MEMORY PERFORMANCE OF CHILDREN WITH ADHD AND READING DISABILITY

A Dissertation

Presented to

The Faculty of the Department

of Psychology

University of Houston

In Partial Fulfillment

Of the Requirements for the Degree of

Doctor of Philosophy

By

Baruch L. Williams

May, 2015

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ABSTRACT

The present study evaluated the use of the Selective Reminding Test in differentiating memory performance among children with Attention Deficit Hyperactivity Disorder (ADHD), Reading Disability (RD), and both ADHD and RD. Participants comprised 88 children (54 ADHD only, 17 RD only, and 17 ADHD/RD). Using a mixed model procedure, performance was compared on two measures of the Selective Reminding Test; Long Term Storage and Consistent Long Term Retrieval. Group x Task interactions were not significant, based on raw scores and z-scores, and there were no Group effects. However, performance of all groups was significantly below average. These results suggested that Long Term Storage and Consistent Long Term Retrieval were both associated with RD and ADHD; however, they were not differentially associated.

ACKNOWLEDGMENTS

I would like to express my sincere gratitude towards Dr. Jack M. Fletcher and Dr. Susan Croll.

Thank you for giving me a chance.

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Dedication Page

To my beautiful two nieces, Nadia and Sarai, I pray that all of your dreams come true and that peace and love always surround you.

"You may encounter many defeats, but you must not be defeated. In fact, it may be necessary to encounter the defeats, so you can know who you are, what you can rise from, how you can still come out of it." – Maya Angelou

"Success doesn't come to you…you go to it." – Marva Collins

Introduction

Over the past several decades, several different definitions of learning disabilities (LD) have evolved. In 1968, the U.S. Office of Education defined "specific learning disability" as "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, speak, read, write, spell, or to do mathematical calculations…" (U.S. Office of Education, 1968, p.34). This definition became the statutory definition of LD when special education services for this population were required of public schools in 1975 and has not been revised over the past 40 years. There are different revisions of special education regulations when the legislation is reauthorized.

As research began to guide policies and practices concerning children with LD, advocacy organizations, such as the National Joint Committee on Learning Disabilities (NJCLD, 1988) proposed revisions to the initial 1968 federal definition of LD's. The NJCLD identified learning disabilities as "a general term that refers to a heterogeneous group of disorders manifested by significant difficulty, in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities". In addition to clearly stating the heterogeneity of learning disabilities, the NJCLD identified learning disabilities as taking place across the life span and as having the ability to concur with other disorders: "these disorders are intrinsic to the individual, presumed to be due to central nervous system dysfunction, and may occur across the lifespan. Problems in self-regulatory behavior, social perception, and social interaction may exist with learning disabilities but do not by themselves constitute a learning disability (NJCLD, 1988)."

In 2004, the Individual with Disabilities Education Act indicated based on new legislation from Congress that states could not require districts to use IQ tests for the identification of students for special education in the LD category, states had to permit districts to implement identification models that incorporated response to instruction, and that children could not be identified for special education if poor achievement was due to lack of appropriate instruction or to limited proficiency in English (Individual with Disabilities Education Act, 2004). These changes were to the regulations guiding policy, with no change to the statutory definition.

Historically there is a general consensus that LD's reflect *unexpected* underachievement and that they can occur in different domains of reading, mathematics, and written language. As such, LD's are heterogeneous and it is important to identify the domain of low achievement. Disagreements over time usually reflect how "unexpectedness" is indicated, with variations based on different methods for assessing cognitive discrepancies, aptitude-achievement discrepancies, and insufficient instructional response (Decker, Hale, & Flanagan, 2013; Fletcher, Francis, Morris, & Lyon, 2005; Francis, Fletcher, Shaywitz, Shaywitz, & Rourke, 1996; Unruh & McKellar, 2013). These issues continue to be studied and debated (Fletcher, Lyon, Fuchs, & Barnes, 2007).

Reading disabilities (RD) are the most commonly identified and particularly the most studied. Reading disabilities also may be classified into various domains depending on, impairments with fluency, comprehension, and word recognition (Fletcher et al., 2007). In this proposal, use of the general term reading disability will represent a word-level reading disability that is often referred to as "dyslexia". For example, the definition of dyslexia from the International Dyslexia Association (2002) is as follows:

> It is characterized by difficulties with accurate and/or fluent word recognition and by poor spelling and decoding abilities. These difficulties typically result from a deficit in the phonological component of language that is often unexpected in relation to other cognitive abilities and the provision of effective classroom instruction. Secondary consequences may include problems in reading comprehension and reduced reading experience that can impede growth of vocabulary and background knowledge. (www.interdys.org)

