COGNITIVE INHIBITION IN CHILDREN

WITH ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

by

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(Under the Direction of Katherine Kipp)

ABSTRACT

Cognitive Inhibition refers to the ability to actively suppress information from working memory space. Such suppression allows more space in working memory to be used for information processing or memory storage as it reduces interference from irrelevant or unnecessary information. In this study, the role of cognitive inhibition as a contributing cognitive deficit in elementary school children with Attention Deficit Hyperactivity Disorder-Combined or Primarily Hyperactive types was examined. Participants were administered a variety of assessment tools designed to assess cognitive inhibition. Differences in cognitive inhibition were demonstrated in ADHD children when compared to their non-diagnosed peers on tasks of directed forgetting and negative-priming Stroop, but not tasks requiring picture naming or a sentence completion task. The results of this study suggested that children with ADHD will demonstrate deficits in cognitive inhibition on tasks of directed forgetting and negative-priming Stroop. The failure of other instruments to also demonstrate such differences may have been due to the developmental level of the tasks failing to discriminate between non-ADHD and ADHD children.

INDEX WORDS: Attention-Deficit/Hyperactivity Disorder, ADHD, Cognitive Inhibition

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DEDICATION

For my parents, thank you for being consistent, supportive, and unbelievably giving. You taught me to pursue my dreams and you gave the tools with which to do it. I will be forever grateful.

For my husband, for letting me be as tall as I want to be.

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CHAPTER 1

Introduction

Background

Attention Deficit Hyperactivity Disorder (ADHD) is a developmental disorder affecting approximately three to nine percent of the school age population (American Psychiatric Association, 1994; Milich, Balentine, & Lynam, 2001). The American Psychiatric Association identified persistent patterns of inattention and/or hyperactivity as the primary features in children with Attention Deficit Hyperactivity Disorder (APA, 1994). This disorder is characterized by difficulty attending and maintaining focus, difficulty sitting still, and general impulsive behaviors (APA, 1994). The DSM-IV identified three subtypes of ADHD: Primarily Hyperactive, Primarily Inattentive, and Combined Type. The primarily hyperactive subtype is identified based on the presence of indicators associated with hyperactivity (e.g. squirming in one's seat, excessive running, fidgetiness) (APA, 1994). The primarily inattentive subtype is identified based on the presence of indicators associated with inattention (e.g. failure to give close attention to details, difficulty sustaining attention) (APA, 1994). Accordingly, the combined subtype is identified based on the presence of indicators associated with both hyperactivity and inattention.

According to Gaub and Carlson (1997) the inattentive subtype is more prevalent, occurring at twice the rate as the combined subtype, in the general population. In contrast, the combined subtype is more prevalent in clinically referred populations, occurring approximately 1.5 more times than the inattentive subtype (Lahey et al., 1994). In regards to gender, ADHD is more prevalent in males than females in both the general and clinically referred populations, with a male to female ratio of 3.5:1 (Carlson & Man, 2000; Milich, Balentine, & Lynam, 2001).

Many individuals diagnosed with ADHD have problems in a variety of settings and domains. For example, children diagnosed with ADHD have been found to perform more poorly on tests of academic achievement than their non-diagnosed peers (Faraone, Biederman, Weber, & Russel, 1998; Milich et. al, 2001). According to Biederman and colleagues (2004), children diagnosed with ADHD perform worse than their non-diagnosed peers on measures of academic achievement and school functioning. These included increased risk for grade retention, learning disabilities, and lower academic achievement in general. Biederman et al. (2004) also found ADHD children to evidence more deficits in global functioning and impaired interpersonal functioning. Lahey and colleagues (1994) found children with ADHD to be more likely to be rated as "liked least" by their classroom peers than non-diagnosed peers. Interestingly, children with ADHD have also been found to have positively-distorted self-perceptions in domains of weakness (Hoza, Pelham, Dobbs, Owens, & Pillow, 2002). For example, ADHD boys with difficulties in the area of aggression rate themselves as having high levels of social competence.

The DSM-IV continues to identify the different types of ADHD as comprising the same disorder but with a different constellation of presenting symptoms. However, recent literature suggests they comprise two separate disorders with one disorder comprising those individuals identified as primarily inattentive and the other disorder comprising those individuals identified as primarily hyperactive or combined type (Milich, Balentine, & Lynam, 2001; Barkley, DuPaul, & McMurray, 1990; Barkley, 1998). Differences emerge regarding the core deficits in ADHD. For those individuals identified as primarily inattentive, deficits in sustained attention and sluggish tempo have been identified as a primary characteristic (Lahey et al., 1988;

Bauermeister, Alegra, Bird, Rubi-Stiec, & Canino, 1992) . In children identified as primarily hyperactive or combined type, deficits in executive functioning have been outlined as primary deficits (Barkley, 2004; Kempton et al., 1999; Sonuga-Barke, 2002; Sergent, 2000; Clark, Prior, & Kinsella, 2000). Executive functioning is the cognitive mechanism necessary for cognitively organizing information and planning and executing a response. Deficits in executive functioning have been documented with studies assessing resistance to interference (Rosenthal & Allen, 1980), strategy use in working memory (Shapiro, Hughes, August, Bloomquist, 1993), and response inhibition tasks (Iaboni, Douglas, & Baker, 1995; Shue & Douglas, 1992). Such deficits in executive functioning will also impact memory development in children with ADHD.

Overview of Memory Development

Before one can understand possible deficits in memory functioning in children with ADHD, an understanding of basic memory development is necessary. Developmental models of cognition in children incorporate a computer metaphor of information processing (Miller, 2002). While no one theory of information processing is readily identifiable, assumptions regarding the core components of information processing are identified (Bjorklund, 2005). These include the idea that the processing of information is what allows humans to act on their world, that the space for processing information is limited, and that information processing includes both an "input" and a "storage" of information (Bjorklund, 2005).

As children develop, they become more able to organize information and use control processes in working memory. For example, beginning in the early elementary years and developing over the elementary school years, children become more effective at spontaneously using rehearsal strategies (repetition of to be remembered information) during tasks requiring memory (Flavell, Beach, & Chinsky, 1966). In addition, older elementary school children are more effective at selecting only task relevant information. Brown and Smiley (1978) exemplified this ability in their study examining children's selection of pertinent information during note-taking and underlining of read passages. As children developed, they became more efficient at identifying relevant information and ignoring unimportant elements of read texts.

Increasing knowledge and metamemory are also contributors to children's improved memory and strategy use (Miller, 2002). As children's own knowledge base expands, they are better able to organize information and develop more effective strategies. Bjorklund (1987) suggested that rich knowledge bases allow children to more efficiently incorporate new information into previously learned information thus freeing working memory capacity. Consequently, working memory space is freed and allows for more information processing and strategy implementation.

An increasing awareness of metamemory (knowledge of memory), on the other hand, enhances children's understanding that more effort may be needed to remember new information and children will begin to experiment with strategy implementation. As with strategy implementation, metamemory appears to be developing across the elementary school years also. Kreutzer, Leonard, and Flavell (1975) demonstrated this development in a study asking kindergarten and fifth-grade students whether acting directly on new information would effect their memory of new information. While kindergarten children did not feel it mattered whether they got a drink of water first or immediately dialed a phone number after being told to remember a phone number, fifth grade students felt the immediate action of dialing the number would enhance their ability to remember the phone number. Such a failure to understand memory functioning inhibits young children's ability to optimize their use of working memory.

It is in working memory where information is evaluated and processed. It is also in working memory where processing and storage space may significantly impact an individual's ability to efficiently process new information. Control processes such as resistance to interference and cognitive inhibition have also been proposed as factors enabling an individual to optimize processing and storage space in working memory (Dempster, 1993; Harnishfeger & Bjorklund, 1993).   Resistance to interference involves an individual's ability to ignore incoming information, particularly if it is task-irrelevant (Lane & Pearson, 1982). Cognitive inhibition, on the other hand, refers to an individual's ability to suppress information that has already been processed into working memory (Harnishfeger & Bjorklund, 1994). It is differences in these control processes that may contribute to developmental differences in working memory functioning. While research has established the role of resistance to interference in ADHD (Rosenthal & Allen, 1980; Savitz and Jansen, 2003) an exploration of the role of cognitive inhibition is still needed.

Overview of Cognitive Inhibition

Cognitive inhibition refers to the process of actively suppressing encoded information (Harnishfeger & Bjorklund, 1994). This process allows for more space within working memory to process relevant information rather than consuming space with task-irrelevant information. The concept of cognitive inhibition is paired with a limited resource model in information processing theory that proposes there is limited space in working memory for processing information (Bjorklund 2000). These models theorize that developmental differences in cognitive performance are not due to changes in working memory space; rather, changes in the efficiency of information processing is what changes as individuals grow older. Harnishfeger and Bjorklund (1993) proposed cognitive inhibition as an extension of this model, positing that the ability to inhibit information contributes to task performance because it can eliminate task-irrelevant information from working memory. In other words, cognitive inhibition allows for a more focused attention and working memory space.

Difficulties with cognitive inhibition may impede an individual's ability to effectively organize and process information during their daily activities. Such deficits could contribute to deficits in executive functioning that have been found and outlined in children with ADHD (Barkley, 2004; Sergeant, 2000; Sonuga-Barke, 2003). As stated previously, executive functioning involves the ability to cognitively plan and organize information for present and future responses. The ability to organize information should be greatly impacted by working memory space being available for cognitive processing. If an individual's working memory space is consumed by task-irrelevant information, the space for processing relevant information would be limited. Therefore, deficits in cognitive inhibition may also be impacting the ability of individuals with ADHD to effectively process pertinent information.

Purpose of the Study

While ample research describing deficits in behavioral inhibition and cognitive deficits in children with ADHD exists, little research has been done to explore deficits in cognitive inhibition in this population. According to the limited resource model, Harnishfeger and Bjorklund (1993) propose that efficient cognitive inhibition allows for individuals to organize and process information more efficiently. This may be due to irrelevant information being suppressed in working memory, thus allowing for more processing space. Because current models of ADHD incorporate problems in working memory as a secondary deficit in children with ADHD (Barkley, 1997; Sergeant, 2000; Sonuga-Barke 2003), intensive study of cognitive mechanisms contributing to working memory function in children with ADHD versus children without ADHD could greatly add to the understanding of how cognition develops in these children. If deficits in working memory inhibit an individual's ability to hold and process necessary information, and children with ADHD have such deficits, understanding the different mechanisms contributing to these deficits would be necessary in order to develop the appropriate support for ameliorating negative effects. More specifically, if resistance to interference were the only contributor to deficits in working memory space for children with ADHD, reducing the amount of interference would be the appropriate strategy for helping these children. This could be actualized by providing a quiet working environment with minimal distracters. However, if cognitive inhibition was also contributing to working memory deficits, then minimizing distracters would not help this difficulty. Rather, strategies would need to be developed that would help children with ADHD suppress irrelevant information. This would then optimize their ability to efficiently use available working memory space.

It has been proposed that deficits in the ability to hold information in working memory make it difficult for children with ADHD to initiate complex behavioral sequences (Barkley, 1997). It is possible that deficits in working memory processing space, not working memory in and of itself, are the primary cause of such effects. That is, while it is not working memory space in general that is limited in children with ADHD, their inability to effectively resist and suppress irrelevant information may cause an overload of information in storage space limiting room for information processing. Deficits in cognitive inhibition, allowing for task irrelevant information to remain in working memory, would consume working memory storage capacity and make it more difficult for children with ADHD to hold larger amounts of information in working memory to be processed and limit working memory processing space.

The purpose of this study is to explore the relationship between cognitive inhibition and Attention Deficit Hyperactivity Disorder. Many studies have established working memory deficits due to poor resistance to interference and poor organization of information in children with ADHD (Borcherding, Thompson, Krusei, Bartko, Rapoport, & Weingartner, 1988; Bremer & Stern, 1976; Leung & Connolly, 1996; Rosenthal & Allen, 1980; Visser, Das-Small, & Kwakman, 1996), few studies exist exploring the role of cognitive inhibition as a working memory deficit in these children.

Previous research has conflicted on whether differences in cognitive inhibition between individuals with and without ADHD are present. Gaultney, Kipp, Weinstein, and McNeill (1999) used a directed forgetting task to investigate difference in cognitive inhibition in children with and without ADHD. In their study, participants were read a list of words to be remembered for a later memory test. After hearing the list of words, participants were then instructed to "forget" the words they just heard and only remember a subsequent list of words to be read immediately. Following a period of distraction, participants were then asked to recall as many words as they could remember from both lists, including the list they had been instructed to forget. For this study, cognitive inhibition would have occurred if participants remembered fewer of the words from the list they were instructed to forget and more words from the list they were instructed to remember. Gaultney et al. (1999) found children with and without ADHD were able to cognitively inhibit the list of words they were instructed to forget. However, the previous research used a large age range (8-15 years), based on availability rather than theoretical considerations. In addition, they did not take into consideration the different subtypes currently identified for ADHD, using all three subtypes of ADHD (primarily inattentive, primarily hyperactive, and combined type) in their study. The failure to discriminate between subtypes may have permitted the use of primarily inattentive participants that would not be expected to demonstrate deficits in working memory and executive functioning. In addition, their wide age-range may have allowed for developmental variations to mask effects that may be more prevalent in younger or older individuals.

White and Marks (2003) used directed-forgetting tasks to assess differences in intentional forgetting in adults with and without characteristics associated with ADHD. In their study, participants were simultaneously presented with two lists. Participants were told that one list was to be remembered for a later memory test while the other list was to be judged for pleasantness. A word from each list was alternately presented one at a time. That is, individuals were presented with a word to be remembered, then a word to be rated pleasant or unpleasant, then a word to be remembered, and so on until the list was exhausted. Following the lists presentations, half of the participants were instructed to forget the lists just presented and only focus on the next presentation of a to be remembered list while the other half were instructed to remember both the to be remembered list just presented and the subsequent to be remembered list presented. Following a second presentation of lists and a brief distracter, both groups were instructed to remember as many words as possible from all lists, including the list they were told to forget and the lists they were told to judge for pleasantness. In their study, participants without characteristics associated with ADHD were able to intentionally forget (cognitively inhibit) directed items. In contrast, participants with characteristics associated with ADHD were unable to demonstrate intentional forgetting (cognitive inhibition).

