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An Examination Of Executive Function And Reading Ability In Children With A Reading Disability And Attention-Deficit/Hyperactivity Disorder

Shyla Leigh Muse

AN EXAMINATION OF EXECUTIVE FUNCTION AND READING ABILITY IN CHILDREN WITH A READING DISABILITY AND ATTENTION-DEFICIT/HYPERACTIVITY DISORDER

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25

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TABLE OF CONTENTS

LIST OF TABLES

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ABSTRACT

This study compared 56 children between the ages of 7 and 13 with Attention-Deficit/Hyperactivity Disorder (ADHD), children with a diagnosis of ADHD and a reading disability (ADHD/RD), children with only a reading disability (RD), and a control group on measures of cognition, reading, executive function, and memory tasks. Specifically, the study was looking to examine the impact of comorbid disorders on the performance of children with ADHD on tests of cognitive function. Given that children diagnosed with ADHD frequently will display a learning disability, often a reading disability, this study also examined the impact of comorbidity on tests of cognitive function. All children were administered several measures of cognitive functioning, reading comprehension, executive function measures, and memory tasks. The data analysis consisted of comparing the children's performance from the four different groups on a variety of tasks.

The results of the present study suggest that there are differences in performance on several measures of cognitive, reading, executive function, and memory ability between the four groups studied. Overall, the Control group had better performance than the other groups. Children in the ADHD and ADHD/RD group had deficits on various executive function and memory tasks. Children in the RD group had lower performance on various reading tasks.

CHAPTER I

INTRODUCTION

Attention-Deficit/Hyperactivity Disorder (ADHD) is found in 3-5% of the general child population. ADHD is more often diagnosed in boys than girls. In community samples, the ratio is 3:1, and in clinic samples, the ratio can be as high as 6:1 (Netherton et al., 1999). ADHD consists of three primary symptoms. The three primary symptoms are inattention, hyperactivity, and behavioral disinhibition or impulsiveness. Inattention is described as the individual having difficulties sustaining attention, especially with boring, dull tasks. The child is often described as a daydreamer, often losing their items, has problems concentrating, and often does not finish their assigned work. A child who is considered to have problems with hyperactivity tends to fidget, talk excessively, and has problems sitting still. A child that starts an activity before listening to the instructions or blurting out answers is seen as having impulsive behavior problems (Barkley, 1998).

The Diagnostic and Statistical Manual of Mental Disorders Fourth Edition-Text Revision (DSM-IV-TR) divides the symptoms into two dimensions, Inattention symptoms and Hyperactive/Impulsive symptoms. There are three primary diagnoses of ADHD. They are ADHD Combined Type, ADHD Predominantly Inattentive Type, or ADHD Predominantly Hyperactive/Impulsive Type. A child is diagnosed as ADHD

Combined Type if they present with at least six of the nine symptoms of Inattention and six of the nine symptoms of Hyperactivity-Impulsivity, and have demonstrated these symptoms for at least the previous six months. A child is diagnosed as having ADHD Predominantly Inattentive Type when they have at least six of the nine symptoms of Inattention and have demonstrated these symptoms for the previous six months. Additionally, they have to present with fewer than six symptoms from the Hyperactivity-Impulsivity dimension. A child is diagnosed with ADHD Predominantly Hyperactive-Impulsive Type when they have six of the nine symptoms of Hyperactivity/Impulsivity and the symptoms must be present for the previous six months. Also, they have to present with fewer than six symptoms from the Inattention dimension. The diagnostic criterion also requires that the symptoms be present in at least two settings and that some of the problematic symptoms have been present before the age of seven (Barkley, 1998).

Applegate et al., (1997) questioned the validity of the age of onset criteria for ADHD. They studied 380 youths ages 4 to 17. The Diagnostic Interview Schedule for Children (DISC) was given to the parent, teacher, and child to assess DSM-IV diagnoses. They also included questions about the age of onset of impairment to the interview. The results of their examination suggest that children diagnosed with ADHD Combined Type (mean = 4.88 years) or ADHD Predominantly Inattentive type (mean = 6.13 years) have a statistically significant later age of onset of impairment than children diagnosed with ADHD Predominantly Hyperactive/Impulsive Type (mean = 4.21). Moreover, the age of onset for ADHD Predominantly Inattentive Type was significantly later than for ADHD Combined Type. Additionally, they found that the age of onset of impairment criterion decreased the accuracy of identifying children with ADHD, especially Primarily Inattentive Type.

There are many problems found in children as a result of ADHD. When ADHD children are compared to normal children, they are more likely to be behind in intellectual development. The ADHD child may have different test-taking behavior or the ADHD child may have lower intelligence, however, it is not clear which is the correct reason. Children diagnosed with ADHD also tend to have problems with independence, personal responsibilities, and self-help abilities, which are seen as means of adaptive functioning. Additionally, children diagnosed with ADHD are more likely to have a diagnosis of a learning disability and poor academic achievement and performance (Barkley, 1998). Lastly, ADHD children tend to have deficits in executive function abilities. Executive function refers to abilities such as cognitive flexibility, self-regulation, organizing space and time, discriminating inhibition of responding, preparing responses, and set maintenance (Reader, Harris, Schuerholz, & Denckla, 1994).

One component of executive functions, cognitive flexibility, can be measured by the Wisconsin Card Sorting Test (WCST). On the WCST, the individual is presented with 128 cards. The cards differ in number, color, and form. The individual sorts the cards into piles based upon one of the different categories (number, color, or form). The examiner only responds with the feedback of correct or incorrect. After ten consecutive correct responses, the category changes without warning. The number of perseverative errors (a pattern of incorrect responses even after feedback about their errors) is often the best indicator of problems with cognitive flexibility.

Sustained attention is another component of executive function. The Continuous Performance Tests (CPT) measures sustained attention. The CPT assesses sustained attention by having the individual respond to the target stimuli and not respond to the non-target stimuli over an extended period of time. The primary dependent variables of the CPT are errors of omission and commission along with response latency and variability of response latency.

The Controlled Oral Word Association Test (COWAT) also measures executive function. The child is given a letter or a category and is asked to produce as many words as possible that begin with the letters presented (F, A, or S) or are members of the categories presented (fruits, animals, or parts of the body) in one minute (Reader et al., 1994).

The Tower of London (TOL) is another measure of executive function. The individual in the TOL is given three wooden balls and a block of wood with three varying sizes of pegs in it. The individual is asked to copy the picture they are shown in a set number of moves. The dependent variables of the TOL are the number of moves and the time taken to complete the task successfully. This task measures behavioral inhibition and spatial planning (Kempton et al., 1999). These are a few measures that can be used to assess an individual's level of executive functioning.

Several studies have compared executive function performance in children with ADHD and controls. One such study was completed by Loge, Staton, and Beatty (1990). They tested 20 ADHD children and 20 controls between the ages of 6 and 12. The participants were administered the Wechsler Intelligence Scale for Children –Revised (WISC-R; Wechsler, 1974), Design Fluency, Verbal Fluency, Reading Comprehension

Test (Woodcock & Johnson, 1977), California Verbal Learning Test, Brown-Peterson Short-Term Memory Test, Wisconsin Card Sorting Task (Heaton, 1981), and Gordon Diagnostic System (Gordon & Mettelman, 1987) which has three tasks: the Vigilance Task, Distractibility Task, and Delay Task. For the Vigilance Task, the participants are presented with a series of numbers in the center of a three-column display and asked to respond whenever a 1 was followed by a 9. The Distractibility Task is similar to the Vigilance Task; however, numbers appear in all three columns. The participant is to respond only when the 1 followed by the 9 appears in the center. The individual, in the Delay Task, pushes a button as many times as they can to earn "points". However, if the individual pushes the button too quickly, no points will be counted because of a predetermined six-second inter-response time, which the individual is unaware of. The individual was informed not to push the button too quickly in order to earn the most points. The results of their study found that on the WISC-R Full Scale IQ, the ADHD participants scored in the average range (mean = 105.6), but their scores were significantly lower than that of the controls (mean = 115.0). The ADHD participants scored significantly lower than Controls on the Digit Span, Block Design, Information, Arithmetic, and Coding subtests of the WISC-R. The ADHD children correctly recalled fewer words and had more word intrusions than the control children on the Brown-Peterson Short-Term Memory Test. There were no differences between the two groups on the Gordon Diagnostic System Delay Task. On the Distractibility and Vigilance Tasks, the ADHD children made more errors of commission than the Controls. Also, on the Distractibility Task, the ADHD children detected fewer targets than the Control children did. There were no significant differences found between the ADHD group and the Controls on the Wisconsin Card Sorting Test, California Verbal Learning Test, and the number of correct responses produced on the fluency tests. However, on the Design and Letter Fluency tests the ADHD children committed more rule violations than the Control children did. They concluded from their study that there are very few deficiencies in the frontal lobe functioning of ADHD children.