Reading Disabilities and ADHD

At one point, difficulties with achievement and behavior were classified under a single construct most commonly referred to as minimal brain dysfunction (Satz & Fletcher, 1980). This occurred because many children showed both learning and behavioral difficulties, especially inattention and hyperactivity-impulsivity. For example, in 1962 the definition of "minimal brain dysfunction" included children of near average, average, or above average general intelligence with certain learning or behavioral disabilities ranging from mild to severe, which are associated with deviations of function of the central nervous system. These deviations may manifest themselves by various combinations of impairment in perception, conceptualization, language, memory, and control of attention, impulse, or motor function (Clements, 1966). Since the advent of the Diagnostic and Statistical Manual of Mental Disorders (3rd ed.; *DSM-III*, American Psychiatric Association, 1980), it has become customary to separate LD's from behavior problems involving inattention and hyperactivity-impulsivity, the latter now referred to as Attention Deficit Hyperactivity Disorder (ADHD). Although ADHD can detrimentally affect academic achievement, separation is important because the treatments are different, LD's involving specialized remedial interventions and ADHD a combination of medication and behavior therapy.

According to the Diagnostic and Statistical Manual of Mental Disorders (4th ed., text rev.; *DSM-IV-TR*; American Psychiatric Association, 2000) , Attention Deficit Hyperactivity Disorder is a persistent pattern of inattention and/or hyperactivity impulsivity that is more frequently displayed and is more severe than is typically observed in individuals at a comparable level of development. Current research has supported distinctions between learning disabilities and attention disorders, although both may produce similar deficits.

There is also a subset of children who experience both reading disabilities and attention disorders. Although an individual can be diagnosed with ADHD only or RD only, ADHD and RD are two disorders that often comorbidly exist in the same children (Gilger, Pennington, & DeFries, 1992; Purvis & Tannock, 2000; Shaywitz, Fletcher, & Shaywitz, 1995; Willcutt et al., 2001). The rate of RD in samples selected for ADHD falls between 25% and 40%, whereas 15% to 35% of individuals selected for RD also meet criteria for ADHD (Willcutt et al., 2001). In the next sections, I will expand the discussion of word level reading problems, ADHD, and comorbidity.

Dyslexia

This study focuses on word-level reading disability which is often referred to as "dyslexia". The core cognitive correlate of dyslexia involves deficits in phonological processing (Fletcher et al., 2007). While ADHD is associated with executive function and inhibition deficits, which will be discussed in a later section, word level reading disabilities largely involve phonological processing. Inhibition deficits have been identified in children with RD, but are not as prominent as the deficits in inhibition seen in children with ADHD (Purvis & Tannock, 2000).

Reading-matched designs have demonstrated phonological processing and its relation with word reading; significant group deficits in phonological processing have been found among older children with RD even when compared to younger normal younger readers who are reading on the same level. Recent studies have also suggested that individuals with RD also have weaknesses in additional neurocognitive domains, such as verbal working memory, processing speed (PS), and response inhibition (Purvis & Tannock, 2000; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005; Shanahan et al., 2006;). Willcutt et al. (2005) found that children with RD only had pronounced deficits on all measures of component reading and language skills, as well as significant weaknesses on measures of verbal working memory. Shanahan et al. found that PS is a cognitive risk factor in children with RD and Purvis and Tannock found that RD was associated with poor inhibitory control due to difficulty processing rapidly presented information.

According to Fletcher et al. (2007), research concerning the anatomical correlates of word-level RD has yielded mixed results. Fletcher et al. reported that some studies have identified differences in the size of the corpus callosum, while others have not found that difference. There has also been conflicting evidence surrounding the association between the symmetry of the planum temporale in dyslexia. In studies that investigated brain regions that extended beyond the planum temporale, the measures that most significantly discriminated children with and without dyslexia involved the right anterior lobe of the cerebellum and the pars triangularis in both hemispheres. There have also been investigations that reported significant correlations of reading ability and assessments of regional brain connectivity involving the left temporal parietal white matter, suggesting less development of white matter in this region.

Functional neuroimaging methods indicates that a network of brain areas is involved in the ability to recognize words accurately, including the basal temporal, temporoparietal, and inferior frontal regions, more predominantly in the left hemisphere (Fletcher et al., 2007). Fletcher et al. described a model for word recognition that can be explained using four major participating areas. The first area is the Broca's area which is responsible for phonological processing involving articulatory mapping, or the pronunciations of words. The second area, Wernicke's area, including portions of the superior temporal and supramarginal gyri, is responsible for phonological processing involving letter- sound correspondence. The angular gyrus acts as a relay station that links information across modalities and finally the visual association cortex in the occipito-temporal region is responsible for graphemic analysis. Price and McCrory (2005) stated:

"A pattern is beginning to emerge, with increased prefrontal activation and decreased occipital-temporal activation now observed over several studies. This pattern suggests that dyslexic readers largely activate the same neural system as skilled readers, but show subtle differences in how the components of this system are engaged. (p.496)"