While these studies report contradictory findings regarding the presence of cognitive inhibition in individuals with ADHD, their sample populations were highly discrepant. More specifically, one sample used school-aged children while the other used adults. In an effort to look more closely at the development of cognitive inhibition in children with ADHD, this study proposes a limited age range, based on developmental research of cognitive inhibition and research on the developmental changes in ADHD symptomatology. As cognitive inhibition has been found to develop in normal children across the elementary school years (Harnishfeger, 1995), the age range for this study will be limited to the late elementary school years. In addition, emerging research suggests that the predominantly inattentive subtype should be a clinically differentiated and distinct disorder, classified separately from the predominantly hyperactive- and combined-type subtypes of ADHD (Milich & Klein, 2001). Failure to eliminate the predominantly inattentive-type from ADHD research may limit findings that would be associated with the Combined- and Primarily Hyperactive- Types only. Therefore, this study excluded individuals with a primarily-inattentive diagnosis in order to explore deficits that may not be similarly associated with this subtype of ADHD.

There has not been any literature linking theories of ADHD with models of cognitive inhibition in working memory. With working memory being one of the four executive functions identified as a deficit in children with ADHD (Barkley, 2004; Sergeant, 2000; Sonuga-Barke, 2003), research further exploring working memory functioning can add to our understanding of this component in children with ADHD.

Research Questions

The purpose of the current study was to determine whether children with Attention Deficit Hyperactivity Disorder differed from children not diagnosed with the disorder on measures of cognitive inhibition. To achieve these goals, in this study the following research questions were addressed:

1. Do children with ADHD differ from those without the disorder in their ability to cognitively inhibit irrelevant information?

It was hypothesized that there would be significant differences between groups on measures of cognitive inhibition. For a detailed description of the tasks used and hypotheses see Appendices). Based on theories of Attention Deficit Hyperactivity Disorder, and empirical research (Lovejoy, Ball, Keats, Stutts, Spain, Janda, & Janusz, 1999), it has been found that differences in memory functioning exist between children with and without ADHD. These studies have included an exploration of resistance to interference (Savitz & Jansen, 2003) and free recall from memory (Lovejoy, Ball, Keats, Stutts, Spain, Janda, & Janusz, 1999). Few empirical studies have explored the possibility of cognitive inhibition also being a contributing factor in deficits of working memory in children with ADHD.

Specifically, cognitive inhibition will be examined based on several tasks used in the literature to explore cognitive inhibition. Groups will be compared based on their performances on a directed forgetting task, a sentence completion task, a picture naming task, and a Stroop negative priming task.

2. Do differences in intellectual functioning impact the use of cognitive inhibition in children with and without ADHD?

Previous research has established the relationship between memory functioning and intelligence. In a meta-analysis of intelligence research, Carroll (1997) identified memory as the third factor of intelligence from a theoretical "general intelligence." In order to control for this factor, an abbreviated assessment of intelligence will be conducted and implemented as a covariate during statistical analyses. Carroll (1997) found that assessments using matrices tasks to load highest on measures of "general intelligence." Consequently, the matrices subtest of the Kaufman Brief Intelligence Tests (K-Bit) was used as a brief measure of intelligence. This subtest uses a matrices task in order to assess nonverbal intelligence. In accordance with Carroll (1997), this would be the most expedient measure of intelligence without a comprehensive assessment of intellectual abilities.

CHAPTER 2

Related Literature

Attention-Deficit/Hyperactivity Disorder

The American Psychiatric Association defines ADHD as a disorder comprised of "a consistent pattern of inattention and/or hyperactivity-impulsivity that is more frequent and severe than is typically observed in individuals at a comparable level of development" (APA, 1994). A clinically identified childhood disorder associated with deficits in attention (versus hyperactive reactions in childhood or organic brain damage) emerged in 1968 in the Diagnostic and Statistical Manual of Mental Disorder- Second Edition (DSM-II) (Milich & Klein, 2001; Mash & Barkley, 2003). With the fourth edition of the DSM, diagnostic criteria for Attention-Deficit/Hyperactivity Disorder were developed identifying two clusters of symptoms: inattention and hyperactivity-impulsivity (APA, 1994). The inattention cluster included symptoms such as failure to give attention to details, forgetfulness, distractibility, and failure to listen when spoken to. The hyperactivity-impulsivity cluster included symptoms such as restlessness, excessive talking, frequent interruption of others, and difficulty waiting for one's turn. In order to meet diagnostic criteria, six or more symptoms from each cluster must be present and must have been present prior to seven years of age. Impairments associated with these symptoms must be impacting the individual in two or more settings and the symptoms must be causing clinically significant impairment in social, academic or occupational functioning. In addition, the symptoms must not be better accounted for by another mental or developmental disorder.

Based on the constellation of symptoms present in an individual, ADHD is coded accordingly into one of three subtypes: Combined Type (having met diagnostic criteria for both inattentive and hyperactive-impulsive symptoms), Predominantly Inattentive Type (having met diagnostic criteria for inattentive symptoms only), or Predominantly Hyperactive-Impulsive Type (having met diagnostic criteria for hyperactive-impulsive symptoms only). Controversy has developed over the past twenty years as to whether the Primarily Inattentive Subtype is in fact a clinically different disorder, rather than a subtype of ADHD (Milich & Klein, 2001). However, studies employing a factor analytic approach to examine symptomatology of school-aged children referred to clinics have evidenced a three factor solution: a hyperactivity-impulsivity factor, an inattention-disorganization factor, and a sluggish tempo factor (Lahey et. al, 1988).

Prevalence rates of ADHD vary across studies, but fall within the range of four to nine percent, with a male to female ratio of 3.5:1.(Milich, R., Balentine, A. C., & Lynam, D. R., 2001). The prognosis for individuals diagnosed with ADHD varies across individuals. Mannuzza and Klein (2000) reviewed follow-up studies examining symptomatology and associated outcomes for individuals diagnosed with ADHD. During their teenage years, such individuals were more likely than their non-diagnosed counterparts to show deficits in both academic and social functioning, and a minority demonstrated antisocial behaviors and drug abuse. As the individuals progressed into adulthood, only a few continued to evidence difficulties, including less formal schooling, lower ranking occupational positions, and symptoms associated with the childhood syndrome. However, the researchers found that approximately two-thirds of individuals diagnosed with ADHD showed no evidence of any mental disorder once they progressed into adulthood.

Neuropsychological Deficits

Developments in research methodology and assessment have led researchers to explore the neuropsychological deficits associated with a variety of disorders. This progress in the exploration of developmental psychopathology has enhanced theoretical models. ADHD is one of the disorders that has been evaluated using such methods.

Recent studies have shown a variety of neuropsychological deficits associated with ADHD (Dykman & Ackerman, 1991; McBurnett et al. 1993). Barkley (1997) has noted deficits in executive functioning to be the primary neuropsychological deficit associated with ADHD. Similarly, Pennington (1997) noted deficits in response inhibition and planning to be a primary neuropsychological deficit in individuals with ADHD. Lovejoy, Ball, Keats, Stutts, Spain, Janda, and Janusz (1999) used a variety of tasks to assess neuropsychological deficits in individuals with ADHD. They found ADHD participants to evidence neuropsychological deficits on the Controlled Oral Word Association Test, the Short-Delay Free Recall Index of the California Verbal Learning Test, the Stroop Neuropsychological Screening Test, and Trail Making Test. Savitz and Jansen (2003) also found ADHD participants to evidence neuropsychological deficits on the Stroop Color-Word Interference Test. Seidman, Benedict, Biederman, Bernstein, Seiverd, Milberger, Norman, Mick, and Faraone (1995) found ADHD participants to evidence neuropsychological deficits on the Rey-Osterrieth Complex Figure. In general, these studies found that individuals with ADHD will have difficulties with a variety of assessment tools designed to assess deficits in neuropsychological functioning, such as planning, resistance to interference, working memory, and motor tasks.

Research using brain imaging, such as functional magnetic resonance imaging (fMRI) and magnetic resonance imaging (MRI) have helped localize brain abnormalities with neuropsychological deficits (Bush, Frazier, Rauch, Seidman, Whalen, Jenike, Rosen, & Biederman, 1999; Sowell, Thompson, Welcome, Henkenius, Toga, & Bradley, 2003). Bush et al. found that while non-ADHD individuals evidence a neurological activation in the Anterior Cingulate Cortex during the Stroop Test, ADHD individuals did not demonstrate this activation. Using MRI technology, Sowell et al. found ADHD individuals to show reductions in brain volume in the right frontal hemisphere and in the caudate nucleus.

Models of ADHD

<u>Model of Behavioral Inhibition</u>. Barkley (1996) proposed a model of ADHD identifying behavioral inhibition as a core deficit in individuals with the disorder. However, Barkley applies his model to the Combined Type and Primarily Hyperactive Subtypes only. Behavioral inhibition is comprised of three processes: the capacity to inhibit prepotent responses, the protection of the delay allowing for alternative behavioral responses to be initiated, and interference control (Barkley, 1997). In Barkley's model, the individual's inability to inhibit behavior contributes to failures in executive functioning. He defines executive functioning as the "private (cognitive) self-directed action that contributes to self-regulation" (Barkley, 1997, p. 68). The executive functions, including prolongation/working memory, self regulation of affect, motivation, arousal, internalization of speech, and reconstitution allow for individuals to predict and control one's environment as well as permit more effective adaptive functioning. Barkley proposes that the capacity for behavioral inhibition begins to emerge first in development, ahead of the four executive functions. In children with ADHD, differences in behavioral inhibition are primary, and the deficits in executive functioning are secondary. In accordance with neuropsychological research, Barkley believes that the behavioral inhibition deficits are based in neurodevelopmental origins rather than social origins, specifically structural and functional

limitations in the prefrontal cortex. In these children, deficits in behavioral inhibition and its related executive functions become most obvious when delay in a response is required or when immediate responses have previously been rewarded. This is seen most clearly with tasks that involve temporal delays, conflicts in previously reinforced consequences, or require the generation of a novel response (Barkley, 1997).

Cognitive-Energetic Model. Sergeant (2000) proposed the cognitive-energetic model of ADHD. This model is comprised of three levels: the first level includes encoding, information processing, and motoric organization (including response inhibition), the second level is comprised of three energetic pools (effort, arousal, and activation), and the third level is comprised of management and evaluation mechanisms (executive functioning). The third level of the cognitive-energetic model is incorporating the theoretical model and research findings associated with Barkley's model of behavioral inhibition (Barkley, 2000). This level is comprised of the deficits in executive functioning discussed previously. However, Sergeant noted that deficits in response inhibition did not distinguish children with ADHD from children with other disruptive behavior disorders (Oosterlaan, Logan, & Sergeant, 1998). Sergeant concluded that other mechanisms, including response to contingencies, were also contributing to symptom presentation in children with ADHD. Consequently, Sergeant sought to identify the locus of the deficits associated in children with ADHD that may distinguish their symptoms from other developmental disorders.

The first level of the cognitive-energetic model is comprised of encoding, cognitive processing, and motoric organization. This level of the cognitive-energetic model facilitates information processing at the initial engagement with environmental information. Sergeant noted that deficits in encoding and central processing were not indicated in children with ADHD.

Rather, the primary deficit at this level was in motor organization (Sergeant & Van der Meere, 1990). For example, studies have shown that the speed and accuracy of response in children with ADHD is weaker than in children without ADHD, particularly in studies implementing a need to stop an already established response (Sergeant & Van der Meere, 1990).

The second level of the cognitive-energetic model is comprised of the energetic pools available to the individual. Energetic pools are comprised of effort, arousal, and activation. Effort was defined by Sergeant as the energy needed to meet the demands of a task. Effort includes the motivation of the individual and response contingencies available to support motivation. If motivation is high, an individual will need less effort to complete the task as they are actively engaged with the task. Similarly, if response contingencies are in place to help maintain and/or increase motivation, less effort will be needed. Arousal is defined as the processing of a stimulus and is limited to the period of time need to process the task. Activation is defined as the neuropsychological activity necessary for processing the information (primarily occurring in the basal ganglia and corpus striatum). Sergeant identified effort and activation as being particularly important for the behavioral inhibition deficits seen in children with ADHD. That is, with decreased activation in the brain, it is theorized that tasks will require more effort for individuals.

The third level of the model is comprised of deficits in executive functioning, similar to that proposed by Barkley (2000). However, as stated previously, Sergeant argued that research does not support deficits in executive functioning, particularly behavioral inhibition, as unique to ADHD. Therefore, Sergeant concluded that the other mechanisms, including decreased activation and effort, may more effectively discriminate deficits in ADHD from other disruptive behavioral disorders. For example, individuals with ADHD have more difficulty with utilization of time when information is presented at a slower rate (Van der Meere, Gunning, & Stemerdink, 1998). It was hypothesized that the rate of information presentation resulted in decreased activation in the energetic state of the individuals, resulting in executive function deficits that were not the result of behavioral inhibition deficits.

Dual-Pathway Model. Sonuga-Barke (2003) proposed ADHD is better envisioned through a dual pathway model, with ADHD being the outcome of both deficits in executive functioning and a psychologically-based motivational style termed delay aversion. Sonuga-Barke aimed to reconcile literature identifying deficits in executive functioning as a dominant contributor to the development of ADHD symptoms with research favoring motivationally based models (Sagvolden, Aase, Zeiner, & Berger, 1998; Sonuga-Barke, 2003; Sonuga-Barke, Williams, Hall, & Saxton, 1996; Tripp & Alsop, 2001). Sonuga-Barke cited the work of both Sergeant and Barkley in conceptualizing deficits in executive functioning in ADHD. However, it was noted that many questions remain regarding whether deficits in executive functioning will necessarily lead to the expression of ADHD symptoms or solely account for the symptoms associated with ADHD.

Delay aversion in children with ADHD was described as a hypersensitivity to the delay between action and rewards, which causes attempts to escape or avoid delay. In other words, in an attempt to shorten the delay period, children with ADHD would either attend to other stimulation in order to distract from the delay (manifested in symptoms of inattention) or would create stimulation themselves (manifested in hyperactivity). Consequently, ADHD children are more likely to focus on environmental cues that will allow for an escape from delay. While acknowledging the abundance of research supporting the role of executive functioning, Sonuga-Barke argued for a model that would also incorporate research findings of deficits in children with ADHD associated with an increased sensitivity to delay, difficulties waiting for desired outcomes, and a decreased ability to focus on a task while waiting for a desired outcome (Kuntsi, Oosterlaan, & Stevenson, 2001; Songua-Barke, Williams, Hall, & Saxton, 1996; Schweitzer & Sulzer-Azaroff, 1995; Tripp & Alsop, 2001).

Sonuga-Barke proposed that deficits in executive functioning and increased delay aversion can manifest themselves in the expression of ADHD characteristics and symptomatology. In addition, the neuropsychological systems associated with both the delay aversion pathway and executive functioning pathway can be related to dysfunction in the dopamine system in the brain and its subsequent interactions with other neurotransmitter systems, such as norepinephrine and serotonin (Russell, 2002; Williams et al, 2002). Therefore, Sonuga-Barke concluded both pathways are contributing to the symptoms associated with ADHD, and while the two systems function independently, they are neurobiologically related (through the dopamine system).