Other studies that have examined executive function ability in ADHD children have found contrasting results from Loge et al., (1990). For example, Pineda et al. (1998) tested 124 boys from 7 to 12 years old. Sixty-two of the boys were diagnosed with ADHD while 62 boys were placed in the Control group. The WISC-R, Wisconsin Card Sorting Test (WCST), and a Verbal Fluency test were administered to the children. Pineda et al., (1990) found that the control group performed significantly better than the ADHD group on all the tests, but group differences were largest on the WCST. They concluded that children with ADHD have executive functioning difficulties, and the WCST is the most sensitive measure of executive functioning.

Lavoie and Charlebois (1994) examined 16 disruptive boys, 16 disruptive boys with significant attention problems, and 16 Controls. The child's mother and teacher filled out The Behar Preschool Behavior Questionnaire, which assessed the child's behavior on three different scales: hostile-aggressive, poor attention span and restlessness, and anxious-fearful. The mother and teacher filled out this questionnaire at two different times, once when the child was 11 and the second time was one year later. Children who met the criteria on the disruptiveness scale at both assessment times and by both the teacher and the mother were placed in the disruptive group. The children who met criteria on the disruptive and inattention scales, when rated by the teacher and the mother at both assessment times, were placed in the disruptive plus significant attention problems group. The control children did not meet criteria for disruptiveness or inattention at either assessment, when rated by the teacher and mother. On the Stroop Color-Word Test the participants are first given a sheet of paper with a number of color hues and asked to name the colors as quickly as possible. Next they are given a sheet with a number of words printed in black and white that name colors. The children are required to name the words as quickly as possible. Lastly, the participants are given a page with a list of color names that appear in a color different from the one named by the word. The participants are required to name the color of the ink that each word is written in, keeping in mind that the color of the ink and the word name are different. The difference in reading time between the third page (color names in incongruous ink) and the first page (color hues) was used as a measure of interference. The results of their study suggest that the disruptive group and the disruptive group with attention problems performed worse on the Stroop Color-Word Test than the Control group. The boys with attention problems had the poorest performance out of the three groups on the color-word card. The disruptive boys without attention problems performed better than the boys with attention problems, but worse than the Control group on the color-word card. The color-word card assesses the individual's ability to focus attention on a single dimension while ignoring the stimuli's other dimensions. They concluded that children with attention problems have difficulty in selecting and extricating one dimension of the stimulus.

Reader, Harris, Schuerholz, and Denckla, (1994) had forty-eight ADHD children ages 6 to 13 participate in their study. The Wisconsin Card Sorting Test (WCST), the Test of Variables of Attention (TOVA), the Rey-Osterrieth Complex Figure (ROCF), and two word fluency tests were administered to the participants. For the word fluency tests, the children were asked to name as many foods and animals as possible. Additionally, the letter trials from the COWAT were administered to the participant, which required the children to name as many words that begin with the letters C, L, and F. The ADHD children completed fewer categories on the WCST than the Controls. Also, the ADHD children made more errors of omission on the TOVA than the Controls. However, the ADHD children performed in the average range on the Word Fluency tests and the ROCF. Reader et al., (1994) concluded that children with ADHD have an increased risk for exhibiting executive function difficulties.

Doyle, Bierderman, Seidman, Weber, and Faraone (2000) had 123 ADHD children and 103 Controls participate in the study. The children ranged in age from 6 to 17 years old. They were participants of a 4-year longitudinal study. The Vocabulary, Arithmetic, Digit Span, Block Design, and Coding subtests from the WISC-R or WAIS-R were administered. The California Verbal Learning Test (CVLT; for the 17-year-olds) or Wide Range Assessment of Memory and Learning (WRAML) Verbal Learning subtest (for children younger than 17 years of age), Rey-Osterrieth Complex Figure (ROCF), the Stroop Color-Word Test, the Wisconsin Card Sorting Test (WCST), the Scattered Letter Version of the Visual Cancellations Test, and an auditory CPT were also administered to the participants. The participants with ADHD made more errors of omission and performed worse than Controls on the auditory CPT, Freedom from Distractibility subscale of the WISC-R/WAIS-R, Color, Word, and Color-Word subscales of the Stroop Test, the WCST, the ROCF, and the Letter Cancellation Task.

Houghton et al. (1998) examined whether the differing ADHD subtypes affect executive functioning. One hundred and twenty-two children between the ages of 6 and 13 years old participated in the study. Sixty-two of the children were placed in the ADHD Combined Type group, 32 children in the ADHD Predominantly Inattentive group, and 28 children were placed in the Control group. The children were administered the Stroop Color and Word test, the Tower of London (TOL), the Matching Familiar Figures Test, the Wisconsin Card Sorting Test (WCST), and the Trail Making Test. The ADHD children discontinued their medication for at least 15 hours prior to their participation in the study. Houghton et al., (1998) found that the Control group performed significantly better than both the ADHD subtypes on all measures. The children in the ADHD Combined Type performed significantly worse on the Stroop Color-Word test and the WCST than the control group and the Predominantly Inattentive ADHD group. The ADHD Predominantly Inattentive group performed worse on the Stroop Color-Word test and the WCST than the Control group; however, the results were not significant. None of the other tests in their study produced any significant differences among the groups. The researchers concluded that executive dysfunction is characteristic of ADHD since the children with ADHD in their examination did not have comorbid diagnoses.

Kempton et al. (1999) examined the effects of stimulants on executive functioning in ADHD children. Fifteen nonmedicated ADHD children, 15 medicated children, and 15 Controls participated in the study. All three groups were administered the Wechsler Intelligence Scale for Children-Third Edition (WISC-3), Wide Range Achievement Test-Third Edition (WRAT-3) to assess math and spelling abilities, the Neale Analysis of

Reading Ability Revised, and the Cambridge Neuropsychological Test Automated Battery (CANTAB). The Neale Analysis of Reading Ability Revised measures the child's reading comprehension and accuracy. The CANTAB consists of six different tests that measure executive functioning. The six different test are: Tower of London planning task (TOL), Pattern/Spatial Recognition, Attentional Set Shifting Task (ID/ED), Spatial Span, Simultaneous and Delayed Matching to Sample (DMTS), and Spatial Working Memory. The child in the TOL task is given three wooden balls and a block of wood with three varying sizes of pegs in it. The child is asked to copy the picture they are shown in a set number of moves. This task measures behavioral inhibition and spatial planning. The Pattern/Spatial Recognition consists of two tasks. In the Pattern Recognition task, the children are presented with an abstract colored pattern and then later asked to recognize which pattern from two stimuli they were shown previously. In the Spatial Recognition task, the children are to identify the spatial positions of the target-stimuli. The Attentional Set Shifting Task consists of an intradimensional shift (IDS) where the child focuses attention on particular examples in stimulus dimensions. In the Spatial Span task, the individual has to remember a sequence of squares. DMTS consists of a complex figure in which the child has to remember. The child, in the Spatial Working Memory task, works towards a goal by using mnemonic knowledge. The results of their study suggest that the nonmedicated ADHD children performed significantly worse on the ID/ED Set-Shifting task, the TOL, and had a significantly shorter spatial span than the Controls and medicated ADHD children. There were no significant differences between the medicated ADHD group and the Controls on tests of executive function. Kempton et al. (1999) concluded that medication for ADHD can increase performance on executive functioning tasks.

Barkley and Grodzinsky (1994) tested a group of children having Attention-Deficit/Hyperactivity Disorder (ADHD)-Combined Type, ADHD-Predominately Inattentive Type, learning disabled children without ADHD (LD), and a normal control group. The participants were administered a wide variety of neuropsychological tests. They were administered a Continuous Performance Test (CPT), which was a 9-minute vigilance test during which numbers were presented on a display screen at the rate of one per second. Each stimulus was displayed for 800 milliseconds with a 200 milliseconds delay between stimulus presentations. The participants were instructed to press a response key as fast as possible whenever a nine was presented after a one. There were 45 target pairs (1 then 9) presented during the testing, and the performance measures were the number correct, the number of omissions, and the number of commissions. When analyzing the number of omission and commission scores, the ADHD- Combined and ADHD-Predominately Inattentive groups performed worse than the LD and Control groups, who did not differ from each other. Therefore, performance on a CPT test was impaired in ADHD children, but their performance on the CPT did not differentiate ADHD-Combined Type from ADHD-Predominately Inattentive Type.