Attention Deficit Hyperactivity Disorder

As previously stated, Attention Deficit Hyperactivity Disorder is a persistent pattern of inattention and/or hyperactivity impulsivity that is more frequently displayed and is more severe than is typically observed in individuals at a comparable level of development (4^{th} ed.; text rev.; *DSM-IV-TR*; American Psychiatric Association). Per most diagnostic classifications (e.g., American Psychiatric Association), ADHD is classified into three different subtypes (now referred to as presentation specifiers; *DSM-V*), Predominantly Inattentive (ADHD-I), Predominantly Hyperactive (ADHD-H/I), and Combined Type (ADHD-C). ADHD-I is marked by six or more symptoms of inattention, but fewer than six symptoms of hyperactivity-impulsivity. ADHD-H/I is marked by six or more symptoms of hyperactivity-impulsivity, but fewer than six symptoms of inattention. ADHD-C is marked by six or more symptoms of inattention and six or more symptoms of hyperactivity-impulsivity. A comprehensive meta-analysis (Willcutt, 2012) was conducted to estimate the prevalence of ADHD, as defined by the *DSM-IV-TR* (2000). Results of the meta-analysis found the following in regards to subtypes of children with ADHD based only on symptom criteria: 38%-57% of individuals met criteria for ADHD-I, while the relative frequency of ADHD- H/I and ADHD-C varied based on the reporter. When considering parent ratings, more children met the criteria for ADHD-H than ADHD-C (37 % vs 25 %) and self-report ratings (36 % vs 22 %). When considering teacher ratings a higher proportion met the criteria for ADHD-C than ADHD-H (24–30%). The prevalence of ADHD, according to the *DSM-V* (2013) may differ from the prevalence indicated in the *DSM-IV-TR* (2000) due to the *DSM-V* (2013) revisions to diagnostic criteria; this research has not been conducted at this time. Controversies surrounding the subtypes include the failure of neuropsychological research to consistently distinguish the inattentive, hyperactive, and combined subtypes which are found in the *DSM-IV-TR* (2000) (Nigg, Blaskey, Huang-Pollock, & Rappley, 2002).

Neuropsychological studies of *DSM-IV -TR* (2000) subtypes have yielded mixed results (Nigg et al., 2002). For example, Houghton et al. (1999) found no differences between inattentive and combined types on numerous executive function tasks, although the combined subtype had qualitatively larger deficits. Faraone, Biederman, Weber, and Russell (1998) also found no differentiation in cognitive skills between subtypes on IQ and academic measures. However, Klorman et al. (1999) found that children with ADHD-C and ADHD-H/I performed more poorly than children with ADHD-I on the Tower of Hanoi and Wisconsin Card Sorting Test. Nigg et al. suggested that ADHD-C and ADHD-I are related disorders that share deficits in vigilance or effortful functions, and on many measures may only differ in severity.

ADHD has frequently been associated with deficits in executive functions (Willcutt et al., 2001). Executive functions are higher level, top down cognitive processes that involve cognitive flexibility, working memory, monitoring of behavior, self-regulation, planning, controlled attention, and regulation of processing speed (Bental & Tirosh, 2007). Executive functions are thought to be mediated by the prefrontal cortex (PFC). Brain imaging and anatomical studies have been used to exhibit executive function and frontal lobe deficits among children with ADHD (Castellanos et al., 1996; Fassbender & Scheweitzer, 2006; Hill et al., 2003; Hynd, Hern, Voeller, & Marshall, 1991; Mostofsky, Cooper, Kates, Denckla & Kaufman, 2002; Snowling, 2009; Spencer, Biederman, & Mick, 2007; Tannock, 1998).

The frontal lobes may be dysfunctional in children with ADHD (Hill et al., 2003). The prefrontal cortex, which is within the frontal lobes, plays an important role in higher level executive functioning such as working memory, attention, inhibition, planning, and organization (Arnsten, Berridge, & McCracken, 2009; Lipschitz, Morgan, & Southwick, 2002; Snowling, 2009; Spencer et al., 2007). Several studies have found smaller volumes of prefrontal cortex (PFC) in children with ADHD (Castellanos et al., 1996; Mostofsky et al., 2002).

Brain imaging studies have captured dysfunction in frontosubcortical pathways in ADHD (Fassbender & Scheweitzer, 2006; Hynd et al., 1991; Snowling, 2009; Spencer et al., 2007; Tannock, 1998). The caudate, putamen, and globus pallidus are subcortical structures that have been indicated. These structures are components of the neural circuitry that contribute to executive function, inhibition, motor function, and reward pathways and provide feedback to the cortex for regulation of behavior.

Comorbidity

When an individual has characteristics of both ADHD and RD, the disorders are referred to as demonstrating comorbidity. The deficits of children with RD as well as with ADHD have been researched as two distinct disorders; however, individuals demonstrating comorbidity have also been researched as a separate group distinct from children with RD only or ADHD only.