Current Treatment for ADHD

Two broad types of treatment have been empirically supported for ADHD (Root & Resnick, 2003). These include clinical behavioral psychotherapy and direct contingency management. An example of a clinical behavioral psychotherapy approach would include Barkley's program for training parents in the skills necessary for parenting defiant children (Barkley 1987). Strategies in this program would include helping parents with consistent responses to positive and negative behaviors, with developing skills for ignoring inappropriate behavior, and skills for reinforcing positive behavior. Treatments implementing direct contingency management would include the establishment of contingencies for the different behaviors exhibited by children with ADHD (Pelham, 2000). More specifically, these include interventions implementing a point system where children can earn points for appropriate behaviors and lose points for inappropriate behaviors. Points earned can then be exchanged for some type of reward that is motivating for the child (free time, game playing with adult, or social accolades).

Psychopharmacotherapy has also emerged as an effective treatment for some of the symptoms associated with ADHD. It has been suggested that approximately six percent of elementary school children are currently receiving stimulant medication for treatment of their symptoms associated with ADHD (Jacobvitz, Sroufe, Steward, & Leffert, 1990). Improvement of symptoms in children with ADHD while on stimulant medication include: improved performance on short- and long-term recall tasks (Tannock, Ickowicz, & Schachar, 1995), more flexible thinking (Douglas, Barr, Amin, O'Neill, & Britton, 1988), and improved visual-motor integration (Douglas, Barr, Amin, O'Neill, & Britton, 1988). It should be noted, however, that treatment effects for medication are increased when combined with direct contingency management interventions (Pelham, 2000).

Contemporary Models of Cognition

In the 1950s and 1960s, challenges to the neo-behaviorist movement as well as advancement in modern technology led to a computer metaphor for modeling changes in children's thinking (Miller, 2002). It has been said that the approach "was never born; it gradually coalesced" (Kendler, 1987, p. 364). It was no longer satisfactory to researchers to view verbal learning theory, the hallmark of neobehaviorism, as advancing the field of learning (Miller, 2002). Verbal learning theory generated many experiments, but was not leading to the development of coherent theories of cognition. Corresponding developments in computer technology suggested to researchers that human thought might process information similarly to computer models, thus the introduction of the computer metaphor for human thinking (Miller, 2002). In these models, human thought could be viewed as an information processing system, with hardware (capacity and speed of information processing) and software (access and use of strategies or other learning devices) contributing to developmental changes in children's thinking (Bjorklund, 2005). With time, these models began to dominate the theoretical approaches to cognitive development and guide research in cognitive developmental psychology (Bjorklund, 2005). Developmentally, age-related changes in cognition were proposed to depend upon the maturation of activation resources, including working memory capacity and information processing speed (Dempster, 1993).

One unified theory of information processing is not identifiable; rather there are underlying assumptions that contribute to the wealth of approaches using a computer metaphor. According to Bjorklund (2005), these assumptions include, first, the idea that through the mental processing of information, individuals can act on their external world or information that is stored in the mind. Second, there is limited capacity for processing information, whether it is due to limited space (to store or operate on information), limited energy (for storage or execution of operations), or limited time (limited speed to perform operations). Third, information is moved through the memory system through pathways between input and storage. Information is thought to initially enter the system through sensory registers, with a separate sensory register for each sensory modality that is presumed to be able to hold large amounts of information and last only a fraction of a second to several seconds (Miller, 2002). Next, information enters the working memory space to be evaluated and processed. Working memory space is considered to be limited and to last for seconds, approximately 15 to 30 (Miller, 2002; Torgesen, Kistner, & Morgan, 1987). Once information enters the working memory space, it is either processed (by being acted upon or verbally rehearsed) or is permanently lost (Miller, 1999). The final store of the system is the long-term memory store, assumed to be unlimited in capacity and time. Evidence regarding the absolute capacity of working memory has not been established, nor evidence for changes in capacity across the life span (Torgesen et al., 1987). Control processes, such as resistance to interference and cognitive inhibition, have been proposed to be contributing control processes that help individuals overcome structural limitations, such as limited storage capacity, on how much information can be handled and that contribute to developmental changes in information processing (Dempster, 1993; Harnishfeger & Bjorklund, 1993). That is, rather than adults having more working memory space, it is proposed that more efficient control processes reduce the amount of working memory space being used at any one time, allowing for more information to enter working memory.

Models of Inhibition

Early models of inhibition emerged from theorists such as Freud and Luria (Harnishfeger, 1995). Freud proposed inhibition as primary in the active repression of unwanted thoughts or behaviors as well as in primary repression of experiences and memories from infancy and early childhood (Freud, 1915/1938). Luria (1961) used inhibition in his developmental theory of verbal regulation of behavior in children. His theory was an expansion of previous work by Vygotsky proposing internalized speech as a mechanism for controlling behavior (Harnishfeger, 1995). According to Luria, very young children are unable to use verbal behavior to inhibit behavioral responses. As children develop, they become able to use external verbal commands (not their own) to inhibit their own behavior. Eventually, children develop the ability to use their own internalized speech as a cognitive mechanism to inhibit behavior.

Models of inhibition continued to appear in developmental theories, but lost prominence once information processing models began to dominate developmental and cognitive psychology (Harnishfeger, 1995). Recently, the emergence of cognitive inhibition and resistance to interference models have been proposed as contributing to contemporary understanding of cognitive development (Harnishfeger, 1995).

Dempster (1993) proposed that susceptibility to interference is an important source of individual and developmental differences in cognition, emerging from differences in the efficiency of the prefrontal lobes. Dempster reviewed a variety of research showing developmental changes in resistance to interference, which he believes contributes to the further understanding of cognitive development. Dempster defines resistance to interference as the ability to resist attention to task-irrelevant information in information processing. Experimental tasks that demonstrate this ability are those requiring a shifting of attention or responses, competition among stimuli or responses, or the shifting of reinforcement contingences (Harnishfeger, 1995).

Harnishfeger and Bjorklund (1994) proposed inhibition as a cognitive control process contributing to cognitive development. They defined cognitive inhibition as the active suppression of information from working memory. This process allows for the removal of task irrelevant information from working memory, allowing other task relevant information to enter the working memory space. As stated previously, working memory is a limited capacity mechanism and control processes, such as cognitive inhibition, are needed in order to optimize information processing in this space.

Cognitive Inhibition versus Resistance to Interference

Within limited resource models of information processing, both cognitive inhibition and resistance to interference have been proposed as control processes keeping task-irrelevant information from working memory space (Harnishfeger & Bjorklund, 1993; Dempster, 1993). Interference refers to susceptibility to performance decrements under conditions of multiple distracting stimuli, such as dual-task performance or selective attention (Lane & Pearson, 1982). Resistance to interference refers to the ability to ignore task-irrelevant information, thus allowing for more efficient processing of relevant information (Dempster, 1993). In order to measure resistance to interference, researchers have used a variety of tasks, such as selective attention tasks and the Stroop Color-Word Interference Test (Dempster, 1993). Strutt, Anderson, and Well (1975) demonstrated the developmental aspects in the ability to selectively attend to information, or resist interference. In their study, participants were required to sort cards with stimulus information centered and defined according to one, two, or three binary dimensions: form (circle or square), line within the form (horizontal or vertical), and star (just above or below the form). Different decks of sorting cards contained both relevant and irrelevant information, with participants being instructed to sort the cards as quickly as possible according to the relevant criteria for the particular deck. The ability to ignore irrelevant information while sorting the cards increased with age, supporting conclusions that resistance to interference is a developmental trend, with younger children taking more time to complete the sorting tasks.

In the Stroop Color-Word Interference Test (Stroop, 1935), individuals are required to name ink colors while resisting the automatic process of reading the word in the stimuli presented. Estimates of resistance to interference are based upon the differences in time to name colors on a color chart and the time to name the colors of ink in which incongruent color-names are written (Dempster, 1993). Comalli, Wapner, and Werner (1962) provided a comprehensive study researching age difference in Stroop performance. They found that the ability to resist interference increased with age, from seven years to adulthood, and decreased in individuals over 65 years of age.

Cognitive inhibition requires the removal of task-irrelevant information from working memory after it has been activated in the memory space (Harnishfeger & Bjorklund, 1993). In order to assess cognitive inhibition, researchers have used tasks including a negative priming condition in the Stroop task and directed forgetting tasks. Researchers using directed forgetting tasks have demonstrated the developmental differences in the ability to cognitively inhibit irrelevant information (Harnishfeger & Pope, 1996; Wilson & Kipp, 1998). Harnishfeger and Pope found that children were less able than adults to inhibit words they were told to forget and were more likely to produce to be forgotten words during recall tasks, suggesting the ability to inhibit information gradually improves over the elementary school years. Tipper (1985) used the negative priming effect in the Stroop task to demonstrate cognitive inhibition by comparing performance on a standard Stroop task to performance on a negatively primed Stroop task. In the negative priming condition, the color to be named on trial *n* is identical to the color word on trial *n*-1. Individuals performed slower on the negative priming condition, supporting the idea that the stimuli to be ignored, the written word, are inhibited and impairing processing. This demonstrates the key difference between cognitive inhibition and resistance to interference. In cognitive inhibition the information must have been activated in working memory and then suppressed. In resistance to interference the information is ignored and prevented from entering the working memory space. If the word in the negative priming Stroop task does not enter the working memory space, difference between the standard Stroop task and the negative priming Stroop task should not be evident.

Cognitive Inhibition versus Behavioral Inhibition

Distinctions between cognitive inhibition and behavioral inhibition also need to be defined. Although theorists believe these two constructs are interrelated, they do have different functions in human social life (Bjorklund & Kipp, 1996). Bjorklund and Kipp define cognitive inhibition in terms of underlying cognitive mechanisms that allow for the suppression of irrelevant stimuli, thus regulating cognitive contents and processes. Inhibition is considered to be behavioral if the behavior displayed is important for its own sake, irrelevant of underlying cognitive processes (Bjorklund & Kipp, 1996). Behavioral inhibition is further defined as containing three interrelated processes 1) the ability to inhibit a prepotent response, 2) the ability to stop an ongoing response, allowing for a period of a delay to make decisions regarding responses, and 3) preventing disruption of the delay period and protecting the self directed responses within the delay period (Barkley, 1997). Barkley (1997, p. 67) defines a prepotent response as “that response for which immediate reinforcement (positive or negative) is available or has been previously associated with that response.” Barkley’s conceptualization of behavioral inhibition is focused on the delay of response, cessation of response, or resistance to distraction when responding (Barkley, 1997). Studies examining cognitive inhibition have included streams of consciousness studies such as the “White Bear” task developed by Wegner (1989). In this task, adult participants are instructed to “try to not think about a white bear” or to “try to think about a white bear” while producing overt streams-of-consciousness. Wegner found that following a suppression of the white bear, adults produced more white bear intrusions when released from suppression. They concluded that the act of suppression produced an increased focus on the distractor. Kipp and Pope (1997) developed the picture-naming task in an effort to explore this phenomenon in young children. Previous research had shown young children lack awareness of a stream-of-consciousness, evidenced by their beliefs that people could sit without thoughts in their mind (Flavell, Green, & Flavell, 1993). Therefore, Kipp and Pope wanted to develop a task measuring developmental changes in the ability to control and inhibit speech without the use of a verbal stream-of-consciousness. Their task required participants to look at and name each picture in a series of pictures except for a target category identified by the researcher, such as "do not name any animals." They compared children's performance on the picture-naming tasks to their performances on a stream-of-consciousness task. They found developmental changes in the ability to produce a stream of consciousness, as well as developmental changes in the ability to inhibit during the picture-naming task. Kipp and Pope concluded that the development of cognitive inhibition contributes to developmental improvements on a variety of tasks.

In order to study behavioral inhibition, researchers studying infants have used standard Piagetian A not B tasks. Researchers have found that infants will continue to reach for a toy in a previously hidden well, despite seeing researchers place the toy in alternative wells (Diamond, Cruttenden, & Neiderman, 1994). These findings have led researchers to conclude that infants are unable to inhibit the behavioral response of reaching because it has been previously reinforced and become a prepotent response (Diamond, 1985). In older children, tasks requiring children to slow down, delay or withhold responses have been used to establish behavioral inhibition (Harnishfeger & Bjorklund, 1993). Logan and his colleagues have used the stop-signal test to measure behavioral inhibition (Logan & Cowan, 1984; Logan, Cowan, & Davis, 1984). This task requires participants to engage their attention to a primary task, such as a forced-choice letter discrimination task, while being instructed to inhibit a response to the primary task whenever an auditory signal is presented. They found that differences between second grade children and adults were not significant, concluding behavioral inhibition to be developed by the second grade. Mischel, Shoda, and Peake (1988) measured behavioral inhibition in children using a delay of gratification paradigm. In their study, children were left alone in a room with a highly desirable object (two marshmallows), and instructed that if they resisted consumption of the object, they would be able to have both objects when the experimenter returned to the room. The children were also told to ring a bell if they didn't want to have to wait any longer while the experimenter was out of the room. Variations in waiting time were used as the prime measure of behavioral inhibition. They found that children who were able to wait longer at the ages of four and five years old were more socially and academically competent as adolescents. In addition, these children were more attentive, planful, and able to adjust to frustration and stress.

Cognitive Inhibition studies with individuals with ADHD

Working memory is one of the four executive functions diminished by ADHD children's deficit in behavioral inhibition. Barkley (1997) proposes that children with ADHD will be less likely to use internally represented information when responding to situations, and will be more likely to be influenced by context. This deficit leads to less planning and use of strategies when organizing internally represented information in working memory (Barkley, 1997). Research has shown ADHD children have less resistance to interference and are less able to remember information when it requires the effective organization of material (Borcherding, Thompson, Krusei, Bartko, Rapoport, and Weingartner, 1988; Bremer and Stern, 1976; Leung and Connolly, 1996; Rosenthal and Allen, 1980). Researchers have used the Stroop Test to show differences between children with and without ADHD, showing children with ADHD process information at slower speeds when distracting information is simultaneously presented (Visser, Das-Small, and Kwakman, 1996).

Gaultney, Kipp, Weinstein, and McNeill (1999) used the negative-priming Stroop Test and a directed forgetting memory task to assess cognitive inhibition in children with ADHD, ranging in age from 8-15 years old. Their results did not evidence significant difference in the ability for ADHD children to cognitively inhibit when compared to non-ADHD children. However, their findings on the negative priming Stroop Test did show that ADHD children were slower on the task, leading the authors to conclude that although ADHD children could cognitively inhibit, it was a more effortful process than for those without ADHD. White and Marks (2003) also used a directed-forgetting task to assess intentional forgetting in individuals with ADHD. In their study, individuals with ADHD were not able to demonstrate intentional forgetting as effectively as the non-ADHD children, leading the authors to conclude that deficits in intentional forgetting effect working memory functioning of individuals with ADHD.