The studies reviewed above suggest that children with ADHD perform worse than controls on a variety of tests of executive functions. One limitation of the existing work is the failure to examine the impact of comorbid disorders on the performance of children with ADHD on tests of cognitive function. Children diagnosed with ADHD frequently will display a learning disability, often a reading disability.

Several studies have examined whether children with ADHD, Reading Disability (RD), and ADHD/RD perform differently on executive function and reading tasks. A learning disability in reading is defined as a significant discrepancy between a child's measured IQ and reading achievement scores. The child's IQ is found to be in the average range whereas their reading achievement scores fall in the below average range. Historically, a large discrepancy between IQ and achievement scores was required for a diagnosis, but that requirement has been challenged.

Pennington, Groisser, and Welsh (1993) compared two common and frequently comorbid developmental disorders, Attention Deficit Hyperactivity Disorder (ADHD) and Reading Disability (RD). The children were compared on two different cognitive domains, phonological processes (PP) and executive functions (EF). "Executive functions are those that are involved in planning, regulation, and verification of activity" (Pennington et al., 1993). Their study consisted of 70 boys, ages 7-10 years old. The participants were placed into one of the following groups: ADHD/RD, RD only, ADHD only, and control. The control group was made up of 20 boys who failed to meet the criteria for either disorder. In order to be classified as ADHD the child had to be at least one standard deviation above the mean on the Hyperactive scale on the Achenbach Child Behavior Checklist, the child was rated by the parent as having problems in more than one third of the situations listed on Barkley's Home Situations Questionnaire, and the child's problems had to of started prior to the age of 6. To be classified as RD, the child had to meet the criteria in the DSM-III, that included a significant discrepancy between the child's observed and expected reading levels, taking into account the child's age, general intelligence, and educational experience. All children were administered several tests that measured their executive function and phonological processing abilities. The Word Attack subtest of the Woodcock-Johnson battery and the Pig Latin test were used to measure the children's phonological processing. The word attack subtest consisted of 50 nonsense words that the child must pronounce. The Pig Latin task required subjects to transform words into their Pig-Latin equivalents. Four measures of executive functioning were used to assess planning, set-shifting ability, impulse control, and sustained attention. The four tasks included the Tower of Hanoi, the Matching Familiar Figures test, The Wisconsin Card Sorting Test, and the Continuous Performance Test. The Tower of Hanoi was used as a measure of planning ability. Specifically the test evaluates their ability to plan and execute a sequence of moves to achieve a designated goal state. The Matching Familiar Figures test was used to assess their impulsivity of response. The Wisconsin Card Sorting Test and the Continuous Performance Test were both used in order to discriminate ADHD children from normal children.

The results revealed, as predicted, a double dissociation between the ADHD only group and the RD only group on measures of executive function and phonological processing. Specifically, the ADHD only group scored significantly below average on the tests of executive function but in the normal range on tests of phonological processing. The reading disabled only and ADHD/RD group demonstrated the opposite pattern of results with relatively normal performance on tests of executive function and impaired performance on tests of phonological processing.

Wu, Anderson, and Castiello (2002) sought to examine the multiple aspects of executive functioning in children with ADHD that included attentional components, impulsiveness, planning, and problem solving. Furthermore they examined whether the pattern of cognitive impairment was modified by the presence of a learning disability (LD). Three groups of children, ADHD without LD (ADHD-LD), ADHD with LD (ADHD+LD), and control, aged 7-13, participated in the study. All children were given several neuropsychological measures. The results indicated that children with ADHD had slower verbal responses and sustained attention deficits. Deficits in selective attention and attentional capacity observed were largely due to the presence of a earning disability. The ADHD+LD group was found to be associated particularly with deficits in selective attention and attentional capacity. The results of their study suggest that ADHD is not associated with a general deficit in executive functioning; rather it is related to a specific deficit in regulation for attentional responses.

The purpose of Willcutt, Pennington, Olson, Chhabildas, and Hulslander (2005) was to examine the relations among the neuropsychological variables, clarify the pattern of neurocognitive weaknesses associated with RD and ADHD independent of the influence of the other disorder, examine the etiology of comorbidity between RD and ADHD, to test the potential utility of a sample of neuropsychological measures as markers for the common genetic etiology of ADHD and RD, and to test if the pattern of neuropsychological weaknesses varied as a function of ADHD subtype. The study consisted of 113 children with ADHD, 109 with RD, 64 children with both ADHD and RD, and 151 children with neither ADHD nor RD. All children were given measures of component reading and language skills, executive functions, and processing speed.

The results of Willcutt et al. (2005), suggest that children with ADHD exhibited weaknesses primarily on the response-inhibition and processing speed tasks as well as a few measures of reading skill and verbal working memory. The children with RD had deficits on measures of reading and language skills, as well as weaknesses on verbal working memory, processing speed, and response inhibition. Children with RD and comorbid ADHD displayed a combination of the deficits seen in the RD only and ADHD only groups. The results also support the hypothesis that ADHD is associated with a significant weakness in response inhibition and those children with RD have difficulties with phonological processing. None of the neuropsychological measures were associated specifically with ADHD, suggesting that the dissociation between ADHD and RD may not be complete. They found that processing speed is the most promising candidate for a neuropsychological deficit that is common to both children with ADHD and children with RD in their study.

Jakobson and Kikas (2007) examined whether children with ADHD-Combined Type have impairments in cognitive functioning and motor skills. Additionally, they examined what effects a comorbid learning disability (LD) had. They administered a battery of cognitive tests to 26 children with ADHD-Combined Type, 24 children with Comorbid ADHD/LD, and 102 Controls aged 7to 10. The tests administered included tasks assessing memory, visuospatial and verbal abilities, and fine motor skills. Overall, the ADHD-Combined Type children performed poorer than the control group in all areas. However, their performance overall was better than the children with comorbid ADHD/LD, with the exception of motor skills. Overall, the results of their study suggest that children with ADHD and comorbid ADHD/LD perform worse overall than Controls in the areas of memory, visuospatial and verbal abilities, and fine motor skills.

In addition to phonological processing and executive function, several studies have demonstrated a different pattern of performance on tests of memory in children with

RD and children with ADHD. Felton, Wood, Brown, and Campbell (1987) investigated verbal memory and naming abilities in reading disabled (RD) and nonreading disabled (NRD) children who were identified as having attention deficit disorder (ADD) or not having attention deficit disorder (non-ADD). The children were given several measures of verbal memory (i.e. Rey Auditory Verbal Learning Test) and naming abilities (i.e. Verbal Fluency). The Rey Auditory Verbal Learning Test consists of five presentations, with recall, of a 15-word list (Trials 1-5), one presentation of a second 15-word (distracter) list (Trial 6), and an additional recall trial of the original list. The Rey measures immediate memory span as well as learning strategies and retention following a distracter activity. The Diagnostic Interview for Children and Adolescents (DICA) was used to determine the presence or absence of ADD, in order to assign the child to an ADD or non-ADD group. The results of this study suggest that deficits in learning and memory for recently acquired information occur as a function of ADD rather than a RD diagnosis. Whereas, deficits in naming were found to be specific to RD only. These results indicated that the impact of ADD and RD were on separate and distinct cognitive tests with only a partial overlap.

In 1989, Felton and Wood focused on specifying the cognitive deficits associated with reading difficulties and separating them from those associated with attentional deficits. They examined three different studies and found that cognitive deficits associated with difficulty in reading were consistent across samples, developmental levels, definitions, and subtypes of reading disabilities. Poor readers were also consistently impaired across studies on measures of naming and phonological awareness after controlling for sex, age, and IQ. Attentional deficits weren't as consistent, but were found to be clearly separate from reading disability effects.

Verbal memory deficits are frequently reported in RD children, however, the specific mechanism underlying the impairments have yet to be determined. Previous research has shown that children with a RD perform less well than controls on verbal learning tasks, including story recall. Kramer, Knee, and Delis (1999) used the California Verbal Learning Test-Children's Version (CVLT-C) to assess verbal learning in 57 dyslexic children and 114 controls that were matched for gender, age, and vocabulary scores on the WISC-R. All children were administered the CVLT-C and the vocabulary subtest from the WISC-R. The CVLT-C begins with five learning trials of a 15-word, semantically categorizable target list, with words read aloud by the examiner at the rate of one word per second. The examinee is instructed to freely recall as many words as possible, in any order. An interference list is then presented for one learning trial, followed by a brief-delay free recall trial and a second recall trial in which subjects are cued with the semantic category name (e.g. fruits). After a 20-minute interval during which non-verbal tasks are administered, long delay free and cued recall and recognition of the target lists are assessed. The recognition trial is a yes-no paradigm in which the 15 target words and 45 distracter words are presented sequentially; the subject is asked to respond with "yes" to each target word and "no" to each non-target. The non-targets are a mix of interference list words that are semantically related to target words, interference list words that are semantically unrelated, novel words that are semantically related to target words, novel words that are phonemically similar to target words, and novel words that are unrelated to target words. Specifically they examined recall and recognition, use of learning strategies, and interference effects. The results indicated that dyslexic children had lower levels of recall and a slower rate of learning across the five learning trials than controls. Also both groups demonstrated a similar rate of forgetting across a delay interval. Further, the dyslexic group performed worse than controls in the recognition tests. Their results suggest that dyslexics have a less efficient rehearsal and encoding mechanisms, which results in deficient encoding of new information, and normal retention and retrieval.