Comorbidity by definition is the simultaneous presence of two or more disorders in one individual. ADHD/RD is described as a comorbid disorder because they often occur together, although they maintain distinct characteristics that differentiate them (Pennington, 2006; Willcutt et al., 2001; Willcutt et al., 2005). The strongest explanation of the comorbidity of ADHD and RD is the *correlated liabilities* hypothesis (Pennington, 2006). According to this hypothesis, ADHD and RD share a common subset of weaknesses. ADHD may include five deficits that place an individual at an elevated risk to manifest ADHD and RD may have four deficits that place an individual at an elevated risk to manifest RD. However, two of the deficits involved with ADHD may be the same two deficits involved with RD, which represent correlated liabilities. Studies have identified correlated liabilities for ADHD and RD including deficits in processing speed, attention, working memory, and to a lesser extent, response inhibition (Mayes, Calhoun, & Crowell, 1998; Willcutt et al., 2001; Willcutt et al., 2005). For the latter, inhibition difficulties are most apparent on alphanumeric stimuli (De Weerdt, Desoete, & Roeyers, 2013), whereas in ADHD such deficits are apparent across multiple stimuli and assessment paradigms

(Willcutt et al., 2005). Cognitive/behavioral functions that have not been identified as correlated liabilities include phonological awareness and impulsivity, which are specific to RD and ADHD, respectively.

The debate surrounding the nature and sources of this comorbidity has encouraged research that evaluates the commonality and separability of ADHD and RD. Shanahan et al. (2006) stated:

> If two disorders are comorbid, looking at the profile of deficits in the comorbid group compared to those of each single group should help address whether the underlying risk factor is shared. If the effects are independent, then the profile in the comorbid group should be either the sum of the profiles in each pure group, with no RD by ADHD interaction, or will be greater than the sum of the profiles in the pure groups. If the effects are at least partially shared the profile in the comorbid group should be less impaired than the sum of the profile in each group, producing an RD by ADHD interaction in the direction of underadditivity. (p.288)

In addition to shared deficits in executive functions, ADHD and RD groups also experience shared deficits in verbal learning and memory. Verbal learning tasks place demands on many aspects of language and executive functions. Therefore, it is necessary to research the underlying memory and executive function deficits that may help to further differentiate these two groups. While verbal learning and memory have been studied extensively in ADHD and RD separately, it has rarely been studied as a comparison between ADHD, RD, and ADHD/RD groups. Review of current literature suggests that the memory profiles of ADHD and RD differ from one another on some measurements. However, on other measurements the deficits between these groups are similar. Assessing these three groups simultaneously allows for evaluation of the separability and commonality of verbal learning and memory performance of ADHD and RD. Differences in profile may have significant implications for interventions. Deficits in verbal learning and memory represent areas of cognitive functioning that have been indicated in children with reading disabilities and in ADHD. The objective of this proposal is to study verbal learning and memory in children with ADHD and RD as single groups and as a comorbid group.

Memory

Memory involves the ability to encode, process, and retrieve information (Swanson & Zheng, 2013). Intellectual functioning, cognitive functioning, learning, and academic performance all have some dependence on memory skills. Therefore, memory represents an important area of concern for children with various learning disabilities, including reading disabilities. In discussing the role of memory in LD generally, Swanson and Zheng suggested reasons memory should be a critical focus. Memory affects all aspects of learning. In addition, the memory skills of students with LD inadequately reflect their cognitive abilities. Therefore, instructional procedures that are not heavily based on memory skills are needed to better assess the abilities of students with LD. These same concerns about memory also influence research and practice in children with ADHD, which is of special concern because of the comorbidity or common co-occurrence of ADHD and RD in children. Mayes et al. (1998) suggested that the frequent comorbidity of ADHD and LD can be partly explained by the overlapping of deficits in executive functions, such as attention, working memory, and processing speed, which are associated with learning problems in general. Mattison and Mayes (2012) found that the addition of LD to ADHD is associated with worse executive function.

In order to explicate the importance of a study of verbal learning and memory in children with RD and ADHD, I will provide a brief review of memory research followed but a review of verbal learning and memory studies that include the ADHD and/or RD populations.

Theoretical Frameworks

Research on memory can be conceptualized based on three theoretical frameworks, which include: information processing, neuropsychological, and behavioral perspectives.

Contemporary information processing perspectives emerged from research by Baddeley (1986, 1992). According to this information processing model, information initially enters through visual and auditory senses. Visual information then progresses to the viusospatial sketchpad, while auditory information travels from the auditory store to the phonological loop. From the visuospatial sketchpad and phonological loop, information travels to the central executive system, which is a control system with a key role in decision making and response selection; these three areas are combined to create "working memory." Information then enters the long-term memory from all three parts of the working memory system. Other frameworks have been proposed, but these largely reflect variations on Baddeley's seminal work (Baddeley, 2003; Buchsbaum & D'Esposito, 2008; Fougnie & Marois, 2011; Heilman, 2006; Wright & Fergadiotis, 2012).