CHAPTER 3

Method

Participants

Participants were forty-five fourth and fifth grade students selected from public elementary schools in Georgia and Texas. The sample consisted of thirty male and sixteen female participants. The mean age was 10.97 years, with a standard deviation of .67. Participants were divided into two groups based on a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD). Group one (n = 23) consisted of those students who had not received a diagnosis of ADHD. The average age of group one was 10.82, with a standard deviation of .62. Group one consisted of eleven males and twelve females. Nineteen of the participants were identified as Euro-American, three were identified as Afro-American, and one participant was identified as Hispanic. Group two initially consisted of twenty-three participants identified as being diagnosed with ADHD. Follow-up interviews with parents revealed that two of the participants had been diagnosed ADHD- Primarily Inattentive and one participant had been identified as having a comorbid thought disorder. Due to research suggesting the primarily inattentive subtype of ADHD may be a distinct and separate disorder (Milich, Balentine, & Lynam, 2001), it was decided this subtype would not be included in the study. Consequently, these three participants were removed from the participant pool. Seventeen of the participants remaining in group two were identified as being diagnosed with ADHD- Combined type, and three were identified as being diagnosed with ADHD- Predominantly Hyperactive. The participants remaining had an average age of 11.10 years, with a standard deviation of .74.

Group two consisted of sixteen males and four females. Seventeen of the participants were identified as Euro-American, two were identified as Afro-American, and one was identified as Hispanic. Demographic data is summarized in Table 3.1. Follow up interviews with parents revealed thirteen of the children were taking prescription medication for their symptoms (see Table 3.2).

Table 3.1 Sample Demographic Data

	n	*% of total sample*
Without ADHD	23	57.5%
Male	11	25.6%
Female	12	27.9%
European American	19	44.1%
African American	3	6.9%
Hispanic	1	2.3%
With ADHD	20	46.5%
Male	16	37.2%
Female	4	9.3%
European American	17	39.5%
African American	2	4.7%
Hispanic	1	2.3%
ADHD- Combined	17	39.5%
ADHD- Primarily Hyperactive	3	6.9%
On Medication	13	30.2%
Off Medication	7	16.2%

Table 3.2 Sample Treatment Data

# of Participants	Treatment with Medication	Type of Medication	Dosage
7	No		
1	Yes	Concerta	54 mg
2	Yes	Concerta	36 mg
1	Yes	Adderall	3.25 mg
1	Yes	Adderall	5 mg
2	Yes	Adderall	10 mg
2	Yes	Adderall	20 mg
1	Yes	Adderall	40 mg
2	Yes	Ritalin	20 mg
1	Yes	Strattaira	15 mg

Measures

All participants were given the same battery of tasks, though the ordering of the tasks was counterbalanced (Appendix A). The tasks selected included a variety of measures designed to assess cognitive inhibition and a brief measure of cognitive ability. The tasks used to assess cognitive inhibition included a directed forgetting task, a picture naming task, a negative priming condition of the Stroop task, and a sentence completion task. The task used to assess cognitive ability was the Matrices subtest from the Kaufman Brief Intelligence Test (K-Bit).

Materials

Kaufman Brief Intelligence Test - Matrices Subtest. Children's cognitive ability was assessed using the Kaufman Brief Intelligence Test- Matrices Subtest. This task was chosen based on Carroll's Three Stratum Theory of intelligence (1997). According to this theory, matrices tasks have the highest loading on the general intelligence factor "g."

Directed Forgetting Task. Previous researchers using directed forgetting tasks found evidence supporting its use as a measure of cognitive inhibition (Harnishfeger & Pope, 1996; Wilson & Kipp, 1998). Findings have shown adults to be able to have a high recall for to-be-remembered words, with little interference from to-be-forgotten items (Bjork, 1970). In addition, recognition tasks have shown the to-be-forgotten items to still be in working memory, as adults are able to recognize to-be-forgotten words as well as to-be-remembered words (Bjork, 1970). Based on these findings, it was assumed that cognitive inhibition was the primary contributor to the ability to have high recall for to be remembered words when task-irrelevant words were inhibited from working memory, but released during a recognition task. In order to measure cognitive inhibition, a directed forgetting measure was administered using a remember-remember condition to provide a measure of recall, and a forget-remember condition to provide a measure of cognitive inhibition. Directed-forgetting is a traditional measure of cognitive inhibition in the research literature. See Appendix B for a more detailed description of the Directed-Forgetting task and appendices C and D for examples of the data collection protocol.

Picture Naming Task. The Picture Naming task is new to the cognitive inhibition literature. This task, developed by Kipp and Pope (1997), is a measure that can assess the development of cognitive inhibition in younger children. Previous research using tasks such as directed forgetting tasks have found cognitive inhibition to begin to surface over the elementary school years (Harnishfeger & Pope, 1996). Kipp and Pope believe children may not be able to exhibit the ability to cognitively inhibit due to the task requirement of remembering lists of words. It was hypothesized that this requirement is unfamiliar to children in the early grade school years, whereas the naming of pictures is a more familiar task. Therefore, asking children to inhibit picture names may be more effective for the assessment of the underlying ability to cognitively inhibit irrelevant information in a task familiar environment. Due to research establishing the development of cognitive inhibition in children, and this researcher's desire to compare that development in children with ADHD, it was considered beneficial to include a task that may measure inhibition in younger children. If the development of inhibition is similar in children with ADHD, but delayed, measures that reveal differences in younger children were considered more appropriate for measuring cognitive inhibition in children with ADHD. For a more detailed description of the picture-naming task, see appendix E. For an example of the picture naming protocols see appendices F and G.

Stroop Task. The Stroop task is a traditional measure of resistance to interference (Stroop, 1935). It has been used in a large number of studies and is well established in the cognition literature. In addition, it has been used in the literature with ADHD children to assess deficits in working memory, specifically resistance to interference (Visser, Das-Small, & Kwakman, 1996). The negative priming condition in the Stroop is intended to measure cognitive inhibition and isolate the effects of inhibition from interference. Previous research has not used the negative priming condition in children with ADHD.

In the negative priming condition, described previously, the process of cognitively inhibiting the color-word impairs the ability to quickly retrieve the word in the subsequent stimuli, slowing down overall completion time. These differences in completion time are intended to measure the effects of cognitive inhibition. For a more detailed description of the procedures used for the Stroop Test and it negative-priming condition, see appendix H. An example of the Stroop Protocol is in Appendix I.

Sentence Completion Task. The sentence completion task was designed to assess cognitive inhibition using an implicit measure of memory rather than an explicit measure of memory (i.e. recall). The advantages to an implicit memory task include that implicit memory does not require the conscious activation of prior information in memory and has been shown to be less sensitive to developmental differences in recall ability. In other words, tasks using explicit memory, such as recall, have found differences in younger and older children that were not present when using implicit measures of memory (Lorsbach & Reimer, 1997). In this task, participants were asked to complete high-close sentences out loud with terminal nouns (e.g. "We made a sandwich with peanut butter and________[jelly]"). For half of the sentences, the responses generated by the participant were confirmed by the presentation of the expected ending. In the other half of the sentences, the participant's response was disconfirmed with an unexpected ending (e.g. "He mailed the letter without any________[help]"). Participants were instructed to remember the word presented by the experimenter at the end of the sentence, rather than the response they generated for the sentences.

This procedure was considered to represent a form of "directed ignoring." Priming served as a measure of cognitive inhibition. "Priming" refers to an increase in the frequency above baseline in which participants end different sentences presented later in time with the previously disconfirmed or target nouns. It was assumed that words that had been confirmed would receive sustained activation, and consequently suppress the activation of disconfirmed words. If participants effectively inhibited disconfirmed words, priming should be greater for target words than for disconfirmed words. If participants were not effectively inhibiting, disconfirmed items would be equal to or greater than target words as their activation had been sustained in working memory. For a more detailed description of the task, see appendix J. For an example of the sentence completion protocol, see appendices K and L respectively, for the study list and for the priming list.

Procedures

After gaining approval from the Human Subjects Committee and the local school authorities, parent permission forms were sent home with all students in a classroom. Each student was given the measures on an individual basis during the school day. The researcher and a trained research assistant collected all the data. Upon meeting the researcher, each student was informed regarding the parent permission forms and their parent's consent for the researcher to be working with the student. Verbal assent from the student was then obtained in order to assure willing participation in the research study. Test administration sessions lasted approximately forty-five to sixty minutes. The sequence of the presented measures was counterbalanced to guard against ordering effects. At the completion of each session, the researcher thanked each student and provided decorative stickers and pencils as compensation for their participation.

CHAPTER 4

Results

The purpose of the current study was to determine whether children without ADHD would out perform children with ADHD on measures of cognitive inhibition. The measures used in the current study included a brief measure of cognitive ability and a variety of tasks designed to assess cognitive inhibition. This chapter presents the results of the analyses for the present study.

Univariate Analysis of Differences in Cognitive Ability

Test scores from the matrices subtests of the Kaufman Brief Intelligence Test (K-BIT) were examined to determine if significant differences between groups on measures of cognitive ability could have been a factor affecting differences on measures of cognitive inhibition. Both groups performed in the average range on the matrices subtest of the K-Bit. The average score for the non-ADHD participants was 108.04, with a standard deviation of 10.36. The average score for the ADHD participants was 106.4, with a standard deviation of 11.22. Univariate tests of significance did not reveal significant differences between the groups on the matrices subtest (F = .249, p = .620). For descriptive purposes, information is provided in Table 4.1.

Table 4.1 Means, Standard Deviations, and Univariate Test of Significance for the K-Bit

Group	Mean	Standard Deviation	F	p
ADHD n = 20	106.4	11.22	.249	.620
Non-ADHD n = 23	108.04	10.36		

Directed Forgetting

The Directed Forgetting task is comprised of four word lists. The first two word lists, Control List 1 and Control List 2, comprise the control condition and require the participant to try to remember all words from each list. The second two word lists, Inhibition List 1 and Inhibition List 2, comprise the inhibition condition. For this condition the participant is told to "forget" the first list and remember the second list. Words remembered from these four word lists are the dependent measures for the Directed Forgetting task. Group means and standard deviations for the dependent measures on the Directed Forgetting Task are presented in Table 4.2

Table 4.2. Means and Standard Deviations for Directed Forgetting

			Non- ADHD (n= 23)		ADHD (n= 20)	
			Mean	Standard Deviation	Mean	Standard Deviation
Words Recalled	Control Condition	List 1	3.43	1.27	2.10	1.48
		List 2	2.69	1.58	3.30	1.56
	Inhibition Condition	List 1	2.17	1.40	1.65	1.76
		List 2	3.08	1.56	2.60	2.04
Words Recognized	Control Condition	List 1	9.61	.89	9.60	.50
		List 2	9.26	1.42	9.45	.76
	Inhibition Condition	List 1	9.09	.84	8.85	1.22
		List 2	9.09	1.16	9.15	1.39

Recall. The number of words recalled was examined in a 2 (group: ADHD, Non-ADHD) X 4 (list: control list 1, control list 2, inhibition list 1, inhibition list 2) with repeated measures on list condition. The analysis yielded significant interaction effects by group (Non-ADHD versus ADHD) for the number of words recalled during the directed forgetting conditions ($F = 3.23$, $p = .02$). An analysis of covariance (ANCOVA) with repeated measures was conducted using participant scores on the matrices task. This analysis yielded similar results with a significant interaction effect by group for the number of words recalled ($F = 3.19$, $p = .03$). These results do not reveal any evidence of covariance.

Due to predictions regarding the pattern of recall for the two groups, paired sample T-tests with directional hypotheses were conducted. For each group, word recall within condition yielded significant results on the control condition (ADHD, $t = -2.373$, $p < .05$; Non-ADHD, $t = 1.729$, $p < .05$). In addition, each group's word recall for the inhibition condition yielded significant results (ADHD, $t = -1.881$, $p < .05$; Non-ADHD, $t = -1.817$, $p < .05$). While the Non-ADHD group remembered more words from the first than the second list during the control condition, the ADHD group remembered more words from the second list than the first list. For the inhibition condition, the ADHD group reflected the same pattern, remembering more words from the second list than the first list, while the Non-ADHD group reversed their control pattern and remembered more words from the second list than the first list. These results are graphically represented in Figure 1.

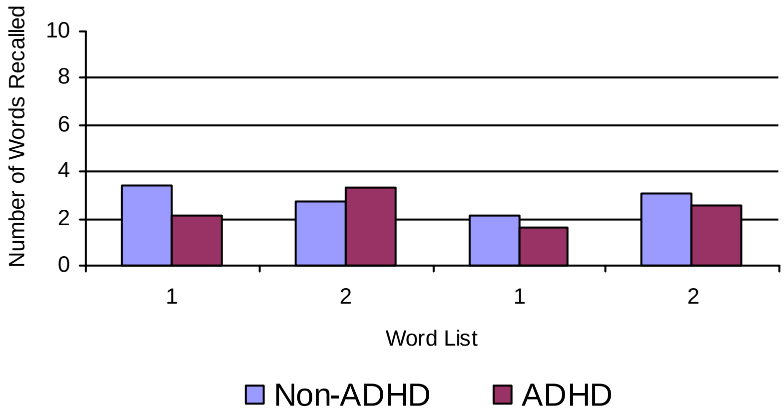

Figure 1. Word Recall on Directed Forgetting.

Recognition. The number of words recognized was examined in a 2 (group: ADHD, Non-ADHD) X 4 (list: control list 1, control list 2, inhibition list 1, inhibition list 2) with repeated measures on list condition.

The analysis of variance (ANOVA) did not yield significant results for word recognition on the directed forgetting task (F = .349, p = .790). Similarly, the analysis of covariance (ANCOVA) did not yield significant results for word recognition on the directed forgetting task (F = .445, p = .721). For both groups, word recognition approached 100%.

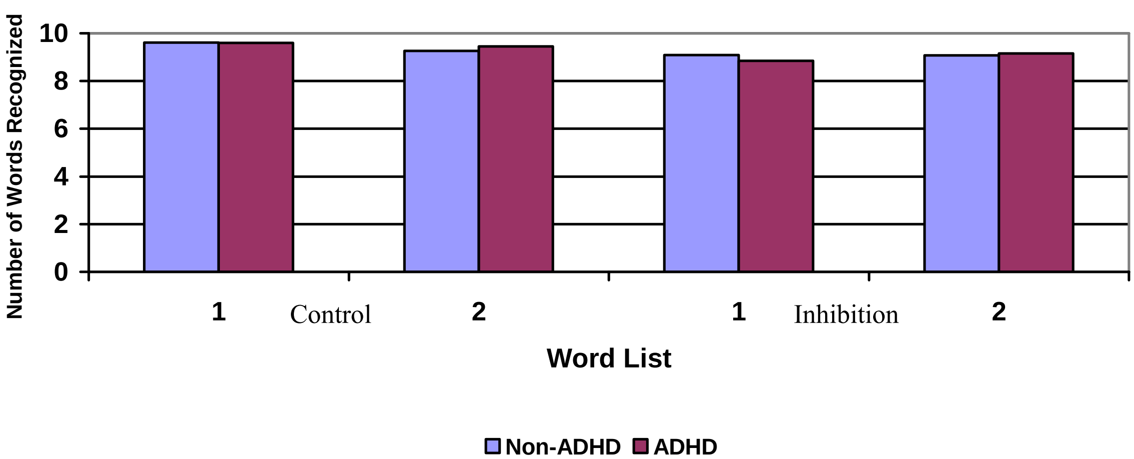

Figure 2. Word Recognition on Directed Forgetting

Picture Naming.