Cutting et al. (2003) administered the CVLT-C to children with ADHD and a group of controls. In contrast to the results of Kramer et al. (1999), Cutting et al. (2003) demonstrated that children with ADHD learned the same number of words as controls, but showed weaknesses in retaining the words after a delay. In contrast, Cahn and Marcotle (1995) reported minimal forgetting in ADHD children using prose passages from the WRAML.

Kaplan et al. (1998) studied the performance of ADHD children on the WISC-III and WRAML. Additionally, they examined long-term memory in ADHD, RD, and ADHD/RD children. Two hundred and ninety-one children were placed into one of the four groups: RD (n = 63), ADHD (n = 53), ADHD/RD (n = 63) and controls (n = 112). The children were administered the WRAML and the Vocabulary and Block Design subtests from the WISC-III. For four of the WRAML subtests (Verbal Learning, Sound Symbol, Visual Learning, and Story Memory), saving scores were calculated. Saving scores take into consideration the degree of forgetting across a delay. The results found that the ADHD, RD, and ADHD/RD children scored significantly lower on the General Memory Index, Verbal Memory Index, Learning Memory Index, and Visual Memory

Index than the control group. Also, the ADHD children scored significantly better than RD children.

The purpose of the proposed research is to directly compare children with ADHD, children with a diagnosis of ADHD and reading disability, children with only a reading disability, and a control group on cognitive measures that have previously produced discrepant results.

CHAPTER II

METHODS

Participants

Fifty-six children between the ages 7 and 13 years of age participated in this study. Six children met the diagnostic criteria for a learning disability in reading. Eight children met the diagnostic criteria for a learning disability in reading and ADHD, and sixteen had a diagnosis of ADHD only. These children were recruited from various psychological clinics in the region. The children with ADHD abstained from their medication on the day of participation, if their medication permitted this. Of the children diagnosed with ADHD, 17 of the children abstained from medication (i.e. Ritalin, Concerta, Adderall, and Focalin) on the day of testing, and 5 of the children in the study diagnosed with ADHD did not taken medication to manage their ADHD symptoms. Two of the children in the study were taking Strattera, which prohibited them from abstaining from their medication on the day of the study. Twenty-six children had no psychological diagnosis and were recruited from the community. The children were tested between 9 a.m. and 5 p.m.

Measures

Intelligence Measures

The Vocabulary subtest from the Wechsler Intelligence Scale for Children-IV (WISC-IV; Wechsler, 2003) was administered. This test consisted of 30 words in which the examiner stated the word and the participant provided a brief definition. Each response was given 0, 1, or 2 points depending on the accuracy of the response and testing continued until the participant produced five consecutive 0-point responses. This subtest assessed the child's verbal ability.

The Digit Span subtest from the WISC-IV was administered to assess short-term memory. It consists of Digits Forward and Digits Backward sections. For the Digit Forward section, subjects were presented with sequences of numbers and were required to repeat the number sequences in the exact order they were presented. The sequences ranged from two to nine digits long with two sequences at each length. Participants were tested until they failed both sequences of a particular length. The Digits Backward section required subjects to repeat the number sequences in reverse order. Digit Span assessed attention and short-term memory.

The Digit Symbol-Coding subtest from the WISC-IV was administered to the child. The subtest consisted of a key containing nine numbers, each of which was paired with its own corresponding symbol. Below the key, the examinee was presented with a series of numbers; the examinee was given a limited amount of time to write down as many symbols as possible corresponding with each of the numbers. The Digit Symbol-Coding subtest assessed processing speed.

The Symbol Search subtest from the WISC-IV was administered to the child. Each item in this subtest consisted of two target symbols and a set of symbols beside the targets; the examinee scanned the set of symbols and indicated if either of the targets appeared in the search group. The examinee was given a limited amount of time to complete as many items as possible. The Symbol Search subtest assessed processing speed.

Parent Measures

A reduced version of the Clinical Interview – Parent Report Form from Barkley (1998) was administered to the parent of the child. The interview covered DSM-IV symptoms for internalizing and externalizing disorders in children. The reduced version covered Oppositional Defiant Disorder, Conduct Disorder, ADHD, Anxiety Disorders, and Mood Disorders.

The Child Behavior Checklist (Achenbach, 2001) assessed several domains of children's emotional and behavioral functioning. It consisted of 112 items in which the parents reported on a three-point scale their child's functioning. The syndromes that could be identified were Social Problems, Attention Problems, Withdrawn, Anxious/Depressed, Aggressive Behavior, Thought Problems, Somatic Complaints, and Delinquent Behavior.

The ADHD Rating Scale - IV (DuPaul et al., 1998) is an 18 item rating scale that covered the 9 symptoms of hyperactivity-impulsivity and the 9 symptoms of inattention that are listed in the DSM-IV. The symptoms were rated on a 4-point scale (0 – rarely, not at all; 1 – sometimes; 2 – often; 3 – very often).

Executive Function Measures

The Conners' CPT (Conners, 1995) consisted of ten upper-case letters including the letter X, which was designated as the target stimulus. Three hundred and sixty letters were presented on a computer screen one at a time. The CPT was divided into 18 consecutive blocks with 20 trials in each block. The 18 blocks contained different time delays between the presentations of successive letters (interstimulus interval, ISI). The ISI was either 1, 2, or 4 seconds. The participants were asked to press the spacebar every time a letter appeared except when the letter was "X".

The Wisconsin Card Sorting Task (WCST; Heaton, 1981) also assessed executive function. It consisted of 128 cards that have designs that differ in number, color, and form. The subject was given four stimulus cards and was asked to sort the deck of cards corresponding with the stimulus cards. After ten consecutive cards had been matched correctly, the category for sorting the cards was switched without warning. The WCST examined the number of trials needed to complete six categories, the number of correct trials, errors, perseverative errors, and the number of nonperseverative errors.

The Controlled Oral Word Association Test (COWAT; Benton and Hamsher, 1978) consisted of two parts, letter fluency and category fluency. In the letter fluency, the subject was allowed 60 seconds to list as many items as possible that began with a particular letter. The letters tested were "F", "A", and "S". In the category fluency test, the subject was allowed 60 seconds to name as many items as possible that would belong in a particular category. The categories were "fruits" and "animals". The number of correct responses was the dependent variable in the Verbal Fluency test.

The Tower of London task (TOL; Krikorian, 1994) contains a block of wood with three wooden pegs of varying heights, three wooden balls of different colors (blue, red, and green) that can be placed on the pegs, and pictures of specific arrangements of the balls on the pegs. The balls were placed in the "start position". The subject was shown an arrangement of the balls and was asked to match the picture in a certain number of moves. The subjects can only move one ball at a time and cannot hold one ball in their hand while moving another ball. The subjects were allowed three trials on each picture arrangement. Three points were awarded for correctly completing the arrangement on the first trial, two points for the second trial, one point for the third trial, and zero points for not correctly matching the arrangement. The examiner recorded the amount of time to complete the arrangement and the number of correct responses.

The Trail Making Test (TMT; Reitan, & Wolfson, 1985) was used to assess motor speed and visual search. The test involved two separate parts. Part A required the individual to draw lines to connect 25 consecutive numbers (i.e., 1-2-3….). Part B required drawing lines between numbers and letters (i.e., 1-A, 2-B, 3-C…). The time taken to complete each part was the primary measure of interest.

The Grooved Pegboard Test is a test of manipulative dexterity. It requires complex visual-motor coordination. The unit is composed of 25 randomly positioned grooved peg slots. The pegs have a key along one side and must be rotated to match the hole before they can be inserted. The child first used their dominant hand to insert the pegs as quickly as possible. The second trial required the use of their non-dominant hand to place the pegs in the pegboard as quickly as possible. The primary dependent variable was the total time it took the children to place the required amount of pegs into the grooves.