The neuropsychological perspectives combine cognitive psychological theory and neurobiological mechanisms. The primary constructs in this perspective are modality-specific short-term memory stores and long-term memory. For example, Squire (1987) proposed that long- term memory could be divided into two separate components. One component involves the conscious awareness of newly acquired information and is termed declarative or explicit memory. The other component of long-term memory involves the acquisition of skills without recollection of previous learning and is termed procedural or implicit memory. Clinical cases of brain-damaged amnesic subjects have supported the concept of fractionation which is the ability to separate different aspects of memory by showing that a deficit in one memory system can exist while another memory system is intact (Baddeley, 1986; Squire, 1987).

Finally, the behavioral perspectives focus on the use of behavioral techniques in developing language comprehension and production in nonhuman primates. Through the use of classical behavioral theory and methods in combination with new methods, there has been demonstration of higher-order cognitive skills in nonhuman primates. Rumbaugh and Washburn (1996) suggested that changes in attentional focus displayed by highly trained nonhuman subjects could serve as a model for developing treatments for ADHD in children.

These theoretical frameworks of memory are important for understanding LD and ADHD for multiple reasons. First, theory provides constructs to better understand the processes involved in memory as well as potential areas of breakdowns in the process that result in qualitative and quantitative memory deficits seen in LD and ADHD. Secondly, theory provides constructs that assist in targeting specific areas of memory requiring intervention in LD and ADHD. As understanding of memory processes becomes refined, a better understanding of memory deficits will most likely follow and inevitably lead to the development of targeted interventions.

Multiple theoretical perspectives have been proposed over time. Information processing is a theoretical perspective that has consistently been invoked throughout literature. Since the initial proposal of the information processing theory, multiple models have been proposed under the umbrella of information processing (Baddeley, 2003; Buchsbaum &

D'Esposito, 2008; Cowan, 1988; Cowan, 2005; Hasher & Zacks, 1988; Heilman, 2006); one of those models is the multi-store model.

Multi-store models. As stated, the multi-store model is a part of the information processing framework; it consists of numerous stores and the transfer of information amongst the stores (Craik & Lockhart, 1972). The stores are predominantly distinguished by their different retention characteristics. Varying emphasis on the retention characteristics of stores and their qualitative effect on memory is what distinguishes one multi-store model from another.

Broadbent (1958) proposed a multi-store model that included two stores: a short-term store and a long-term store. Following perception, items are held over the short-term by recycling them in a transient storage system. From there information can be transferred into and retained in a permanent long-term store. Since Broadbent's proposal, literature has expanded on this model and the multi-store view of memory has become widely accepted. Contemporary versions postulate that there are three stores in the multi-store model, including sensory stores, short-term memory, and long-term memory along with additional subdivisions of the stores (Baddeley, 2003; Kaplan, Dewey, Crawford, & Fisher, 1998).

To begin, sensory storage has a moderately large capacity in comparison to the later stores. Information can enter into the sensory regardless of whether or not the person is paying attention to the information. When an individual focuses their attention on material in the sensory storage, information can be transferred to the short-term storage.

The short-term storage has limited capacity. There is a belief that short-term storage is instrumental in skills such as language comprehension (Wagner, 1996). Crowder (1982) suggested that as an individual is reading through a text, short-term memory provides a verbatim record of the last several words that can be accessed by higher-level comprehension processes. In support of short-term memory storage, Wagner suggested that the well-known memory cases, such as H.M. (Milner, 1966) and K.*F*. (Warrington & Shallice, 1972) support the concept of short-term memory storage and long-term memory storage. These cases represent two individuals, one (H.M.) who had relatively preserved short-term memory, but impaired long- term retention of new information. For example, H.M.'s performance on digit span was in the normal range, but he exhibited deficits when attempting to learn lists of paired associates. In contrast, K.*F*. had an impaired short-term memory, with a digit span of only one item, but did not exhibit deficits in long-term retention of new information relative to the amount of information retained in short-term memory.

According to Baddley (1966, 2003), verbal items are usually coded phonemically in the short-term storage, but semantically in the long-term storage. Material is usually forgotten from the short-term storage with a shorter time period than it is forgotten from the long-term storage. During free recall, literature has supported that the last items presented are retrieved from short-term storage and earlier items are retrieved from long-term storage.