The Picture Naming Task included two trials, the control condition and the inhibition condition. Dependent measures for both conditions included completion time and total words recalled and target words recalled. The inhibition condition also included the number of naming errors as a dependent measure. Group means and standard deviations for the dependent measures on the Picture Naming tasks are presented in Table 4.3.

<u>Total Recall</u>. The number of total words recalled was examined using a 2 (group: ADHD, Non-ADHD) X 2 (trial: control, inhibition) analysis of variance (ANOVA) with repeated measures on trial conditions. The analysis did not yield significant interaction effects by group (Non-ADHD versus ADHD) for the total number of words recalled during the picture naming conditions ($F = .138$, $p = .712$). The analysis of covariance yielded similar results with no evidence of covariance ($F = .298$, $p = .588$). Due to predictions regarding the pattern of recall for the two groups, paired sample T-tests with directional hypotheses were conducted. For each group, word recall within condition yielded significant results (ADHD, $t = -.5015$, $p < .01$; Non-ADHD, $t = -3.361$, $p < .01$). Both groups remembered more words from the control condition than the inhibition condition. See Figure 3.

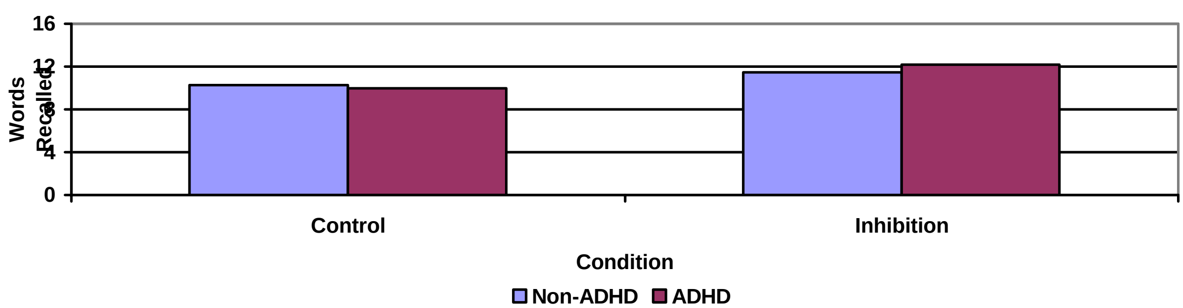

Figure 3. Total Words Recalled for Picture Naming

Table 4.3. Means and Standard Deviations for Picture Naming

		Non- ADHD (n= 23)		ADHD (n= 20)	
		Mean	Standard Deviation	Mean	Standard Deviation
Total Words Recalled	Control Condition	10.26	.50	10.00	.54
	Inhibition Condition	11.48	.57	12.20	.61
Target Words Recalled	Control Condition	3.96	1.07	4.1	1.07
	Inhibition Condition	3.30	1.22	3.3	1.26
Target Words Recognized	Control Condition	8.00	.000	7.95	.224
	Inhibition Condition	7.78	.600	7.75	.444
Picture Naming Time (seconds)	Control Condition	26.5	10.176	33.77	12.206
	Inhibition Condition	29.6	8.86	36.01	2.011
Picture Naming Errors		.174	.491	.350	.671

Target Recall. The number of target words recalled was examined using a 2 (group: ADHD, Non-ADHD) X 2 (trial: control, inhibition) analysis of variance (ANOVA) with repeated measures on trial conditions. The analysis did not yield significant interaction effects by group (Non-ADHD versus ADHD) for the number of target words recalled during the picture naming conditions ($F = .081$, $p = .778$). A paired sample T-test revealed a significant main effect for both the Non-ADHD group ($t = 1.974$, $p < .05$) and the ADHD group ($t = 2.027$, $p <$

.05). Both groups were able to recall more targets for the control condition versus the inhibition condition. An analysis of covariance (ANCOVA) with repeated measures yielded similar results as the ANOVA (F = .224, p = .639), suggesting no evidence for covariance. See Figure 4.

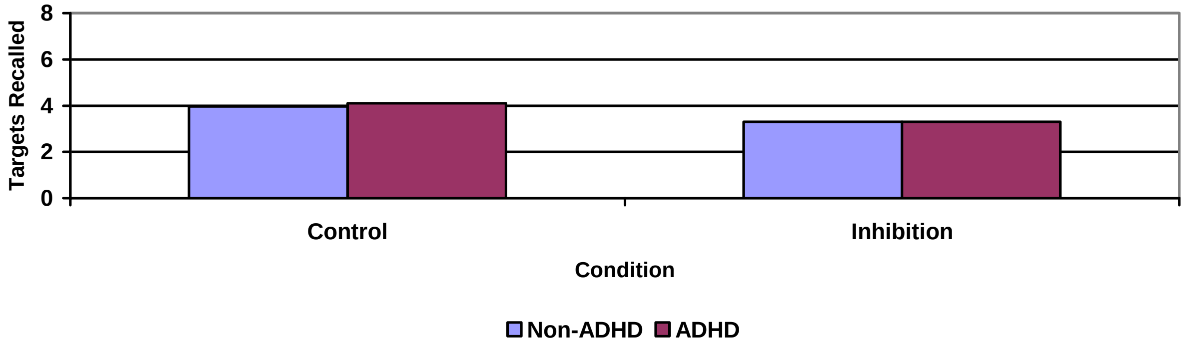

Figure 4. Targets Recalled for Picture Naming

Time. Card completion time examined using a 2 (group: ADHD, Non-ADHD) X 2 (trial: control, inhibition) analysis of variance (ANOVA) with repeated measures on trial conditions. The analysis did not yield significant interaction effects by group (Non-ADHD versus ADHD) in the amount of time to complete the picture naming card for the different conditions (F= .055, p = .816). Similarly, an analysis of covariance did not yield significant results for group differences (F = .050, p = 825), suggesting no evidence for covariance. See Figure 5.

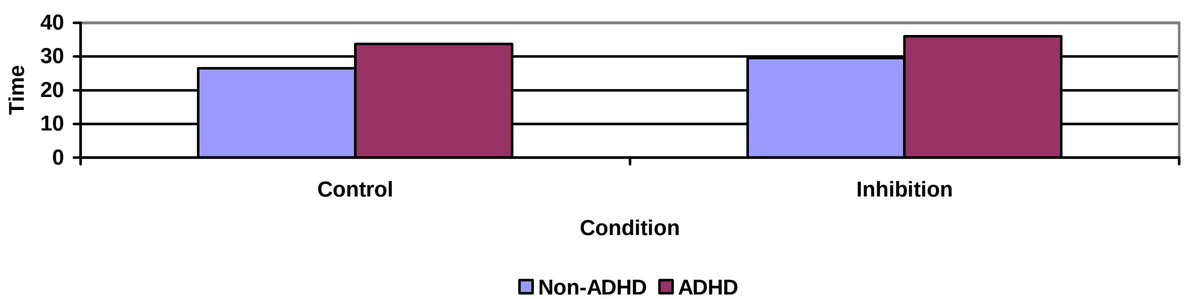

Figure 5. Picture Time Completion for Picture Naming

Naming Errors. A one-way analysis of variance (ANOVA) did not yield significant group differences for the number of naming errors committed during the inhibition condition of the Picture Naming task (F =.982, p = .328). Consistent with previous results, an analysis of covariance (ANCOVA) did not yield significant group differences for the number of naming errors (F = .897, p = .349). See Figure 6.

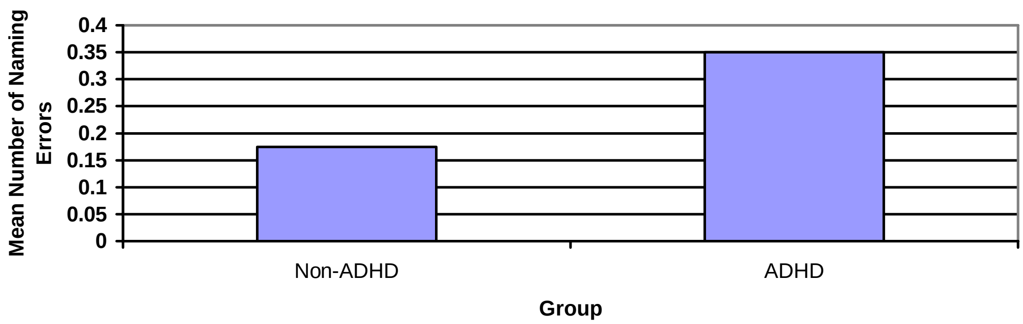

Figure 6. Naming Errors for Picture Naming

Stroop Task.

The dependent measures for the Stroop task included naming speed for each trial, interference score (proportional change in naming speed between the control trial and interference trial), inhibition score (proportional change in naming speed between the interference trial and the inhibition trial), and the number of errors committed. Group means and standard deviations for the dependent measures on the Stroop asks are presented in Table 4.4.

Table 4.4. Means and Standard Deviations for the Stroop Task

		Non- ADHD (n= 23) Mean and Standard Deviation	ADHD (n= 19) Mean and Standard Deviation
Naming Speed (seconds)	Control Stroop	14.24 (3.25)	16.73 (3.68)
	Interference Stroop	28.80 (5.03)	36.68 (9.60)
	Inhibition Stroop	29.45 (5.48)	30.21 (6.56)
Interference Score		1.08 (.44)	1.36 (.58)
Inhibition Score		.03 (.17)	-.21 (.17)
Errors	Control Stroop	.13 (.34)	.42 (.77)
	Interference Stroop	1.43 (1.41)	2.32 (2.33)
	Inhibition Stroop	1.22 (1.59)	1.84 (2.36)

Naming Speed. Naming speed was examined in a 2 (group: ADHD, Non-ADHD) X 3 (condition: control, interference, inhibition) analysis of variance (ANOVA) with repeated measures on condition. The analysis yielded significant interaction effects by group for the time it took to complete each condition during the Stroop task ($F = 12.24$, $p = .00$). Due to predictions regarding the pattern of recall for the two groups, paired sample T-tests with directional hypotheses were conducted. For the ADHD group, the change in time between the control Stroop and interference Stroop was significant ($t = -11.065$, $p < .01$) as well as the change in time between the interference Stroop and the inhibition Stroop ($t = 4.826$, $p < .01$). As predicted, the time to complete the control and interference Stroop increased between the two conditions. However, in contrast to predictions, the time to complete the interference Stroop and the inhibition Stroop decreased. For the Non-ADHD group, the change in time between the control Stroop and the interference Stroop was significant ($t = -17.286$, $p < .01$), but the change in time between the interference Stroop and the inhibition Stroop was not significant ($t = -.637$, $p > .05$). This is consistent with predictions regarding non-ADHD participants. See Figure 7.

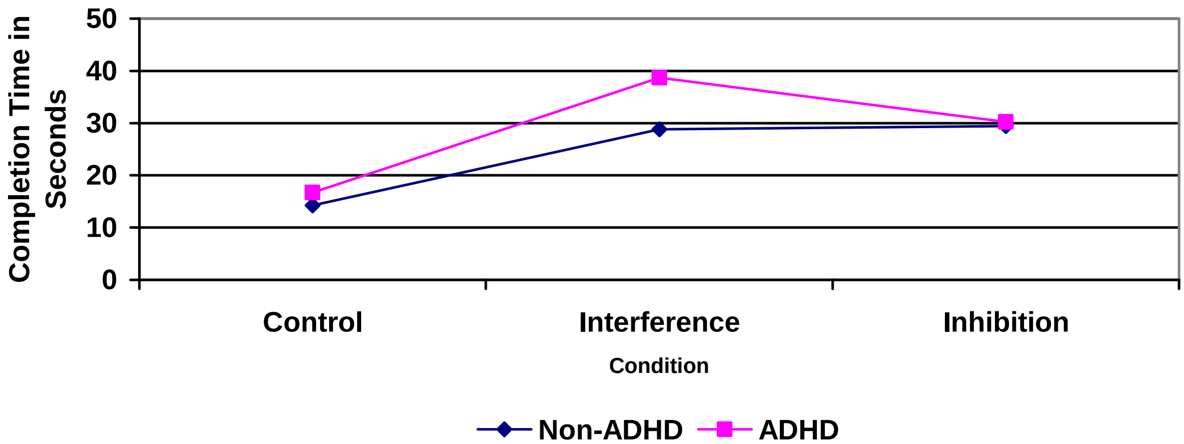

Figure 7. Stroop Time

Interference and Inhibition. Interference and Inhibition scores were examined in a 2 (group: ADHD, Non-ADHD) X 2 (condition: interference score, inhibition score) analysis of variance (ANOVA) with repeated measures on condition. The analysis yielded significant interaction effects by group (Non-ADHD versus ADHD) for the proportional change in time between the interference score and the inhibition score ($F = 8.64$, $p = .005$). The analysis of covariance (ANCOVA) with repeated measures yielded similar results with a significant interaction effect by group for the proportional change in time between the interference Stroop and the inhibition Stroop ($F = 8.37$, $p = .006$), suggesting no evidence of covariance. While the ADHD participants had a higher proportional change score between the control and interference Stroop than the Non-ADHD participants, they had a lower proportional change score between the interference Stroop and the inhibition Stroop. See Figure 8.