Memory Measures

The Story Memory subtest from the Wide Range Assessment of Memory and Learning, Second Edition (WRAML-2; Sheslow & Adams, 2003) was administered. The subtest consisted of Story Memory Immediate Recall, Story Memory Delay Recall, and Story Memory Delay Recognition. In Story Memory Immediate Recall, the passage was were phonemically similar to target words, and novel words that were unrelated to target words.

Achievement Measures

Three subtests from the Wechsler Individual Achievement Test (WIAT), the reading comprehension, listening comprehension, and psuedoword subtests were administered.

The Reading Comprehension subtest required the child to read sentences and short passages and then answered questions about the main idea, specific details, or the order of events. He or she was also asked to make inferences, draw conclusions, or define unfamiliar words by using context clues.

The Listening Comprehension subtest required the child to listen to a word or sentence and match it to a picture or look at a picture and respond with the corresponding word.

The Pseudoword Decoding subtest required the child to read nonsense words aloud from a list (phonetic work attack).

Procedure

The participants were tested between 9:00 a.m. and 5:00 p.m. The children were tested in a private room individually. Subjects first filled out a demographic sheet requesting their name, age, gender, and grade in school. They were given a consent form to be signed by the parent and an assent form to be signed by the child, if both were in agreement for the child to participate. The experiment was then explained to the subjects. The parent filled out the Child Behavior Checklist and the ADHD Rating Scale IV. In addition, each parent was administered a reduced version of the structured Clinical

Interview – Parent Report Form from Barkley (1998). The Vocabulary, Digit Span, Digit Symbol-Coding, and Symbol Search subtests from the WISC-IV were administered first to the child. Then the child was given the Story Memory Immediate Recall subtest from the WRAML-2. Next the child took the Conners' CPT. After a short break following the Conners' CPT, the child was given the Story Memory Delay Recall and the Story Memory Recognition subtests from the WRAML-2. Next the child was administered the CVLT-C. Afterwards, the child was administered the Wisconsin Card Sorting Test. After a twenty minute delay the child completed the CVLT-C delayed recognition and recall. Then, the child was given the Tower of London test. Then the child was administered the Reading Comprehension, Listening Comprehension, and Pseudoword subtests form the WIAT-II. The final test that was administered to the child was the Verbal Fluency test. Upon completion of the Verbal Fluency test the child was paid $25 for their participation and then dismissed.

CHAPTER III

RESULTS

Fifty-six children between the ages of 7 and 13 were recruited from the community and placed into one of four groups (ADHD/RD, ADHD, RD, and Control). The children placed into the ADHD group scored at or above the 80^{th} percentile on the inattention and at or above the 85^{th} percentile on the hyperactivity/impulsivity subscale of the ADHD rating scale (Dupaul et al., 1998). Additionally, they had a standard score at or above 90 on the Reading Comprehension subtest of the WIAT-II. Children with an RD diagnosis had a standard score at or below 85 on the Reading Comprehension subtest and scored at or below the 75^{th} percentile on the inattention and hyperactivity/impulsivity subscales of the ADHD rating scale. Those in the ADHD/RD group scored at or above the 80^{th} percentile on the inattention and at or above the 85^{th} percentile on the hyperactivity/impulsivity subscale and had a standard score at or below 85 on the Reading Comprehension subtest. The children in the Control group scored at or below the 75^{th} percentile on the inattention and hyperactivity/impulsivity subscales of the ADHD rating scale and had a standard score at or above 90 on Reading Comprehension.

Table 1 shows the number of children that fell into the different groups and the average ages across the groups. A one-way analysis of variance (ANOVA) was performed on age. Subsequent testing using a Tukey revealed significant difference found between Groups, $F\ (3,55)=4.708,\ p<.05$. More specifically, children in the ADHD/RD group were significantly older than the ADHD and control children.

Table 1. The Mean Age of Participants as a Function of Group

	ADHD/RD	ADHD	RD	Control
Mean	12.38	9.88	12.50	9.96
SD	2.67	1.75	9.96	2.09
N	8	16	6	26

The frequency of gender distributed across the four groups is displayed in Table 2. ADHD is diagnosed more frequently in males than females (Netherton et al., 1999). The distribution of gender across the ADHD and ADHD/RD groups in the present study is consistent with the general population (i.e. more males than females with ADHD). A reading disability is more frequently diagnosed in males than females. In the present study the distribution of males and females in the RD groups is equal. Given the small sample size of the RD group, the gender distribution of the RD group likely did not affect the results of the present study. The gender of the Control group is not equally distributed due to random chance.

Table 2. The Frequency of Gender Distribution as a Function of Group

	ADHD/RD	ADHD	RD	Control
Male	6	10	3	11
Female	2	6	3	15

Parent Measures

The parents completed the Child Behavior Check List (CBCL), which asked them the frequency with which their child exhibited a number of behavior(s) in the past 6 months on a scale of 0 (Not True), 1 (Somewhat or Sometimes True), or 2 (Very True or

Often True). These symptoms are then arranged into 11 dimensions and it provides us with t-scores across the 11 dimensions. The higher the t-score the greater the degree to which the symptoms associated with the dimension are present. A series of one-way analyses of variance (ANOVA) of the CBCL t-scores revealed significant differences between groups on all dimensions (see Table 3). The ADHD/RD group scored significantly higher than the Control group on the Social Problems, Delinquent Behaviors, and Aggressive Behaviors dimensions and significantly higher than the RD and Control group on the Thought Problems and Attention Problems dimensions. The ADHD group scored significantly higher than the other three groups on the Anxiety/Depression dimension and significantly higher than the Control children on the Withdrawn and Somatic Problems dimensions. On the Social Problems, Thought Problems, Attention Problems, Delinquent Behaviors, and Aggressive Behaviors dimensions, the ADHD group scored significantly higher than the RD and Control groups (Table 3).

Table 3. CBCL Scores Across Groups

CBCL Dimension		ADHD/RD	ADHD	RD	Control
Withdrawn	M	58.88	60.06	55.50	52.85
	SD	10.71	8.96	6.86	5.13
Somatic	M	53.00	57.81	55.83	51.96
	SD	3.12	8.25	9.35	3.03
Anxiety/Depression	M	57.13	62.44	53.17	52.81
	SD	8.01	10.28	6.34	5.24
Social Problems	M	60.38	64.38	52.83	51.12
	SD	7.54	10.31	4.26	2.63
Thought Problems	M	63.13	66.31	53.00	51.58
	SD	10.30	6.11	6.87	2.98
Attention Problems	M	67.00	72.56	54.33	50.62
	SD	6.30	8.95	6.25	1.13
Delinquent Behaviors	M	57.88	59.56	51.83	50.77
	SD	6.94	7.18	2.04	1.31
Aggressive Behaviors	M	60.25	65.75	52.83	51.08
	SD	9.10	9.42	4.49	2.15
Internalizing Behavior	M	54.75	60.81	50.50	45.23
	SD	10.07	9.23	12.01	9.63
Externalizing Behavior	M	59.25	64.06	46.00	41.88
	SD	8.97	7.82	9.63	7.73
Total	M	62.75	66.56	47.00	39.46
	SD	7.11	6.58	10.88	8.90

Intelligence Measures

Each participant's Vocabulary subtest of the WISC-IV was scored as 0, 1, or 2 for each item, and the child's standard score served as the dependent variable. An analysis of variance of the vocabulary scores indicated a significant difference between Groups, F (3,55)=8.140, $p<.05$ (Table 4). Subsequent testing using the Tukey indicated that the Control children had significantly higher Vocabulary scores than all other groups. No other significant differences were found between groups. As a result of the significant difference across groups on vocabulary scores and age, all subsequent measures were analyzed with an analysis of covariance (ANCOVA) using vocabulary and age as covariates.

Table 4. The Mean Vocabulary Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Mean	7.63	9.38	7.33	11.58
SD	1.60	2.80	2.66	2.58

The standard scores of Symbol Search, Coding, and Digit Span subtests of the WISC-IV were all subjected to a one-way ANCOVA. Subsequent tests revealed no significant differences on the Symbol Search and Digit Span subtests. On the Coding subtest the ADHD/RD group had significantly lower standard scores than both the ADHD and Control groups and the ADHD group had significantly lower scores than the Control group $F(1,55)=4.652, p<.05$ (Table 5). No significant differences between the RD group and the other groups were present.