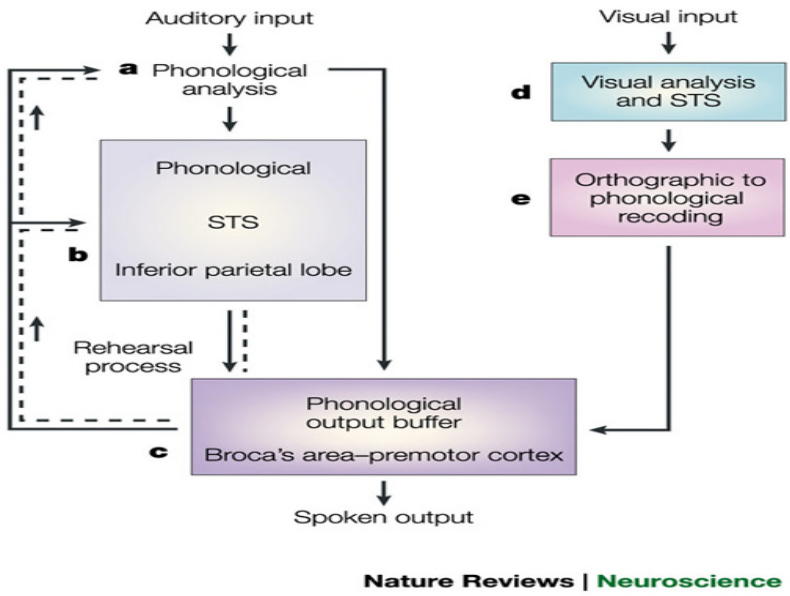

Figure 1. Example of a Multi-Store Model (Baddeley, 2003)

Criticisms of multi-store models. Although past literature has supported the multi-store model, certain aspects of the model have been critiqued. Craik and Lockhart (1972) challenged the multistore approach based on the concepts of capacity, coding, and retention.

According to Craik and Lockhart (1972), the nature of the limited capacity of short-term storage is obscure; meaning that it is unclear whether this limitation is due to processing capacity, storage capacity, or an interaction between the two. However, studies that have attempted to measure the capacity of short-term storage have considered the number of items to be the appropriate scale of measurement. Various studies have indicated a very wide range of capacity estimates in short-term storage, based on if the items in question are words, letters, digits, sentences, etc. (Cowan, 2000, 2010; Craik& Masani, 1969; Crannel & Parrish, 1957; Nairne, 2002). It has been suggested that the most widely accepted explanation of the variation in capacity is that capacity is limited in terms of chunks (Craik & Lockhart, 1972; Conwan, 2000, 2010). This means that the amount of items can be coded into a chunk, although this is based on the meaningfulness of the material.

The multi-store model has also been critiqued based on the forgetting characteristics across the various stores. Studies have resulted in different outcomes for retention functions of various stores based on the type of paradigm and the experimental conditions (Conwan, 2000; Murdock, 1967, 1971; Nairne, 2002; Neisser, 1967; Posner, 1969; Waugh & Norman, 1965). Craik and Lockhart (1972) suggested that retention depends on study time, amount of material presented and mode of test, and the extent to which the material is familiar, compatible and meaningful to the subject.

Craik and Lockhart (1972) concluded that it seems certain that stimuli are encoded in different ways within the memory system and that a word may be encoded at various times in terms of its visual, phonemic, semantic features, verbal associates, or an image. They also suggested differently encoded representations persist for different lengths of time, although the concept of limited capacity at some points in the system appears to be valid. Finally, they suggested that the roles of perceptual, attentional, and rehearsal processes should also be noted.

Wagner (1996) suggested that although there have been criticisms of the storage systems involved in the multi-store models, specifically related to short-term storage, this does not mean that an individual's performance on a task such as reading is not constrained by memory limitations. However, Crowder (1982) criticized the emphasis placed on a dedicated system of processing that is distinct in its properties from other systems of processing; specifically he criticized the conceptualization of memory limitations as reflecting the operations of dedicated short- term stores. Wagner supports alternative conceptualizations of short-term memory that have regarded it as that portion of long-term memory that is temporarily at a heightened state of activation at a particular moment in time (Cowan, 1993; Shiffrin, 1993). This implies that short-term memory is not a distinct store but rather involves activation patterns over a large number of neural circuits that are the same as those involved in both processing and long-term storage. This view is consistent with Hebb's (1949) cell assembly theory which suggests that memory represents continued activity or reverberation of the neural cells involved in perception (Wagner, 1996).

Alternative conceptualizations of short-term memory also imply that while the capacity for short-term storage is limited, this limitation is due to the temporary heightened state of activation of a given portion of long-term memory. Shiffrin (1993) also included short-term memory functions as the core of cognitive control processes, including attention. Therefore, short-term memory plays a role in processes such as determining where to direct peripheral attention, how to encode new inputs, and engaging the process of rehearsal (Wagner, 1996).