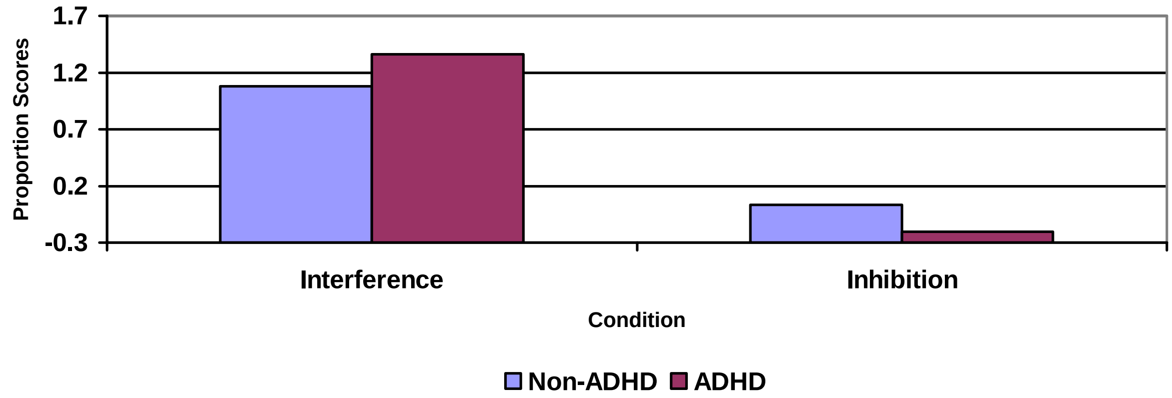

Figure 8. Stroop Interference and Inhibition Scores

Naming Errors. Naming errors were examined in a 2 (group: ADHD, Non-ADHD) X 3 (condition: control, interference, inhibition) analysis of variance (ANOVA) with repeated measures on condition. The analysis of variance did not yield significant results for the number of errors made by group while completing the different conditions of the Stroop Test (F= .556, p = .576). The number of errors completed by each group was minimal. See Figure 9.

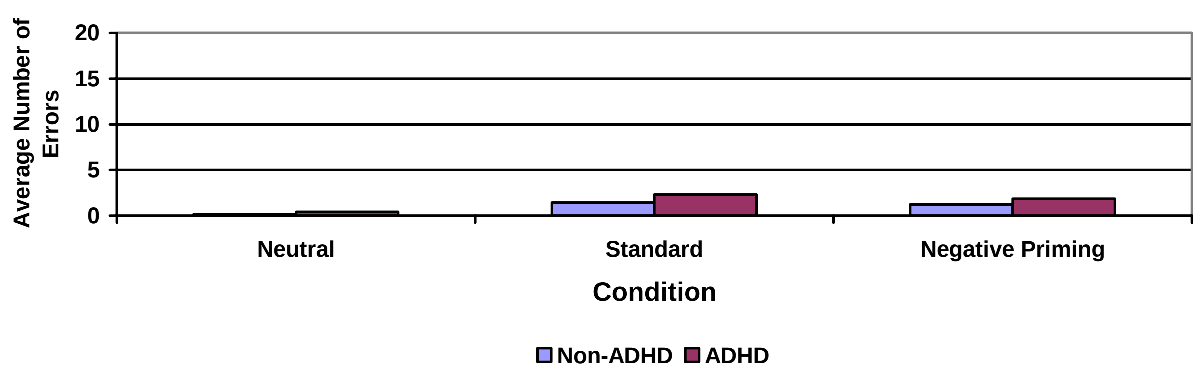

Figure 9. Naming Errors for the Stroop Task

Sentence Completion.

The dependent measures for the sentence completion task included the number of words used during the open-ended sentence completion task, both target and disconfirmed, that were primed during the priming trial of the task. Group means and standard deviations for the dependent measures on the sentence completion task are presented in Table 4.5.

Table 4.5. Means and Standard Deviations for Sentence Completion

	Non- ADHD (n= 23)		ADHD (n= 20)	
	Mean	Standard Deviation	Mean	Standard Deviation
Disconfirmed Words that were Primed	-.082	.247	-.051	.380
Target Words that were Primed	-.057	.264	-.026	.275

Priming effects. Priming effects were examined in a 2 (group: ADHD, Non-ADHD) X 2 (condition: disconfirmed, target) analysis of variance (ANOVA) with repeated measures on condition. The analysis did not yield significant interaction effects by group for the number of disconfirmed words primed ($F = .105$, $p = .748$) nor the number of target words primed ($F = .142$, $p = .708$). The two groups did not differ significantly in their response to disconfirmed nor primed words, suggesting no difference in cognitive inhibition on this task. In addition, both groups were less likely to repeat a disconfirmed word, suggesting ineffective priming results. See figure 10.

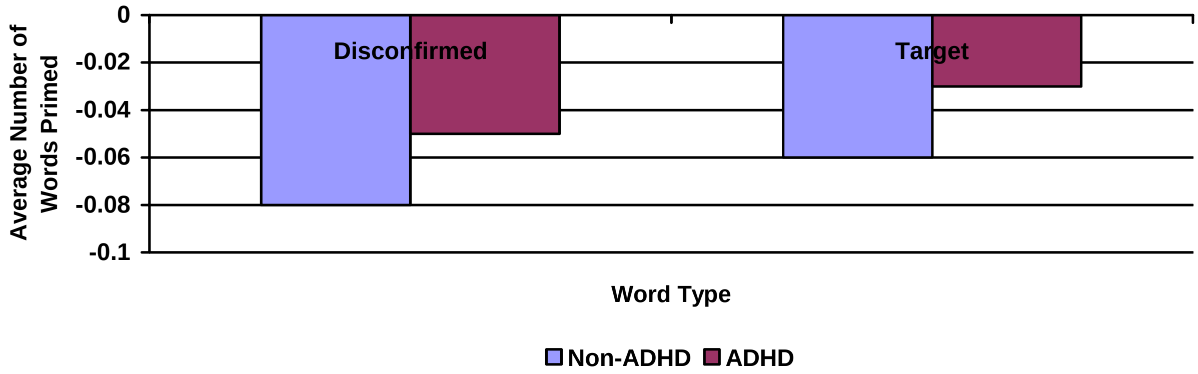

Figure 10. Sentence Completion Priming Effects

CHAPTER 5

Discussion

Evidence for Deficits in Cognitive Inhibition

Directed Forgetting.

Although the patterns of words recalled during the Directed Forgetting Task were not consistent with the expected findings, the patterns of recall do suggest the development of cognitive inhibition in children without ADHD. It was predicted that during the control condition, both groups would not evidence significant differences on word recall for the two lists. It was found that non-ADHD participants recalled more words from the first list than the second list, while ADHD participants recalled more words from the second list than the first list during the control condition. The pattern for the non-ADHD participants is consistent with research evidencing the "primacy effect" in developing children, while the pattern for the ADHD participants was more consistent with expectations for younger children (Hitch, Halliday, Schaafstal & Hefferman, 1991). This finding showed that participants with ADHD were more likely to demonstrate working memory processes consistent with younger children than their same age peers without the disorder. This was consistent with previously identified deficits associated with working memory functioning in children with ADHD (Barkley, 2003).

During the inhibition condition, the ADHD participants retained the same pattern, supporting a developmentally delayed memory development for word recall. The non-ADHD participants reversed their pattern from the control condition (demonstrating a "primacy effect") and evidenced the same pattern as the ADHD participants. That is, both groups remembered more words from the remember list than the forget list during the inhibition condition. In non-ADHD participants, this supports the development of cognitive inhibition. That is, though these participants demonstrated a tendency to remember more words from the first list during the control condition, this tendency was suppressed when they were directed to "forget" the words from the first list. Their memory for more words from the second list during the inhibition condition suggests these participants are capable of actively suppressing information from working memory. In contrast, the ADHD participants demonstrated the same pattern during the inhibition condition as in the control condition, suggesting their word recall was more likely to consistently reflect a developmentally delayed effect rather than cognitive inhibition.

In order to further explore this finding, patterns of recognition were important in order to determine whether the change in pattern for the non-ADHD participants truly reflected a suppression of words from memory rather than a failure to encode the words. Examination of the data supports a suppression of words rather than the failure to encode words for the non-ADHD participants. In other words, while the non-ADHD participants demonstrated a stronger recognition of words from the first list during the control condition, their word recognition was identical for the remember and forget lists during the inhibition condition. This would support the hypothesis that the participants were cognitively inhibiting the information, rather than failing to encode the information.

Although results were not significant for the ADHD participants, their word recognition demonstrated an unusual pattern. While these participants were recalling more words from the second list during the first condition, they recognized more words from the first list. Their patterns during the inhibition condition reflected a consistent developmentally delayed effect, with the participants being able to recall and recognize more words from the second list rather than the first list.

Picture Naming.

It was hypothesized that the Non-ADHD participants would recall the same number of words in both the control and inhibition condition of the picture naming trials. In contrast, it was hypothesized the ADHD participants would recall more words from the control trial than the inhibition trial due to a failure to inhibit target words. In contrast, both groups remembered more words from the control trial. This suggests that both groups were demonstrating the ability to inhibit during the inhibition condition. It is possible this task was not developmentally appropriate for finding differences between the two groups.

Naming Errors. It was hypothesized that the ADHD participants would commit significantly more naming errors during the inhibition condition than the non-ADHD participants. This expectation was based on research showing children with ADHD have more difficulty inhibiting a behavioral response than non-ADHD children (Barkley, 2003). It was acknowledged that differences between the groups during this task may not reflect cognitive inhibition, rather it would more likely be a reflection of behavioral inhibition. Although the pattern of results for naming errors was consistent with the hypothesis, the differences between the two groups were non-significant. Naming errors committed by each group were minimal, reflecting a well developed ability to inhibit verbal responses to stimuli for both groups and that would not impact ability to recall words for either group.

Naming Time. The analyses did not reveal significant differences by group for the amount of time it took to complete each naming trial of the Picture Naming Task. Both groups were able to complete the two tasks in approximately the same amount of time.

Stroop Task.

Naming Speed. It was hypothesized that the Non-ADHD participants would have a faster naming speed on the interference Stroop versus the inhibition Stroop, while the ADHD participants would use approximately the same amount of time for the two conditions. Contrary to this hypothesis, non-ADHD participants did not evidence a change in naming speed for the two conditions. It does not appear this measure was able to assess cognitive inhibition in these participants, possibly due to age or underdeveloped inhibition control processes. It should be noted that while the results were not statistically significant, patterns did suggest cognitive inhibition was developing in the non-ADHD participants.

Interestingly, ADHD participants' naming speed decreased between the interference Stroop and the inhibition Stroop. This suggested that rather than assessing an inhibition control process, this task may have evidenced a "priming" effect for the ADHD participants. In other words, while the negative-priming Stroop challenges the participant by requiring an immediate retrieval of the previously inhibited word, the ADHD participants appeared to be better able to retrieve the word, most likely due to a failure to fully inhibit the word. This finding suggests a retention of information in working memory space, reflecting a lack of control processes being used. For this particular task, this lack of a control process appeared to help ADHD participants complete the task faster than expected. While the finding as a whole did not reflect cognitive inhibition in non-ADHD participants, it did suggest a complete lack of inhibition in participants with ADHD.

Interference versus Inhibition. Consistent with the hypotheses, ADHD participants evidenced a higher interference score when compared to Non-ADHD participants and a lower inhibition score when compared to Non-ADHD participants. Again, interference was a measure of the proportional change in naming speed between the control Stroop and the interference Stroop (Dempster, 1993). Inhibition was a measure of the proportional change in naming speed between the interference Stroop and inhibition Stroop (Tipper, 1985). Consistent with previous research examining the effects or resistance to interference in children with ADHD, ADHD participants evidenced an increased difficulty with resisting interference than non-ADHD participants (Savitz & Jansen, 2003).

Naming Errors. It was hypothesized that non-ADHD participants would commit fewer naming errors than ADHD participants in both the interference and inhibition Stroop. However, the two groups did not differ in naming errors on these tasks. Surprisingly, ADHD participants committed only a minimal number of naming errors on the interference Stroop (mean = 2.32, standard deviation = 2.33) and on the inhibition Stroop (mean = 1.84, standard deviation = 2.36). This finding was consistent with the findings for the ADHD participants on the picture naming trials. That is, a limited ability to inhibit prepotent responses was not differentiating the ADHD participants from the non-ADHD participants.

<u>Sentence Completion</u>.

Priming Effects. Contrary to hypotheses and previous research using the sentence completion task (Lorsbach & Reimer, 1997), neither group evidenced priming effects for this task. In addition, while the groups were not evidencing a priming effect, they actually appeared to be negatively primed. Rather than evidencing a tendency to re-use words for which they should have been primed, the two groups were *less* likely to use a word for which they should have been primed.

Although these results do not lend themselves for interpretation within the realm of cognitive inhibition, they were consistent with findings previously found by other researchers using the task (Kipp, personal communication). It was in the researcher's opinion that the task was interpreted as a measure of creativity by the participants. During the initial priming phase, participants were asked to state a word to complete a sentence. The researcher would then either confirm/prime the word by using the same word or disconfirm the word by stating another word as the correct ending for the sentence. For example, the sentence "He mailed the letters without any_______" was most likely to produce the response "stamps" from the participants. However, the researcher would disconfirm this word my stating the correct end of the sentence to be "help." While this was intended to disconfirm the word "stamps", thus causing the participant to inhibit the word and try to remember the word "help" instead, the participants appeared to be focusing more on whether they were able to accurately "guess" the correct ending rather than trying to remember the words chosen by the examiner. Consequently, it appeared participants began to try to produce responses that were accurate for the sentence, but not typical. This impeded the examiner's ability to determine whether priming was occurring.

Implications for Future Research and Conclusions

While some of the tasks used in this study supported the development of cognitive inhibition in participants without ADHD (Directed Forgetting), other tasks failed to demonstrate the expected difference between the two groups (picture naming and Stroop task). However, these findings did not suggest that ADHD participants were as able to cognitively inhibit as non-ADHD participants. That is, on tasks showing cognitive inhibition in non-ADHD participants, ADHD participants were not able to cognitively inhibit. On tasks failing to demonstrate group differences for cognitive inhibition, either both groups were cognitively inhibiting or neither group was able to cognitively inhibit. More specifically, on the picture naming task, both groups were able to cognitively inhibit. This may be due to the task being more appropriate for younger children. If ADHD children are more likely to be developmentally delayed in the development of cognitive inhibition, tasks that are developmentally appropriate for younger children to display cognitive inhibition effects may be similarly appropriate for children with ADHD to demonstrate the use of cognitive inhibition. In contrast, neither group was able to use cognitive inhibition in the negative priming condition of the Stroop task. This task may not have been developmentally appropriate for assessing cognitive inhibition in children.

It would be important for future research to thoroughly examine developmental differences on these tasks in order to determine when cognitive inhibition begins to emerge for each task. This would be important to establish for both the tasks on which differences were found (directed forgetting task) and the tasks that did not demonstrate differences (picture naming task and Stroop task). It is possible that the size of the effects on tasks where differences were found may be more accentuated in younger children, further supporting developmental differences associated with the developmental disorder. Consequently, this study may have leapt ahead of necessary research establishing developmental effects on cognitive inhibition independent of ADHD.

