letters come on the screen and will be asked to not press the bar when a certain letter comes on the screen.

Everything we learn about you and your child will be confidential. His or her responses will not be linked to his or her name or your name in my written dissertation or linked in any verbal report of this study. Additionally, if I publish the results of this study in a scientific magazine or book, I will not identify you or your child in any way. Confidentiality however, does not extend to the reporting of physical or sexual abuse. If your child or adolescent reports physical or sexual abuse or reports an intention to harm self or others, I will disclose this information to the proper authorities. In such case, your child could not participate in the study until the authorities have completed the investigation.

Subject Consent to Take Part in a Study of Cognitive and Memory Performance Patterns Associated with ADHD Subtypes (continued)

There are no costs to you or your child for participating in the study. I will compensate your child $25.00 for their participation in the study. The completion of the behavioral rating scale and background information interview is expected to take between 30 minutes and 1 hour. The assessment portion of the study is expected to take a maximum of two hours. There is a slight risk related to being in the study. Some of the tasks may be tedious for your child and they may become frustrated with them. Your child is free to discontinue the study at any time. Additionally, your child is free to stop and take a break when needed.

Your decision whether to take part and to allow your child to take part in the study is voluntary. You are free to choose not to allow your child to take part in the study. If you chose not to allow your child to take part in the study, it will not affect your or his or her present or future relationship with The University of Texas at Austin. If you have questions about the study please ask me. If you have questions later, call me at 210-545-7163. If you have any questions or concerns about your child's participation in this study, call Professor Clarke Burnham, Chair of the University of Texas at Austin Institutional Review Board for Protection of Human Research Participants at 512-232-4383.

Your signature indicates that you have decided to participate in the study and to allow your child to take part in the study. Your signature also indicates that you have read and understand the information presented and that you have had it explained to you. I will give you a signed copy of the form to keep.

____
Printed Name of the Subject

Signature of Parent or Legal Guardian	Date
Signature of Investigator	Date

I have read the description of the study entitled Cognitive and Memory Performance Patterns Associated with ADHD Subtypes that is printed above, and I understand what the procedures are and what will happen to me in the study. I have received permission from my parent to participate in the study, and I agree to participate in it. I know that I can quit the study at any time.

Signature of Child (13-16 years of age)	Date

APPENDIX C

Sample Child Assent Form for Participants 8-12 years of Age

Thinking and Remembering Patterns Shown
by Children and Adolescents with ADHD

I agree to be in a study about thinking and remembering patterns shown by children and adolescents with attention problems or ADHD. This study was explained to me by (Circle one: my mother/father/parents/guardian) and (Circle one: she/he/they) said that I could be in it. I understand that I am being asked to be in the study as a “control person” because I do not have problems with attention or ADHD. The only people who will know about what I say and do in this study will be Louise O’Donnell and Margaret-Semrud-Clikeman, Ph.D. who are in charge of the study. I understand that if the findings of this study are written in a scientific magazine or book, no one will be able to find out my results.

In this study I will be asked to do a number of activities. These activities include remembering words and numbers, telling what some words mean, telling how two things could be alike, building some things with blocks, looking at pictures to find what is missing in each one, solving arithmetic problems and copying designs. I will also sit in front of a computer screen and be asked to press the spacebar when certain letters come on the screen and I will be asked to not press the bar when a certain letter comes on the screen.

Writing my name on this piece of paper means that the page was read (by me/to me) and that I agree to be in the study. I know what I will be asked to do. If I decide to stop the study, all I have to do is tell the Louise O’Donnell. If I want to stop and take a break during the study, again all I have to do is tell Louise O’Donnell.