Table 5. The Mean WISC-IV Subtest Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Symbol Search				
Mean	8.00	10.75	8.33	11.35
Adjusted Mean	8.95	10.85	9.39	10.75
Coding				
Mean	6.00	8.31	8.17	10.64
Adjusted Mean	6.01	8.51	8.20	10.50
Digit Span				
Mean	8.00	8.94	5.83	10.73
Adjusted Mean	8.80	8.96	6.71	10.27

Achievement Measures

The Listening Comprehension subtest of the Wechsler Individual Achievement Test (WIAT) was scored according to standardized instructions and age and grade normed standard scores were computed. A one-way ANCOVA of the age-normed standard scores revealed no significant differences (Table 6) as well as no significant differences for the grade-normed standard scores (Table 6).

Table 6. The Mean Listening Comprehension Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Age				
Mean	90.88	103.50	79.67	107.81
Adjusted Mean	98.28	103.96	87.89	103.35
Grade				
Mean	93.00	104.00	81.50	109.31
Adjusted Mean	99.89	104.42	89.15	105.16

The Psuedoword subtest of the Wechsler Individual Achievement Test (WIAT) was scored according to standardized instructions and age and grade normed standard scores were computed. A one-way ANCOVA of the age-normed standard scores revealed significant differences, $F(1,56)=6.594$, $p<.05$ (Table 6) and significant differences for the grade-normed standard scores were also found $F(1,56)=6.862$, $p.<05$ (Table 7). When examining the age based norms the Control group scored significantly higher than the other groups and the ADHD group scored significantly higher than the RD group. When examining the grade based norms the Control group had significantly higher scores than the other groups. No other significant differences were found between the other groups.

Table 7. The Mean Psuedoword Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Age				
Mean	87.00	97.69	78.50	110.27
Adjusted Mean	90.33	96.65	82.07	109.06
Grade				
Mean	89.75	96.00	80.00	109.65
Adjusted Mean	91.22	94.91	81.52	109.52

Memory Measures

Standard scores for Immediate Recall, Delayed Recall, and Recognition for the WRAML were all subjected to a one-way ANCOVA. A significant effect of group was found on the Immediate Recall subtest. Subsequent tests found that the ADHD/RD group scored significantly lower than all other groups, $F(1,50)=4.020$, $p<.05$. A significant effect of group was also found on Delayed Recall. Subsequent tests found that the ADHD/RD group had significantly lower scores than both the RD and Control groups and the ADHD group had significantly lower scores than the Control group, $F(1,50)=4.627$, $p<.05$. Subsequent tests revealed no significant differences on Recognition (Table 8).

Table 8. The Mean WRAML Subtests Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Immediate				
Mean	6.43	10.21	9.50	11.88
Adjusted Mean	7.91	10.44	11.45	11.03
Delay				
Mean	5.71	9.43	8.25	11.96
Adjusted Mean	7.33	9.50	10.30	11.14
Recognition				
Mean	10.29	10.79	10.25	11.10
Adjusted Mean	10.73	10.57	10.73	11.54

A one-way ANCOVA was conducted on all dimensions of the California Verbal Learning Test-Child Version (CVLT-C). Raw scores on the List A Trials 1-5 Total measure are converted to age-corrected t-scores, with a mean of 50 and a standard deviation of 10. Raw scores on all of the other CVLT-C measures are converted to age-corrected z-scores. The z-scores have a mean of 0 and a standard deviation of .5. The range of t-scores is +5 to -5 and are reported in increments of .5. No significant differences between groups were found on all dimensions (Table 9).

Table 9. The Mean CVLT-C Scores as a Function of Groups

CVLT-C Dimension	ADHD/RD	ADHD	RD	Control
List A Trials 1-5 SS				
Mean	44.00	50.13	45.33	52.65
Adjusted Mean	46.79	50.17	48.42	51.06
List A Trial 1Recall SS				
Mean	.13	-.16	-.08	.33
Adjusted Mean	.12	-.10	-.09	.30
List A Trial 5 Recall SS				
Mean	-.88	-.19	.00	.17
Adjusted Mean	-.63	-.20	.28	.49
List B Recall SS				
Mean	-.75	-.32	-.75	-.21
Adjusted Mean	-.55	-.23	-.52	-.38
Free Recall % Change				
Mean	-23.40	-14.55	-20.92	-18.46
Adjusted Mean	-25.49	-12.87	-23.07	-18.35
Free Recall Diff. Score				
Mean	-.88	-.38	-.67	-.54
Adjusted Mean	-.83	-.36	-.61	-.58
List A Short Delay SS				
Mean	-.69	-.09	-.17	.00
Adjusted Mean	-.58	-.07	-.05	-.07
Short Delay % Change				
Mean	-8.55	-15.58	-14.33	-17.50
Adjusted Mean	-15.98	-13.60	-22.35	-14.58
Short Delay Diff. Score				
Mean	.25	.09	-.17	-.17
Adjusted Mean	.12	.13	-.31	-.12

Table 9 (cont.).

CVLT-C Dimension	ADHD/RD	ADHD	RD	Control
Short Delay Cued Recall				
Mean	-.31	.13	-.08	.02
Adjusted Mean	-.17	.14	.08	-.08
Long Delay Free Recall				
Mean	-.25	-.25	-.17	-.08
Adjusted Mean	-.14	-.27	-.05	.05
Long Delay % Change				
Mean	77.51	5.74	5.03	9.04
Adjusted Mean	99.26	.77	28.57	-.02
Long Delay Diff. Score				
Mean	.44	-.16	.00	.10
Adjusted Mean	.44	-.20	.00	.12
Long Delay Cued Recall				
Mean	-.31	-.06	-.08	.15
Adjusted Mean	-.07	-.08	.19	.03
Learning Slope SS				
Mean	-1.1	-.03	-.25	.-15
Adjusted Mean	-.72	-.13	.19	-.32
Correct Recognition Hits				
Mean	-.56	-.10	.08	.46
Adjusted Mean	-.25	-.17	.42	.33
Discriminability SS				
Mean	-.69	.28	-.25	.83
Adjusted Mean	-.22	.17	.25	.64
RD vs. LDFR Diff. Score				
Mean	-.44	.53	-.08	.73
Adjusted Mean	-.08	.43	.30	.59
False Positive Total SS				
Mean	-.13	-.50	.17	-.75
Adjusted Mean	-.38	-.45	-.11	-.64
Response Bias SS				
Mean	-.06	-.53	.25	-.17
Adjusted Mean	-.01	-.53	.31	-.21

Executive Function Measures

Standard scores were computed separately for the FAS and Animals portion of the Controlled Oral Word Association Test (COWAT). A one-way ANCOVA of the FAS standard scores revealed no significant differences, as well as no significant differences for the Animal standard scores (Table 10).

Table 10. The Mean COWAT Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
FAS				
Mean	82.60	89.53	91.80	95.04
Adjusted Mean	83.07	88.67	93.76	95.07
Animal				
Mean	90.00	92.27	102.60	94.04
Adjusted Mean	91.31	91.74	105.14	93.59

Standard scores were computed separately for Trails A and B. A one-way ANCOVA revealed no significant differences for the Trails A and Trails B standard scores (Table 11).

Table 11. The Mean Trails Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Trails A				
Mean	102.60	98.47	74.40	96.92
Adjusted Mean	119.39	97.47	96.70	89.70
Trails B				
Mean	78.40	101.93	92.60	107.60
Adjusted Mean	91.53	101.31	109.81	101.91

Standard scores were computed separately for both the Dominant hand and Non-Dominant hand from the Grooved Pegboard. A one-way ANCOVA of the Dominant hand standard scores revealed no significant differences, as well as no significant differences for the Non-Dominant hand standard scores (Table 12).

Table 12. The Mean Grooved Pegboard Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Dominant Hand				
Mean	87.75	80.60	95.17	99.74
Adjusted Mean	86.05	79.68	93.43	101.09
Non-Dominant Hand				
Mean	91.75	71.93	78.67	91.57
Adjusted Mean	94.93	70.94	82.25	90.72

The total raw scores and total time (measured in seconds) for the Tower of London were subjected to a one-way ANCOVA. No significant differences were found on either the raw scores or total time (Table 13).

Table 13. The Mean Tower of London Scores as a Function of Groups

	ADHD/RD	ADHD	RD	Control
Total Raw Score				
Mean	26.40	26.93	28.00	28.54
Adjusted Mean	26.24	27.16	27.88	28.46
Total Time				
Mean	240.00	250.36	140.67	249.46
Adjusted Mean	221.66	240.24	107.81	262.23

A one-way ANCOVA was completed for each score of the Wisconsin Card Sort Test. The ANCOVA revealed significant differences between groups for Total Errors, $F(1,53)=2.991$, $p<.05$. Subsequent tests found that the ADHD/RD group had significantly more errors than both the ADHD and Control groups. No significant differences were present on the number of errors between the ADHD, RD, and Control groups. Significant group differences were also found for the number of non-perseverative errors, $F(1,53)=2.945$, $p<.05$. Subsequent tests revealed that the ADHD/RD group had significantly more non-perseverative errors than both the ADHD and Control groups. No significant differences on the number of non-perseverative errors were present between the ADHD, RD, and Control groups. The analysis revealed no significant differences between groups on the other measures of the WCST (Table 14).