While it was a concern that the use of medication by some of the ADHD participants would blur the differences in cognitive inhibition, this does not appear to have been a factor. That is, if medication were able to equate the two groups in the use of cognitive inhibition as a control process, both groups would have been able to demonstrate a cognitive inhibition effect. Therefore, while neither group was found to demonstrate cognitive inhibition effects on some tasks, the tasks that did evidence these differences did not appear to be effected by the use of medication. The use of medication, however, may have affected the findings that ADHD participants were not making more naming errors than non-ADHD participants.

Previous research has evidenced short-term memory improvement for children with ADHD who are taking medication for their symptoms. However, research has not explored whether medication elicits a similar improvement in memory control processes. If it is found that medication does not aid in the use of control processes, improvements in short term memory may be limited to laboratory settings and not applicable in real world settings. That is, control prcesses allow for more efficient use of memory space when competing information is taking up memory space. In the real world setting, these processes may be more heavily taxed than in a controlled laboratory setting where competing information is usually controlled for. This would help clarify the effects of medication in real world setting as well and may help teachers be better able to understand the deficits ADHD children still exhibit once medication is being used for treatment of their symptoms.

If further research is able to solidify a relationship between cognitive inhibition and ADHD, this would contribute to the understanding that behavioral inhibition is not the only factor taxing working memory in children with ADHD. This information would then contribute to the emerging multiple pathway models that are aiding in the differentiation between ADHD and other disruptive behavior disorders.

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Appendix A

Experimental Order

ADHD Inhibition Study

Experimenter __________________ Teacher ________________________

Participant# ___________________ School _________________________

Date _________________________ Grade _________________________

Birthdate______________________ ADHD Status Y N

Age___________________________

Race__________________________ Medications_____________________

Gender________________________ _______________________________

KBIT____________________

Experimental Order A
Inhibit: Animals

A

Matrices
Directed Forgetting #1 (Control)
Picture Naming #1
Sentence Completion (part 1)
Puzzle
Sentence Completion (part 2)
Picture Naming #2
Stroop
Directed Forgetting #2

B

Matrices
Directed Forgetting #1
Stroop
Picture Naming #1
Sentence Completion (part 1)
Puzzle
Sentence Completion (part 2)
Picture Naming #2
Directed Forgetting #2

Appendix B

Directed Forgetting Materials and Procedures

Materials. Four sets of 10 unrelated words were used for the recall test in the experiment. For counterbalancing purposes, four lists of words were assigned to either the control condition (remember-remember) or the experimental condition (forget-remember). An additional two sets involving the forced choice for recognition between words was also constructed. The four word sets were equated for word frequency (Ms=67.7, 70.9, 67, and 68.2) and word length (Ms=4.8, 4.8, 4.4, and 4.6). Word length was simply an average of the number of letters in the words. Word frequency was an average of the number of times each word appears in children's literature per million words (Thorndike and Lorge, 1944).

Procedure. In the control condition, each participant was given general instructions concerning the nature of the recall task. The participants were then read the first list of words at a rate of 1 word every four seconds. The participants were asked to repeat each word to assure the word was heard correctly. After the participants were read the first list, they were reminded to remember each word and to remember the next list to be read also. The participants were then read the second list of words at the same rate as the first. After both lists were read, the participants were presented the Matching Familiar Figures Test for 30 seconds as a buffer-clearing task. Recall was then assessed by asking the participants to name as many words as they can remember from both lists. Following recall, participants were then presented with the recognition tasks. Each word from the recall lists was paired with an unrelated word in random order. Participants were read the word pairs and were instructed to decide which word was on the previously presented lists.

In the experimental condition, participants were once again given the general instructions regarding the recall task. The first list was read at the same rate as the previous lists. Once again, participants were requested to repeat each word to assure accuracy. Following the presentation of the first list, the participants were told to forget the list they have just been read: "This time, I want you to forget all the words you just heard and only remember this next set of words for later." Participants were questioned regarding the instructions to ensure they understand what they were going to do: "Now, what do I want you to do with the words I just read? And what do I want you to do with the words I am going to read?" The next list was then read at the same rate as the previous lists with the same accuracy check. Following the presentation, participants were once again given the Matching Familiar Figures Test for 30 seconds as a buffer-clearing task. Recall and the recognition task follow.

Hypotheses. It was expected that participants would remember the same number of words from the two word lists (list 1 and list 2) in the control condition of Directed Forgetting. It was further expected that during the inhibition condition participants with ADHD would show less inhibition than non-ADHD participants, recalling the same number of the words from the "to be remembered" list as the "to be forgotten" list, due to an inability to cognitively inhibit the "to be forgotten" list. In contrast, Non-ADHD participants would remember more words from the "to be remembered" list than the "to be forgotten" list due to effective cognitive inhibition. See Table B.1

Table B.1 Hypothesized ADHD Group by Condition Outcomes for Recall in the Directed Forgetting Task.

	Control Condition	Inhibition Condition
Non-ADHD	List 1 ≥ List 2	List 1 < List 2
ADHD	List 1 ≥ List 2	List 1 = List 2

Appendix C

Control Condition for Directed Forgetting

I am going to read some words to you. After I read each word I want you to repeat the word so I know you heard me correctly. I want you to try and remember all the words I say.

Remember to read words at 4-second intervals

Wall
Blanket
Boat
Daisy
Owl
Butter
Fire
Weed
Mother
Scale

I want you to remember all the words you just heard and remember this next set of words for later. Okay? Now, what do I want you to do with the words I just read? And what do I want you to do with the words I am going to read?

Car
Elbow
Dress
Horse
Milk
Apple
Magnet
Spider
Church
Box

Present the MFFT for **30 seconds** using the following instructions: *I need you to find the picture at the bottom of the page that matches the top page exactly.*

After 30 seconds
Now I need you to remember as many of the words as you can from the lists I read you in any order you want.

______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________

Recall TBR1_____

Recall TBR2______

Now tell me if you remember any or these words.
Did I read ______ to you, or _________to you?

Subject#_______

Recog TBR1_____

Recog TBR2______

Fire or Woman	**Daisy** or Doll
Mother or Stew	**Scale** or Fox
Plate or **Blanket**	Fish or **Boat**
Apple or Arm	Stove or **Weed**
Car or Moss	*Elbow* or Floor
Quarter or *Spider*	Nail or **Butter**
Box or Earth	*Magnet* or Goat
Vine or *Milk*	*Dress* or Penny
Train or **Owl**	Kitchen or *Horse*
Church or Uncle	**Wall** or Piano

Appendix D

Experimental Condition for Directed Forgetting

I am going to read some words to you. After I read each word I want you to repeat the word so I know you heard me correctly. I want you to try and remember all the words I say.

Ear
Bread
Map
Soap
Bank
Hour
Pencil
Wheel
Brother
Jar

Remember to read words at 4-second intervals

What you have heard so far has been practice. This time, I want you to forget all the words you just heard and only remember this next set of words for later. Okay? Now, what do I want you to do with the words I just read? And what do I want you to do with the words I am going to read?

Candle
Bear
Cake
Sword
Nose
Pillow
Baby
Moon
Puppet
Egg

Present the MFFT for **30 seconds** using the following instructions: *I need you to find the picture at the bottom of the page that matches the top page exactly.*

After 30 seconds
Now I need you to remember as many of the words as you can, even the words that were just practice and I told you to forget in any order you want.

______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________
______________	______________	______________	______________

Recall TBF_______

Recall TBR_______

Now tell me if you remember any or these words.
Did I read ______ to you, or _________to you?

Subject #___________

Pencil or Board	**Soap** or Branch
Brother or Back	**Jar** or Clock
Door or **Bread**	Fan or **Map**
Pillow or Mountain	Guard or **Wheel**
Candle or City	*Bear* or Bridge
Ant or *Moon*	Cherry or **Hour**
Egg or Dish	*Baby* or College
Fern or *Nose*	*Cake* or Glue
Ice or **Bank**	Frog or *Sword*
Puppet or Mouse	**Ear** or Hill

Recog TBF_______

*Recog TBR*_______

Appendix E

Picture Naming Materials and Procedures

Materials. One practice card (8” x 10”) and two sets of test cards (11” x 15”) were used in the picture-naming task. Each set contains a control card and an inhibition card. The control card contained eight pictures of the target category (animals or food), eight pictures of an unrelated category (furniture or vehicles) and 6 unrelated pictures. The inhibition card contained eight pictures of the target category, eight pictures of an unrelated category, and 14 unrelated pictures. The control card contained fewer pictures in order to equate the number of pictures named for the control and inhibition cards.

Recognition cards were also used in the task. Each card contained two pictures, each from the target category of the test card. However, only one picture actually appeared on the test card and the other was a random picture from the target category.

Set-up. The four cards were used in counterbalancing to separate the control condition from the inhibition condition and each card contained one target category of pictures. When the target category for inhibition was “animals,” the target category for the control card was “food.” When the target category for inhibition was “food,” the target for the control card was “animals.”

Procedure. The first picture-naming trial in the experimental order was the control condition. Each participant was first presented with a practice card and instructed to name each picture in the card as fast as they can. Each participant practiced with the card three times, and was encouraged each time to try and go faster in order to become accustomed to naming the pictures quickly. Following the practice card, participants were presented with the control card. They were instructed to name each picture as quickly as possible and told that they would be timed for speed and would later be asked to remember as many of the pictures as possible.

Following the naming of all items, the card was promptly removed from the participant. They were then asked to recall as many items from the card as they could remember. Each participant was prompted to remember as many items from the target category as possible: “Are there any more fruits or vegetables/animals you can remember from the card?” Following recall, the participants were presented with recognition cards and were told to point to the picture that was on the card they just saw.

Later in the experiment order, the inhibition trial was presented. The participant was instructed they would once again be naming pictures on a card, but were also instructed to inhibit a target category with these instructions:

> We are going to look at a card with pictures on it again. Like before, I’d like you to name all the pictures on the card as fast as you can. The only difference this time is I’d like you to NOT name any fruits or vegetables/animals. If you do make a mistake and name a fruit or vegetable/animal don’t worry about it, just keep going. And again, I will be asking you to remember as many pictures as possible, but want you to forget all the fruits and vegetables/animals.

Following the naming of the pictures, the card was promptly removed. Participants were then requested to freely recall as many items from the card as possible. Once again, participants were prompted to remember items from the target category: “Are there any fruits or vegetables/animals you can remember from the card.”

Hypotheses. It was expected that children without ADHD would be able to effectively inhibit pictures during the inhibition condition and would be able to recall the same number of pictures for both conditions. In contrast, ADHD children would not be able to effectively inhibit pictures in the inhibition naming condition and would remember more words from the control condition. See Table E.1.

Table E.1. Hypothesized ADHD Group by Condition Outcomes for Picture Recall in the Picture Naming Task.

	Control Condition		Inhibition Condition
Non-ADHD	Picture Recall	=	Picture Recall
ADHD	Picture Recall	>	Picture Recall

It was expected that children with ADHD would make more picture naming errors during the inhibition condition than non-ADHD children due to difficulties with cognitive and behavioral inhibition. See Table E.2.

Table E.2. Hypothesized Picture Naming Errors by Group for Picture Naming.

	Picture Naming Errors		
Group	Non-ADHD	<	ADHD

It was also expected that children with ADHD would require more time to complete the inhibition condition, suggesting more difficulty cognitively inhibiting task-irrelevant information, when compared to Non-ADHD children. See Table E.3.

Table E.3. Hypothesized ADHD Group by Condition Outcomes for Picture Naming Time.

	Control Condition		Inhibition Condition
Non-ADHD	Naming Speed	=	Naming Speed
ADHD	Naming Speed	<	Naming Speed

Appendix F

Picture Naming Control Condition

Place Practice Card in front of subject *In a minute I 'm going to show you a card containing several pictures. It will be similar to this practice card except the real card will have more pictures on it. What I would like you to do is start at the first picture* [point to top left picture...and subsequently each picture after that] *and go from picture to picture naming each one out-loud as fast as you can. Don't stop until you have named all the pictures on the card. Give each picture only one name, and try to be correct when naming the pictures, but don't get stuck on one. If you are not entirely sure what though picture is, just give it your best guess and go on to the next picture as fast as you can. UNDERSTAND? OK, lets practice with this card. When I say go, name all of the pictures on the card as fast as you can. READY...GO.* [SUBJECT NAMES PICTURES] *GREAT! I'd like you to practice again, this time see if you can go even faster...Try to go as fast as you can. OK? READY...GO* [SUBJECT NAMES PICTURES] *GREAT! Let's try one more time to see if you can go even faster. READY...GO.* [SUBJECT NAMES PICTURES]. *That was your best time yet!*

Control time ________________

Okay, now we are going to play the actual game. This next card is going to have several rows of pictures. Try to name all of the pictures on the card as fast as you can. Start with the picture on the upper left and name each picture in order from left to right, top to bottom, just as you would if you were reading a book. I am going to time you to see how fast you can complete the card. And I want you to try and remember as many of the pictures as you can. Start when I say go, OK? READY...
[Make sure the last 8 pictures on the card are missing before you place the card in front of the subject] *GO*

Remove card as soon as the subject is finished
Good! Tell me all the items that you can remember from that last card, not the practice card, in any order that you like. There is no time limit, go ahead whenever you are ready. (When subject has stopped…) *Are there any more items that you can remember from the card? Are there any more fruits or vegetables you can remember from the card?*

____
____
____

Number of items recalled ______________

Number of **Targets** Recalled ______________

Good! Now I want you to point to the picture that was on the card I just showed you.
Circle the picture recalled

Grapes or Mushroom	Pumpkin or Lettuce	Number of Targets Recognized ____________
Bell Pepper or Apple	Lemon or Pear	
Carrot or Cherry	Onion or Corn	
Strawberry or Banana	Pineapple or Watermelon	

Appendix G

Picture Naming Experimental Condition

We are going to look at a card with pictures on it again. Like before, I'd like you to name all the pictures on the card as fast as you can. The only difference this time is I'd like you to NOT name any animals. If you do make a mistake and name an animal don't worry about it, just keep going. And try and remember as many pictures as you can, except you don't need to remember any animals. Don't start until I say go. I'm going to time you again to see how fast you can complete the card. Try to go as fast as you can. READY...Go.

Targets Named during Inhibition

____

Inhibition time________________

Naming Errors

____

Remove card as soon as the subject is finished

Good! Tell me all the items that you can remember from that last card, not the practice card, in any order that you like. There is no time limit, go ahead whenever you are ready. (When subject has stopped…) *Are there any more items that you can remember from the card? Are there any more animals you can remember from the card?*

____

____

____

Number of items recalled ____________

Number of **Targets** Recalled _____________

Good! Now I want you to point to the picture that was on the card I just showed you.