____ ____________________

Child’s Signature Date

____ ____________________

Signature of the Researcher Date

APPENDIX D

SAMPLE SNAP-ODD CHECKLIST

SNAP-IV DSM ADHD/ODD Checklist

Name________________________ Birthdate______________ Grade________ Gender________

Completed by Teacher___ Mother___ Father___ Other________________ Date____________

Check the column which best describes this child:		Not at All	Just a Little	Quite A Bit	Very Much
1. Fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities	1.	___	___	___	___
2. Has difficulty sustaining attention in tasks or play activities	2.	___	___	___	___
3. Does not seem to listen when spoken to directly	3.	___	___	___	___
4. Does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)	4.	___	___	___	___
5. Has difficulties organizing tasks and activities	5.	___	___	___	___
6. Avoids, dislikes, or is reluctant to engage in tasks that require sustained mental effort (such as schoolwork or homework)	6.	___	___	___	___
7. Loses things necessary for tasks or activities (e.g., school assignments, pencils, books, tools, or toys)	7.	___	___	___	___
8. Is easily distracted by extraneous stimuli	8.	___	___	___	___
9. Is forgetful in daily activities	9.	___	___	___	___
10. Fidgets with hands or feet or squirms in seat	10.	___	___	___	___
11. Leaves seat in classroom or in other situations in which remaining seated is expected	11.	___	___	___	___
12. Runs about or climbs excessively in situations where it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)	12.	___	___	___	___
13. Has difficulty playing or engaging in leisure activities quietly	13.	___	___	___	___
14. Is always "on the go" or "acts as if driven by a motor"	14.	___	___	___	___
15. Talks excessively	15.	___	___	___	___
16. Blurts out answers to questions before the questions have been completed	16.	___	___	___	___
17. Has difficulty waiting in lines or awaiting turn in games or group situations	17.	___	___	___	___
18. Interrupts or intrudes on others (e.g., butts into others' conversations)	18.	___	___	___	___
19. Loses temper	19.	___	___	___	___
20. Argues with adults	20.	___	___	___	___
21. Actively defies or refuses to comply with adults' requests or rules	21.	___	___	___	___
22. Deliberately annoys people	22.	___	___	___	___
23. Blames others for his or her mistakes or misbehavior	23.	___	___	___	___
24. Is touchy or easily annoyed by others	24.	___	___	___	___
25. Is angry and resentful	25.	___	___	___	___
26. Is spiteful or vindictive	26.	___	___	___	___

APPENDIX E

SAMPLE CVLT-C SCORING REPORT

California Verbal Learning Test

Children's Version

Dean C. Delis, Joel H. Kramer, Edith Kaplan, and Beth A. Ober

The CVLT-C Scoring Assistant

Alan J. Fridlund and Dean C. Delis

The Psychological Corporation

Child's Name: Sample Case
ID#:
Age: 13 Years, 9 Months, 8 Days
Gender: Male
Grade: N/A
School: None
Reason for Referral: possible ADHD
Referral Source: ANC

Child's Handedness: Right
Evidence of Hearing Impairment: No
Medications: none

Examiner:

Raw and Standard Scores for Key CVLT-C Measures

Level of Recall (Number Correct) and Contrast Scores	Raw Score	Scaled Score	**Learning Characteristics, List A Trials 1-5**	Raw Score	Scaled Score
List A Total Trials 1-5	36	30	Semantic Cluster Ratio (Observed/Expected)	0.5	-2.5
Confidence Interval List A Total Trials 1-5	---	23-37	Serial Cluster Ratio (Observed/Expected)	2.5	0.0
List A Trial 1 Free Recall	5	-1.0	Percent of Total Recall from: Primacy Region	22	-1.5
			Percent of Total Recall from: Middle Region	33	-1.5
List A Trial 5 Recall	10	-1.0	Percent of Total Recall from: Recency Region	44	3.0
List B Free Recall	6	-0.5	Learning Slope	1.1	-0.5
			Percent Recall Consistency	77	-0.5
	Percent Change	Differ. Score	**Recall Errors**		
List B Free Recall vs List A Trial 1 Free Recall	20.0	.5			
	Raw Score	Scaled Score	Perseverations (Free and Cued Recall Total):	1	-1.0
			Free-Recall Intrusions (Total):	0	-0.5
List A Short-Delay Free Recall	8	-1.0	Cued-Recall Intrusions (Total):	0	-1.0
	Percent Change	Differ. Score	Intrusions (Free and Cued Recall Total):	0	-1.0
Short-Delay Free Recall vs List A Trial 5	-20.0	0.0			
	Raw Score	Scaled Score	**Recognition Measures and Contrast Scores**		
List A Short-Delay Cued Recall	9	-1.0	Correct Recognition Hits	13	-0.5
List A Long-Delay Free Recall	8	-1.0	Discriminablity	95.56	0.0
	Percent Change	Differ. Score			Differ. Score
Long-Delay Free Recall vs Short-Delay Free Recall	0.0	0.0	Recognition Discriminablity vs Long Delay Free-Recall Score	---	1
				Raw Score	Scaled Score
	Raw Score	Scaled Score	False Positives (Total)	0	-0.5
List A Long-Delay Cued Recall	8	-1.5	Response Bias	-0.33	-1.0

Notes:

California Verbal Learning Test

Children's Version

Sample Case

Main Test Results

	Correct Total	Categories Pl	Cl	Fr	Sw	Fu	Semantic Cluster Obs	Exp	O/E	Gl	Serial Cluster Obs	Exp	O/E	Perserv. Total	Intrusions Tot	Sh	NS	XAB
List A																		
Trial 1	5 = 33.3%	1	2	2			0	0.8	0.00	0	0	0.2	0.00	0	0	0	0	
Trial 2	7 = 46.7%	1	3	3			2	1.7	1.17	2	1	0.3	3.16	0	0	0	0	
Trial 3	6 = 40.0%	1	3	2			0	1.3	0.00	0	0	0.3	0.00	0	0	0	0	
Trial 4	8 = 53.3%	3	2	3			0	1.8	0.00	0	2	0.4	5.63	0	0	0	0	
Trial 5	10 = 66.7%	4	3	3			2	2.4	0.83	2	1	0.4	2.34	0	0	0	0	
Total	36 = 48.0%	10	13	13			4	8.0	0.50	4	4	1.6	2.49	0	0	0	0	
List B	6 = 40.0%			3	1	2	1	1.3	0.75	1	1	0.3	3.64	0	0	0	0	0
Short Delay																		
Free Recall	8 = 53.3%	3	3	2			3	1.8	1.71	3	0	0.4	0.00	0	0	0	0	0
Cued Recall	9 = 60.0%	3	3	3										0	0	0	0	0
Long delay																		
Free Recall	8 = 53.3%	2	3	3			5	1.6	3.21	5	0	0.4	0.00	1	0	0	0	0
Cued Recall	8 = 53.3%	2	3	3										0	0	0	0	0
Recognition	13 = 86.7%																	

Supplementary Test Results

List A, Trials 1-5	**List B**
Least-Squares Regression Line: Slope: 1.10 Intercept: 3.90 Pooled Recall Consistency Index: 76.92 Percent of Total Recall from Primacy Region: 22.22% Middle Region: 33.33% Recency Region: 44.44%	Shared Category Words: 3 Supr Shared Category Words: 1 Nonshared Category Words: 2 Re: Wtd Avg List A Tr 1-5: %Shared Categ Words: 66.15% %Supr Shared Category Words: -44.62% %Nonshared Category Words: 25.22% Total on List B Compared to List A Trial 1: 0.5
Short-Delay List A Free Recall Compared to List A Trial 5: 0.0 = -20.00%	Long-Delay Free Recall Compared to Short-Delay Free Recall: 0.0 = 0.00%

Errors (False Positives) On Long-delay Recognition		
BS	(List B Shared)	0
BSS	(List B Superordinate Shared)	0
BN	(List B Nonshared)	0
NP	(Neither List - Prototypical))	0
PS	(Phonemically Similar)	0
UN	(Unrelated)	0