Table 14. The Mean WCST Scores as a Function of Groups

WCST Dimension		ADHD/RD	ADHD	RD	Control
Trials Administered	Mean	123.75	115.44	112.67	105.83
	Adj. Mean	126.97	113.54	116.03	105.51
Total Correct	Mean	70.13	83.38	81.67	74.35
	Adj. Mean	69.38	82.57	80.75	75.40
Total Errors	Mean	85.13	102.31	100.83	105.78
	Adj. Mean	83.57	102.82	99.16	106.41
Perseverative Resp.	Mean	95.00	104.88	103.67	107.22
	Adj. Mean	93.50	105.62	102.08	107.63
Perseverative Errors	Mean	92.88	105.00	102.83	107.13
	Adj. Mean	91.44	105.63	101.30	107.60
Nonperseverative Err.	Mean	80.88	98.06	97.17	103.04
	Adj. Mean	79.05	98.74	95.22	103.72
Categories Completed	Mean	4.00	5.06	5.33	5.00
	Adj. Mean	3.66	5.13	4.60	5.17
Trials to Complete 1st	Mean	13.38	17.13	12.83	17.00
	Adj. Mean	14.07	16.98	13.59	16.66
Failure Maintain Set	Mean	1.25	2.13	1.17	1.22
	Adj. Mean	1.50	2.03	1.43	1.13

T-scores were obtained of the 12 measures of the Continuous Performance Test (CPT). The higher the t-score the worse the participants performance was on the particular dimension. A one-way ANCOVA was completed for each dimension of the CPT. The ANCOVA revealed a significant difference for the number of omission errors, $F(1,54)=4.375$, $p<.05$. Subsequent tests indicated that the ADHD group made significantly more errors of omission than the RD and Control groups. Significant differences were also found on the Hit Rate Standard Error dimension, $F(1,54)=16.723$, $p<.05$. A subsequent test revealed that the ADHD/RD and ADHD groups had greater inconsistency in their response speed than the RD and Control groups. A significant difference between groups was found for the Variability dimension. Subsequent tests found that the ADHD/RD and ADHD groups had greater response speed inconsistency across blocks of the test than the RD and Control groups, $F(1,54)=18.446$, $p<.05$. Significant differences were found on the Detectability dimension. Subsequent tests found that the Control group was able to better distinguish between the X and non-X distributions than the ADHD/RD and RD groups, $F(1,54)=3.219$, $p<.05$. Significant differences were found between groups on the Response Style dimension. Subsequent tests found that the Control group had a significantly different response style than the ADHD and RD groups, $F(1,54)=3.037$, $p<.05$. Significant differences were found between groups on the Perseverative Responses dimension. Subsequent tests found that the ADHD/RD group made significantly more perseverative responses (reaction times <100 ms) than all other groups, $F(1,54)=9.897$, $p<.05$. No significant differences were found between the other groups on the number of perseverative responses. Significant differences were found between groups on the Hit Standard Error Block Change dimension. Subsequent tests found that the ADHD/RD and ADHD groups had lower consistency over the duration of the test than the Control group $F(1,54)=3.175$, $p<.05$. Significant differences were found between groups on the Hit Reaction Time Inter-Stimulus Interval Change dimension. Subsequent tests found that the Control group maintained or had faster response speed as the length of the inter-stimulus interval increased than the ADHD/RD and ADHD groups $F(1,54)=3.977$, $p<.05$. Significant differences between groups were found on the Hit Standard Error Inter-Stimulus Interval Change dimension. Subsequent tests found that the Control group had greater consistency in reaction times at the different inter-stimulus intervals than the ADHD/RD and ADHD groups. The RD group also showed greater consistency than the ADHD/RD group $F(1,54)=8.751, p<.05$. Subsequent tests revealed no significant differences between groups on the other dimensions of the CPT (Table 15).

Table 15. The Mean CPT Scores as a Function of Groups

CPT Dimension		ADHD/RD	ADHD	RD	Control
Omissions	Mean	58.70	64.85	50.61	47.31
	Adj. Mean	55.96	63.74	47.02	49.65
Commissions	Mean	56.86	51.20	52.06	45.97
	Adj. Mean	57.53	51.78	53.10	45.17
Hit Rate	Mean	57.68	58.01	51.92	49.12
	Adj. Mean	56.90	56.95	50.49	50.36
Hit Rate SE	Mean	64.97	62.79	49.47	47.14
	Adj. Mean	66.35	61.65	50.37	47.27
Variability	Mean	63.33	61.37	48.78	45.71
	Adj. Mean	63.04	60.63	48.06	46.43
Detectability	Mean	58.00	51.25	55.89	47.53
	Adj. Mean	59.37	51.96	57.76	46.25
Response Style	Mean	51.36	54.45	54.61	48.56
	Adj. Mean	54.92	53.69	58.08	47.22
Perseverations	Mean	66.38	57.96	46.56	47.01
	Adj. Mean	71.66	56.81	51.71	45.03
HR Block Change	Mean	49.81	49.08	48.80	47.29
	Adj. Mean	52.07	49.26	51.35	45.94
Hit SE Block Change	Mean	54.46	49.39	46.09	45.88
	Adj. Mean	54.98	50.08	47.04	45.07
HR Inter-Stimulus	Mean	62.04	59.47	51.66	51.55
	Adj. Mean	66.27	58.36	55.68	50.11
Hit SE Inter-Stimulus	Mean	59.83	58.75	48.72	48.28
	Adj. Mean	61.76	58.33	50.60	47.55

CHAPTER IV

DISCUSSION

The results of the present study revealed several differences between children with and without ADHD on measures of executive function ability. The differences were found after age and verbal ability were statistically adjusted. On the CPT, the Control group overall had significantly better performance than the other groups. The ADHD and ADHD/RD children were more impulsive, inattentive, and had slower and more inconsistent response times than non-ADHD children. These findings are consistent with several studies comparing ADHD and non-ADHD children (e.g., Barkley & Grodzinsky, 1994, Reader et al., 1994, Doyle et al., 2000). On the WCST, ADHD children differed significantly from non-ADHD children on the following measures: number of errors, and non-perseverative errors. Specifically, the ADHD/RD group had significantly more total errors and non-perseverative errors than the ADHD and Control groups. The results of the present study suggest that ADHD children have significantly more executive function deficits than non-ADHD children, especially on the CPT and WCST. This is consistent with the work of Pineda et al., (1998), in which they found that children without ADHD perform better on the WCST and Verbal Fluency measures than those children with ADHD. These results are inconsistent with the results of Loge et al., (1990) in which he concluded that ADHD children have few executive functioning difficulties. The other executive function measures in the present study did not find significant differences between groups (i.e., Trails, Grooved Pegboard, COWAT, TOL). The results of the present study are consistent with Reader et al., (1994), in that no significant differences were found between ADHD and non-ADHD children on the Verbal Fluency test and inconsistent with Loge et al., (1990) in which they found no differences between ADHD and non-ADHD children on the WCST, CVLT-C, and Verbal Fluency measures. Additionally, the results are inconsistent with several studies in which differences were found between ADHD and non-ADHD children. Specifically, the following studies found that ADHD children performed worse than non-ADHD children on the Tower of London (Houghton et al., 1998, Kempton et al., 1999) and Trail Making Test (Houghton et al., 1998).

When examining the prose memory measures, the present study found that control children performed better on the WRAML than the other groups. These results are consistent with Kaplan et al., (1998). They found that ADHD, ADHD/RD, and RD children had poorer performance on the General Memory Index, Verbal Memory Index, Learning Memory Index, and Visual Memory Index than the Control children on the WRAML. No differences were found between groups on the CVLT-C in the present study. These results are consistent with Loge et al., (1990) in which they found no differences between ADHD and non-ADHD children on the CVLT-C. However, the results are inconsistent with Kramer et al., (1999) in which they found that RD children had lower levels of recall, slower rates or learning across the 5 trials than controls, and worse on recognition. In Kramer et al., (1999), they compared dyslexic children with controls.