Although there are criticisms of the multi-store models and other models have been proposed, generally there appears to be a consensus that there are some levels of distinction or phases in memory. Multi-store models as well as other models have significant implications for LD and ADHD. As previously stated, models help to form a better understanding of normal memory processes as well as deficits in memory which may influence interventions; multi-store models have specifically driven the construction of memory measures such as verbal list learning. Knowledge of stores, levels, and phases of memory assists in identifying specific memory deficits found in children with LD and/or ADHD. Furthermore, these models may assist in distinguishing memory performance of two disorders that commonly exist together, reading disabilities and ADHD.

Verbal Memory in RD and ADHD

Performance on paired- associate learning tasks and verbal list learning tasks have a clear and distinct place in reading disabilities as well as attentional disorders as indicated by past and present literature. Generally, the ability to learn, retain, and recall information, which is affected by RD and ADHD, is critical for children's success in school (Cutting, Koth, Mahone, & Denckla, 2003; Swanson & Zheng, 2013). Verbal learning lists and paired associate learning tasks allow for the assessment of deficits in learning, retention, and recall in RD and ADHD, which are necessary deficits to identify due to their potential impact on academic performance. Children with these deficits are often slower in learning a variety of language based tasks including reading.

As stated by Kramer, Knee, and Delis (2000) the specific mechanisms underlying verbal memory impairments have not been clearly defined. Children with word-level reading disability (e.g., dyslexia) and/or ADHD may perform poorly when recalling verbal information, but performance may reflect a deficit in the initial coding and storage of the information or alternatively, a deficit in retrieving the information that has already been stored. Verbal learning lists and paired associate learning tasks assist in teasing out the nature of deficits in individuals with disorders such as RD and ADHD.

In addition research has indicated a link between performance on memory tasks and fronto-subcortical involvement, which has been associated with ADHD. Cutting et al. (2003) suggested that the hypothesis of fronto-subcortical involvement in ADHD is connected to performance on memory tasks, because many of the structures in the fronto-subcortical circuits are responsible for subsets of memory processes. The frontal lobe is important during memory formation because it guides encoding and retrieval. Overall, children with ADHD showed a weakness in retrieval of information only on a verbal learning tasks; their performance may be associated with abnormalities seen in cognitive structures of the brain. Crocker, Vaurio, Riley, & Mattson (2011) also reported that frontal-subcortical systems are consistently found on structural imaging and that the pattern of performance observed in ADHD is consistent with memory difficulty associated with damage to this system.

Multiple paradigms, which are based on multi-store models, have been used to study verbal memory and learning in either RD or ADHD, or both, including but not limited to: the Paired Associate Learning (PAL) Task, California Verbal Learning Test- Children's Version (CVLT-C), Wide Range Assessment of Memory and Learning (WRAML), Rey-Auditory Verbal Learning Test (R-AVLT), and the Selective Reminding Test (SRT).

Paired Associate Learning (PAL). PAL has been studied primarily in ADHD, but there is a study that addresses PAL in normal readers. There are multiple versions of Paired Associate Learning tasks, including those involving verbal material, visual material, or both. Generally, the PAL task involves a list of paired words or objects. The list is usually presented to a participant as pairs of words or objects. The examiner then reads the first word of each pair and asks the participant to recall the associated word. The examiner does not give feedback on the accuracy of responses. This procedure takes place over multiple trials. Successful performance on the PAL tasks requires encoding strategies such as rehearsal, organization, or elaboration (Schneider & Bjorklund, 1998). Search and retrieval strategies are also employed to retrieve information from long-term storage. The PAL task has a long history in research on ADHD and research has shown improvement of PAL performance for children who were taking stimulants (Dalby, Kinsbourne, Swanson, & Sobol, 1977; Douglas, Barr, Amin, O'Neil, & Britton, 1988).

PAL in ADHD. Chang et al. (1999) evaluated the extent to which deficits in mnemonic strategies, or learning techniques that aid information retention, exhibited by children with ADHD (Inattentive and Combined subtypes) in PAL are affected or moderated by the presence of or comorbidity with oppositionality while ruling out learning disorders. The PAL test was administered to 22 controls and 197 children with inattentive and combined subtypes of ADHD either in combination with or without ODD. Performance on PAL was assessed by measures of the extent and speed of learning and qualitative analysis of overt errors.

Pooling over ODD categories, results indicated that non- ADHD children exceeded ADHD children on two measures of learning including acquisition as well as learning rate. Chang et al. (1999) reported that their results, along with results from previous studies, point to a core weakness by ADHD children in rote learning, a reflection of their deficits in working memory and deployment of mnemonic strategies.

PAL in RD. Research that solely targets performance on the PAL task has not been evaluated in children with RD only. However, one study evaluated performance on PAL in normal readers. Windfuhr and Snowling (2001) evaluated 75 six to eleven year normally developing readers on visual-verbal paired associate learning .Of particular interest in this study was the hypothesis that phonological awareness and paired associate learning would be significantly related. The extent to which paired associate learning depends upon the ability to store verbal items in a temporary form, as indexed by short-term memory measures was also investigated.