Circle the picture recalled

Horse or Penguin	Giraffe or Lobster
Dog or Owl	Skunk or Elephant
Bear or Kangaroo	Camel or Lion
Cheetah or Monkey	Snake or Rabbit

Number of Targets Recognized

____

Appendix H

Stroop Materials and Procedures

Materials. Cards are used representing three different Stroop conditions: neutral, interference, and negative priming. In the neutral condition, participants identified the ink colors of a list of x-strings. In the interference condition, participants identified the ink colors of a list of color names printed in various ink colors that were not related to the color name. For example, the word red was written in the ink color blue. In the negative priming condition, the ink color to be named on trial n was identical to the color name on trial n-1. Each card contained 20 items.

Procedure. Following an introduction, participants were presented with two practice cards. The first practice card asked the participant to read five color names written in black ink, and then to name five ink colors presented in block form. Each participant was then presented with two cards for each condition, beginning with the neutral card, the interference card, and negative priming card, and then repeating the order with different cards for the same conditions. Participants were timed for how long it took to read each individual card.

Hypotheses. It was expected that children without ADHD would take more time to complete the inhibition condition than the interference condition. In contrast, ADHD children would not differ in time for the different conditions due to a failure to cognitively inhibit stimuli. See Table H.1.

Table H.1. Hypothesized ADHD Group by Condition Outcomes for Naming Speed for the Stroop Task.

	Interference Condition		Inhibition Condition
Non-ADHD	Naming Speed	<	Naming Speed
ADHD	Naming Speed	=	Naming Speed

It was expected that participants without ADHD would show decreased effects of interference than participants with ADHD and show increased effects of inhibition when compared to ADHD participants. See Table H.2.

Table H.2. Hypothesized ADHD by Condition Outcomes for Interference and Inhibition Patterns for the Stroop Task.

	Interference	Inhibition
Proportional Change	Non-ADHD < ADHD	Non-ADHD>ADHD

It was further expected that participants with ADHD would commit more naming errors than non-ADHD participants on both the interference and inhibition conditions due to difficulties inhibiting prepotent responses (Barkley, 1996; Barkley 2003). See Table H.3.

Table H.3. Hypothesized Naming Errors by Group for the Stroop Task.

	Interference Condition	Inhibition Condition
Naming Errors	Non-ADHD < ADHD	Non-ADHD <ADHD

Appendix I

Stroop Protocol

We are going to play another game that we call rainbow words. In this game we will be reading some words and naming some colors. Listen carefully to the directions I give you for each card.

[Word/Color card]: *For this card can you read the words out loud from top to bottom?.........Good.*

[Color card] ***Now can you name the colors from top to bottom?.........Good.***

[Practice Card] *Now we are going to practice with this card. Here are some words and rows of x's mixed together. What I want you to do is to name the ink colors from top to bottom as fast as you can. Try to be accurate, but if you make a mistake don't worry about it, just keep going. I'll ask you to begin as soon as I say go. Remember to name the ink colors as fast as you can. UNDERSTAND? OK, READY....Go.*

[A1] *Good! Now we will begin the actual experiment. From now on I will be keeping track of your time and mistakes. Just like in practice, when I tell you to go, I'd like you to name all the ink colors as fast as you can. This next card contains rows of x's. Try to be accurate, but also go fast. OK, READY...GO.*

Red	Orange	Yellow	Blue	
Black	Red	Green	Orange	
Green	Blue	Orange	Yellow	
Black	Red	Green	Blue	
Green	Blue	Red	Green	Time:__________
Errors______				

[B1] *Good! Now we are going to do the same thing with a different card containing words. Try to name the ink colors as fast as you can. READY....GO.*

Orange	Blue	Black	Yellow	
Blue	Yellow	Yellow	Black	
Yellow	Black	Blue	Red	
Black	Red	Green	Orange	
Green	Orange	Orange	Yellow	Time:__________
Errors______				

[C1] *Good! Now we are going to do the same thing with another card. Again, try to name the ink colors as fast as you can. READY....GO.*

Orange	Orange	Green	Red	
Green	Blue	Black	Black	
Yellow	Black	Yellow	Yellow	
Blue	Yellow	Green	Blue	
Red	Red	Orange	Green	Time:__________
Errors______				

Stroop (Cont.)

[A2] *Good! This next card is going to contain rows of x's again. Same as before, try to mane the ink colors as fast as you can.*

Black	Yellow	Black	Red	
Yellow	Blue	Red	Yellow	
Red	Black	Green	Blue	
Blue	Orange	Yellow	Orange	
Green	Yellow	Black	Green	Time:__________
Errors______				

[B2] ***Good! This next card contains words. Again, try to name the ink colors as fast as you can. READY...Go.***

Green	Black	Red	Green	
Yellow	Blue	Orange	Red	
Blue	Green	Green	Blue	
Orange	Blue	Black	Green	
Red	Black	Blue	Yellow	Time:__________
Errors______				

[C2] *Good! Now we are going to do the same thing with this card. Once again, try to name the ink colors as fast as you can. READY...GO.*

Red	Red	Green	Black	
Blue	Yellow	Black	Red	
Black	Blue	Red	Green	
Green	Red	Yellow	Orange	
Blue	Orange	Blue	Yellow	Time:__________
Errors______				

Appendix J

Sentence Completion Materials and Procedure

Materials. A study list and priming list were created using sentences generated by Lorsbach and Reimer (1997). The study list contained twelve sentences. Six sentences that contained a highly constrained terminal noun, generated from previous studies with Lorsbach and colleagues, were included as filler sentences (e.g. "Butterflies fly by flapping their *wings").* Six critical sentences were used that contained a high probability response and a low probability response, generated and normed by Lorsbach and Reimer. The high probability responses were referred to as "disconfirmed" nouns, and the low probability responses were referred to as "target" nouns. For each of the six critical sentences, the high probability response was "disconfirmed" for the participant when the low probability response was presented to the participant as the "real" ending of the sentence. The unexpected, low probability, responses served as the to-be-remembered target nouns. The filler sentence nouns were never disconfirmed.

The priming list contained 24 sentences, each of which moderately constrained the respective terminal nouns. Twelve of the 24 sentences were designed to indirectly test memory for the disconfirmed and target nouns from the study list. Of these sentences, 6 tested for disconfirmed nouns and 6 tested for target nouns. For example, the study lists contained the sentence frame, "The fireman is fighting a ___." which had the high-probability response "fire" as well as the low probability ending "cold." In this case, "fire" provided the anticipated, but disconfirmed ending, and "cold" provided the low-probability target ending that served as the to-be-remembered noun. The other 12 sentences served as control sentences, and were used for counterbalancing the task with different subjects.

Procedure. Participants were told they would be read a series of sentences for which they were to say out loud what they thought the ending of the sentence would be. They were then instructed that following a brief delay, the examiner would present the "real" ending of the sentence. They were told it did not mean their answer was right or wrong, but they were to remember the real end of the sentence for later. Two practice sentences were read to be sure the participant understood the task. The sentences were presented with six seconds for the participant to speak their response, followed by the examiner reading the "real" end of the sentence. Five seconds were allowed between sentences. Following the presentation of the 12 study list sentences, participants were given a puzzle to complete for five minutes, serving as a non-verbal filler activity.

After the filler activity, participants were then told they would be read a new set of sentences for which they were to provide an ending. They were asked to complete the sentences with the first word that came to mind. These sentences were the priming list and each participant's response was recorded for each sentence.

Hypothesis. In accordance with previous research (Lorsbach & Thomas, 1997), it was expected that participants without ADHD would not show significant inhibition effects, remembering approximately equal numbers of confirmed and disconfirmed words. That is, these participants would still respond to the priming of the confirmed words, but would fail to significantly inhibit the disconfirmed words. In contrast, it was expected that participants with ADHD would not show priming for confirmed words above the priming for disconfirmed words due to failures to inhibit disconfirmed words. Consequently, ADHD participants would remember more disconfirmed words than target words. These findings were expected based on research conducted by Lorsbach and Thomas (1997) showing younger children to remember more disconfirmed nouns than targeted nouns, and with conclusions drawn that these findings were due to failures to inhibit. See Table J.1.

Table J.1. Hypothesized ADHD Group by Condition Outcomes for Word Recall for the Sentence Completion Task.

	Words Recalled		
Non-ADHD	Target Words	=	Disconfirmed Words
ADHD	Target Words	<	Disconfirmed Words

Appendix K

Sentence Completion Protocol

Part 1: Study List

In a minute I am going to read you some sentences. There will be a pause before the last word in the sentence. During the pause, I want you to guess what the last word of the sentence might be. Then I will tell you what the real end of the sentence is. Sometime the last word will be the word you guessed and sometimes it will not be. No matter what, I want you to try and remember the word I say at the end of the sentence.

I am going to read you some sentences for practice. For each sentence there will be a pause before the last word. Guess what the last word is going to be and then listen for the real last word. The real last word is the word that you want to remember for later.

A. The pigs wallowed in the _______. _________*(mud)*
B. At first the girl refused, but then she changed her ________. _________*(clothes)*

Ask if they are ready to continue with the actual experiment and turn on the tape player.
Read the sentences allowing 5 seconds for them to fill in the blank. Then say the word in all capital letters at the end of the sentence. Allow 6 seconds between sentences.

1. Bugs bunny likes to eat ____________________(carrots) CARROTS.
2. Rain, rain, go away. Come again another ___________________(day) DAY
3. He mailed the letters without any_________________(stamps) HELP.
4. The bright sun was hidden behind a large___________________(cloud) MOUNTAIN.
5. Apples grow on an apple__________________(tree) TREE
6. The fireman is fighting a__________________(fire) COLD.
7. After seeing the tangles, the girl said "I need to brush my _________________(hair) DOG.
8. The chicken laid an __________________(egg) EGG.
9. The theater was so crowded he could not find his _______________(seat) FRIENDS.
10. When it started to rain, they stopped the baseball__________________(game) PARTY.
11. He put a dollar into his piggy___________________(bank) BANK.
12. Butterflies fly by flapping their __________________(wings) WINGS.

Filler test
We are going to do something different now. We need to collect some data for another study we are working on. This is not a memory task. We will get back to that later.

Work on filler task (a puzzle) for five minutes.

Appendix L

Sentence Completion Protocol

Part 2: Priming List

In these sentences, I would like you to fill in the blank with the first word that comes to mind.

1. The farmer is harvesting the_____________________________(corn).T
2. My brother bought tickets to the __________________________(game). ****D**
3. When he left home he amazed his _________________________(friends).*** *T**
4. For garden plants to grow, they need lots of ___________________(water).D
5. While reading, I saw a picture of the movie star in the _____________(magazine).T
6. Danny caught the ball with his _____________________________(hand).T
7. The little boy was frightened by the big ________________________(dog). ****T**
8. The men will attempt to climb that steep _______________________(mountain).****T**
9. He stayed home from school and took some medicine for his ____________(cold).****T**
10. Billy was very tired and wanted to go to ________________________(sleep).T
11. My teacher asked me if I needed some __________________________(help).****T**
12. The woman was introduced to the ____________________________(man).T
13. Mother said, "When you finish playing, please put away your __________(toys)."T
14. Mary got dressed to go to __________________________________(school). D
15. The student moved because she was in the wrong __________________(seat)**.**D**
16. She has very pretty ______________________________________(hair). ****D**
17. The sandwich would taste better with a slice of ___________________(cheese).D
18. I cannot do my homework because I forgot my ____________________(book). D
19. I wanted to warm up, so I stood beside the ______________________(fire). ****D**
20. Look in the sky and see that _________________________________(cloud).****D**
21. Father said, "We cannot leave unless I find my ___________________(key). D
22. Because it was so dark outside, I could hardly read the _______________(sign). D
23. We were having fun until we ran out of food at the _________________(party).****T**
24. The package was not sent because it did not have any ________________(stamps). ****D**

Appendix M

Pilot Study

Pilot testing was conducted with six ADHD and six non-ADHD participants at an elementary school in order to gather preliminary information for the current study. The pilot testing implemented the same procedures and materials as the current study. Participants were divided into two groups based on a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD). Group one (n = 6) consisted of those students who had not received a diagnosis of ADHD. The average age of group one was 9.3, with a standard deviation of .59. The mean score on the Matrices subtest of the K-Bit was 101.5 (sd = 13.75). Group two (n = 6) consisted of participants identified as being diagnosed with ADHD. The mean score on the Matrices subtest of the K-Bit for group two was 98.33 (sd = 11.23). Data analyses revealed the following results:

Directed Forgetting. The participants for the pilot study produced the following mean recall and recognition scores on the Directed Forgetting Task. Preliminary analyses following the plan outlined above did not reveal significant effects, although the patterns of performance were in the expected directions. See Table M.1

Table M.1 Directed Forgetting

Non-ADHD Children:

	Control Condition (Remember-Remember)	Experimental Condition (Forget-Remember)
List 1	1.83 (.75)	0.83 (.75)
List 2	3.33 (1.03)	2.50 (1.04)

ADHD Children:

	Control Condition (Remember-Remember)	Experimental Condition (Forget-Remember)
List 1	1.33 (1.03)	1.00 (1.54)
List 2	2.5 (1.37)	1.67 (1.96)

Picture Naming. The participants for the pilot study produced the following mean scores on the Picture Naming Task. Preliminary analyses following the plan outlined above did not reveal significant effects, although the patterns of performance were in the expected directions, with the exception of naming errors. See Tables M.2, M.3, M.4, M.5.

Table M.2 Picture Naming Naming Errors

	Mean Number of Errors
Non-ADHD	.167
ADHD	0

Table M.3 Targets Recalled

	Control	Experimental
Non-ADHD	3.5 (1.87)	4.0 (.63)
ADHD	2.8 (1.94)	4.5 (1.38)

Table M.4 Targets Recognized

	Control	Experimental
Non-ADHD	8.0 (.00)	7.8 (.41)
ADHD	7.8 (.41)	7.8 (.41)

Table M.5 Picture Naming Time

	Control	Experimental
Non-ADHD	33.51 (9.74)	32.60 (5.49)
ADHD	30.20 (5.60)	39.36 (13.39)

Stroop. The participants for the pilot study produced the following mean scores on the Stroop Task. Preliminary analyses following the plan outlined above did not reveal significant effects, although the patterns of performance were in the expected directions. See Tables M.6, M.7

Table M.6 Stroop Interference and Inhibition Scores

	Interference	Inhibition
Non-ADHD	130.0% (53%)	8.3% (17%)
ADHD	105% (38%)	7.6%(15%)

Table M.7 Stroop Errors

	Neutral	Standard Stroop	Negative Priming
Non-ADHD	.08	4.08	2.5
ADHD	.08	4.0	3.1

Sentence Completion. The participants for the pilot study produced the following proportion for target and disconfirmed words on the Sentence Completion Task. Preliminary analyses following the plan outlined above did not reveal significant effects. See Table M.8.

Table M.8 Sentence Completion Proportion Scores

	Proportion of Targets named	Proportion Disconfirmed named
Non-ADHD	0	0
ADHD	0	0