Recognition Compared to:	
Long-Delay Free Recall	1.0
Signal detection (Nonparametric):	
Discriminabilty	95.56
Response Bias	-0.33

Hits	False Positives
13 / 15	0 / 30
Misses	**Correct Rejections**
2 / 15	30 / 30

Key: Signed Comparisons:
(+) Enhancement
(-) Decrement

Obs - Observed Cluster
Exp - Expected Cluster
Gl - Global Score
Sh - Shared Category

NS - Nonshared Category
XAB - Intrusions from List A on List B or intrusions from List B on SD and LD trials.

California Verbal Learning Test
Children's Version

Sample Case

Trial Responses

List A	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	List B	Trial
bananas	C - puzzle	C - belt	C - marbles	C - marbles	C - marbles	doughnuts	C - pineapple
sweater	C - strawberries	S - hat	C - belt	C - hat	C - belt	cherries	$ - desk
puzzle	C - sweater	$ - strawberries	C - strawberries	$ - strawberries	C - strawberries	table	C - brownies
jacket	C - watermelon	S - watermelon	C - sweater	C - shorts	C - hat	plums	C - lemons
grapes	C - hat	C - sweater	C - peaches	C - watermelon	C - balloons	cookies	S - cherries
blocks		C - grapes	C - hat	C - puzzle	C - peaches	lamp	C - lamp
watermelon		C - puzzle		C - peaches	S - watermelon	ice cream	
shorts				$ - balloons	C - sweater	pears	
crayons					$ - puzzle	bed	
peaches					S - blocks	candy	
balloons						rug	
hat						lemons	
strawberries						brownies	
belt						pineapple	
marbles						desk	

Short Delay - List A				Long Delay - List A			
Free Recall	Cued Recall			Free Recall	Cued Recall		
	Things to Wear	Fruits			Things to Wear	Fruits	
C - sweater	C - jacket	C - strawberries		C - jacket	C - jacket	C - watermelon	
S - hat	C - hat	C - watermelon		S - sweater	C - sweater	C - peaches	
C - marbles	C - sweater	C - peaches		S - hat	C - hat	C - strawberries	
S - blocks				C - watermelon			
C - strawberries				S - strawberries			
S - watermelon				S - peaches			
C - jacket				C - blocks			
C - balloons				S - puzzle			
				P - jacket			
	Playthings				Playthings		
	C - blocks				C - puzzle		
	C - puzzle				C - blocks		
	C - balloons						

Recognition

Shorts	-Y	Blocks	-Y
Glasses	-N	Oranges	-N
Table	-N	Sweater	-Y
Crayons	-N=	Ice cream	-N
Pants	-N	Drapes	-N
Cherries	-N	Plums	-N
Mop	-N	Jacket	-Y
Bananas	-Y	Strawberries	-Y
Cat	-N	Balloons	-Y
Marbles	-Y	Pineapple	-N
Cookies	-N	Doll	-N
Apples	-N	Roses	-N
Desk	-N	Pears	-N
Muzzle	-N	Bell	-N
Keys	-N	Puzzle	-Y
Hat	-Y	Doughnuts	-N
Grapes	-Y	Lamp	-N
Candy	-N	Toothbrush	-N
Ball	-N	Peaches	-Y
Rug	-N	Belt	-N=
Watermelon	-Y	Dress	-N
Banners	-N	Clocks	-N
Magazine	-N		

False Positive Err - * / Miss - =

Key: S Semantic Cluster (Free Recall)
$ - Serial Cluster
I[a/b] - Intrusion Off Lists [from List A/B]
Is - Semantically Clustered I (Free Recall)
Ix - Cross-Category Intrusion (Cued Recall)
P - Perseveration
Ps - Semantically Clustered P
Pi - Perseveration Intrusion
P+ - Semantically Clustered Pi

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