Willcutt et al., (2005) found that children with ADHD exhibited weaknesses primarily on the response-inhibition and processing speed tasks as well as a few measures of reading skill and verbal working memory. The children with RD had deficits on measures of reading and language skills, as well as weaknesses on verbal working memory, processing speed, and response inhibition. Children with RD and comorbid ADHD displayed a combination of the deficits seen in the RD only and ADHD only groups. None of the neuropsychological measures were associated specifically with ADHD, suggesting that the dissociation between ADHD and RD may not be complete. They concluded that a processing speed deficit is common to both children with ADHD and RD. The results of the present study found that the ADHD/RD and ADHD groups had significantly lower processing speeds than the Control group and that the ADHD/RD group had a significantly lower processing speed than the ADHD group. However, in contrast to the Willcutt et al., (2005) study, the present study did not find the RD-only group to have a significantly lower processing speed than the other groups (i.e. ADHD/RD, ADHD, and Control groups).

When examining the reading tasks (phonological processing task), significant differences were found on the Psuedoword naming tasks. Specifically, the RD group had worse performance than the ADHD and Control groups. The children with comorbid ADHD/RD did not differ significantly from the other groups. However, the results of the present study are consistent with previous research (e.g., Pennington et al., 1993, Willcutt et al., 2005) in which children with RD were found to have phonological processing deficits.

The results of the present study suggest that children with ADHD have executive function, immediate and delayed memory, and processing speed deficits. Additionally, children with RD have phonological processing and processing speed deficits. The present results are primarily consistent with previous research examining executive functioning, memory, and phonological processing abilities.

A limitation to the present study is the small sample size of the four groups. Children were referred from clinics and the local school system. We established rigorous inclusion criteria for our clinical groups. Unfortunately, many of the children referred to the present study failed to meet our inclusion criteria. Yet diagnostic criteria in the present study match the current diagnostic criteria for both ADHD and RD.

Clearly, longitudinal work needs to be conducted or groups of various ages need to be tested to examine the temporal occurrence of ADHD and RD to establish if and how one disorder emerges from the other.

REFERENCES

Achenbach, T.M. (2001). Manual for the child behavior checklist/6-18 and 2001 profile. Burlington: Department of Psychiatry, University of Vermont.

Achenbach, T.M., & Edelbrock, C. (1983). Manual for the child behavior checklist and revised child behavior profile. Burlington, VT: Thomas Achenbach.

Appelgate, B., Lahey, B.B., Hart, E., Biederman, J., Hynd, G.W., Barkley, R.A., Ollendic, T., Frick, P.J., Greenhill, L., Mc Burnett, K., Newcorn, J.H., Kerdyk, L., Garfinkel, B., Waldman, I., & Shaffer, D. (1997). Validity of the age-of-onset criterion for ADHD: A report from the DSM-IV field trials. Journal of the American Academy of Child and Adolescent Psychiatry, 36, 1211-1221.

Barkley, R.A. (1998). Attention-Deficit/Hyperactivity Disorder: A handbook for diagnosis and treatment- second edition. New York: Guilford Press.

Barkley, R.A., & Grodzinsky, G.M. (1994). Are tests of frontal lobe functions useful in the diagnosis of attention deficit disorders? The Clinical Neuropsychologist, 8, 121-139.

Benton, A.L., & Hamsher, K., (1978). Multilingual Aphasia Examination: Manual of Instructions-Revised. Iowa City, IA: AJA Associates, Inc.

Cahn, D.A., & Marcotte, A.C. (1995). Rates of forgetting in attention deficit hyperactivity disorder. Child Neuropsychology, 1, 158-163.

Conners, C.K. (1995). The Continuous Performance Test (CPT). , Toronto: Multi-Health Systems.

Cutting, L.E., Koth, C.W., Mahone, E.M., & Denckla, M.B. (2003). Evidence for unexpected weaknesses in learning in children with attention-deficit/hyperactivity disorder without reading disabilities. Journal of Learning Disabilities, 36, 259-269.

Delis, C., Kramer, J.H., Kaplan, E., & Ober, B.A. (1994). California Verbal Learning Test-Children's Version (CVLT-C). The Psychological Corporation, Harcourt Brace and Company, San Antonio.

Doyle, A. E., Bierderman, J., Seidman, L. J., Weber, W., & Faraone, S. V. (2000). Diagnostic efficiency of neuropsychological test scores for discriminating boys with and without attention deficit-hyperactivity disorder. Journal of Consulting and Clinical Psychology, 68, 477-488.

DuPaul, G.J., Power, T.J., Anastopoulos, A.D., & Reid, R. (1998). ADHD Rating Scale-IV: Checklists, Norms, and Clinical Interpretation. New York, NY: The Guilford Press.

Felton, R.H., Wood, F.B., Brown, I.S., Campbell, S.K., & Harter, M.R. (1987). Separate verbal memoryt and naming deficits in attention deficit disorder and reading disability. Brain and Language, 31, 171-184.

Felton, R.H. & Wood, F.B. (1989). Cognitive deficits in reading disability and attention deficit disorder. Journal of Learning Disabilities, 22, 3-22.

Gordon, M., & Mettelman, B.B. (1987). Technical guide to the Gordon Diagnostic System. New York: Gordon Systems, Inc.

Heaton, R.K., (1981). Manual for the Wisconsin Card Sort Test. Odessa, FL: Psychological Assessment Resources, Inc.

Houghton, S., Douglas, G., West, J., Whiting, K., Wall, M., Langsford, S., Powell, L., & Carroll, A. (1998). Differential patterns of executive function in children with Attention-Deficit Hyperactivity Disorder according to gender and subtype. Journal of Child Neurology, 14, 801-805.

Jakobson, A., Kikas, E. (2007). Cognitive functioning in children with and without Attention-Deficit/Hyperactivity Disorder with and without comorbid learning disabilities. Journal of Learning Disabilities, 40, 194-202.

Kaplan, B., Dewey, D., Crawford, S., & Fisher, G. (1998). Deficits in long-term memory are not characteristic of ADHD. Journal of Clinical and Experimental Neuropsychology, 20, 518-528.

Kempton, S., Vance, A., Maruff, P., Luk, E., Costin, J., & Pantelis, C. (1999). Executive function and attention deficit hyperactivity disorder: Stimulant medication and better executive function performance in children. Psychological Medicine, 29, 527-538.

Kramer, J.H., Knee, K., Delis, D.C. (2000). Verbal memory impairments in dyslexia. Archives of Clinical Neuropsychology, 15, 83-93.

Krikorian, R. (1994). The Tower of London task: Procedure and preliminary norms. Journal of Clinical and Experimental Neuropsychology, 16, 840-850.

Lavoie, M.E., & Charlebois, P. (1994). The discriminate validity of the Stroop Color and Word Test: Toward a cost-effective strategy to distinguish subgroups of disruptive preadolescents. Psychology in the Schools, 31, 98-107.

Loge, D.V., Staton, D., & Beatty, W.W. (1990). Performance of children with ADHD on tests sensitive to frontal lobe dysfunction. Journal of the American Academy of Child and Adolescent Psychiatry, 29, 540-545.

Netherton, S.D., Holmes, D., & Walker, C.E. (1999). Child and adolescent psychological disorders: A comprehensive textbook. Oxford University Press: NY.

Pennington, Groisser, & Welsh (1993). Contrasting cognitive deficits in attention deficit hyperactivity disorder versus reading disability. Developmental Psychology, 29, 511-523.

Pineda, D., Ardila, A., Rosselli, M., Cadavid, C., Mancheno, S., & Mejia, S. (1998). Executive dysfunctions in children with attention deficit hyperactivity disorder. International Journal of Neuroscience, 96, 177-196.

Reader, M. J., Harris, E. L., Schuerholz, L. J., & Denckla, M. B. (1994). Attention deficit hyperactivity disorder and executive dysfunction. Developmental Neuropsychology, 10, 493-512.

Reitan, R., & Wolfson, D. (1985). The Halstead-Reitan Neuropsychological Test Battery Theory and Clinical Interpretation. Tucson, AZ: Neuropsychology Press.

Sheslow, D., & Adams, W. (2003). Wide Range Assessment of Memory and Learning-Second Edition. Wilmington, DE: Psychological Corporation.

Wechsler, D. (2002). The Wechsler Individual Achievement Test-Second Edition. San Antonio, TX: Psychological Corporation.

Wechsler, D. (2003). The Wechsler Intelligence Scale for Children – Fourth Edition. San Antonio, TX: Psychological Corporation.

Willcutt, E.G., Pennington, B.F., Olson, R.K., Chhabildas, N., & Hulslander, J. (2005). Nueropsychological analyses of comorbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. Developmental Neuropsychology, 27, 35-78.

Wu, K., Anderson, V., & Castiello, U. (2002). Neuropsychological evaluation of deficits in executive functioning for ADHD children with or without learning disabilities. Developmental Neuropsychology, 22, 501-531.