Results suggested a significant correlation between paired associate learning (r= .56; p<.001) and basic word reading as well as non- word reading (r= .49; p<.001). Phonological awareness accounted for more variance in PAL than any other skills. This is consistent with the widely accepted theory that many children with RD experience deficits in phonological processing and that phonological skills are amongst the best predictors of future reading abilities (Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Swanson and Zheng (2013) suggested that this difficulty impairs their ability to retrieve verbal information from short-term memory, although it does not appear to have broad effects on general intellectual ability apart from deficits on language-related functions.

PAL in ADHD and RD. Douglas and Benezra (1990) evaluated 84 elementary schools boys (30 ADHD-H/I, 24 RD, and 30 controls) using a comprehensive battery of verbal and nonverbal tasks chosen to assess a broad range of rehearsal and effort demands. These tasks included PAL and word lists. In relation to the PAL task, participants were analyzed on various measures of the PAL.

Douglas and Benezra (1990) found that boys with ADHD-H/I recalled fewer unrelated pairs of words than controls; differences between ADHD-H/I and RD were not significant. Boys with RD recalled fewer related pairs than controls, but differences between ADHD-H/I and RD were not significant. More intrusion errors, poorer recognition scores, and more acoustic errors were present in ADHD-H/I, while more semantic errors were present in RD. Douglas and Benezra concluded that the cognitive deficits associated with ADHD-H/I are attributable to self-regulatory processes that control the deployment of deliberate, sophisticated rehearsal and problem-solving strategies and sustained, repeated effort. These cognitive deficits in RD were attributable to difficulties in verbal processing and not organizational skills.

Overall, performance on PAL tasks reveals that children with ADHD experience deficits in retrieval from long-term storage that is closely tied to their ability to organize, selfregulate, use elaborate rehearsal strategies, and utilize working memory. Children with RD may experience retrieval deficits on PAL tasks that are closely tied to their abilities related to phonological awareness and verbal processing.

Verbal List Learning Tasks

A number of list learning tasks have been used to investigate memory deficits in children with ADHD and RD. I will begin with a review of studies using the CVLT-C.

California Verbal Learning Test- Children's Version (CVLT-C). The CVLT-C (Delis, Kramer, Kaplan, & Ober, 1994) is a task that includes two lists of 15 words. Each list contains three groups of semantic categories, with 5 words per cluster. The first list is presented in five consecutive trials, for each trial the participant is asked to recall as many words as possible without receiving feedback on accuracy, which assess encoding, learning, and the ability to retrieve information. The second list is the presented and the participant is asked to recall as many words from the new list, this list represents an interference effect. Immediately following, the participant is asked to recall as many words as possible from the first list, which measures the ability to retain and retrieve information. Free recall, cued recall, and recognition of the first list are evaluated after a 20- minute delay, these also measure the ability to retain and retrieve information from long-term memory under the constraints of a delay.

CVLT-C in ADHD. Cutting et al. (2003) evaluated the mechanisms underlying verbal learning in 38 children (18 ADHD, 20 controls). Multiple measures were used to evaluate recall and retrieval problems as well as additional skills that were not relevant to this paper. Their findings indicated significant differences among ADHD groups on free delayed recall and cued delay recall. Overall, the ADHD group initially learned the same number of words as controls but showed weaknesses recalling the words after delay, even when provided with cues or when simply asked to recognize the words on a list. Post hoc analyses with the response bias index from the CVLT-C revealed that the ADHD group was significantly more biased toward providing no responses on the recognition format. Therefore, Cutting et al. concluded that the weakness in retention in children with ADHD is most likely not due to deficits in storage, but more likely due to lack of efficient strategies (other than those measured by the CVLT-C) during the encoding stage which hinders the recall of newly learned verbal material.

Crocker et al. (2011) compared verbal learning and memory in three groups of 22 children with heavy prenatal alcohol exposure (ALC), with ADHD without prenatal alcohol exposure (ADHD group), and a control group of children with neither prenatal alcohol exposure nor ADHD (the CON group). Each child was given the CVLT-C as a part of a larger battery of tests. On learning trials they found that the ALC group performed significantly worse than the remaining two groups and that ADHD group performed significantly worse than the control groups. Both the ALC group and ADHD group recalled fewer words than the controls on the delayed recall trials. Crocker et al. concluded that children with ADHD showed impaired learning and retention but intact recognition of presented material, reflecting relative difficulty in retrieval of learned material that may be explained by impaired ability to organize information during learning or application of inefficient strategies to aid in retrieval of encoded material.

CVLT-C in RD. Kramer et al. (2000) investigated the specific mechanisms underlying verbal memory deficits in children with RD using 57 children with dyslexia and 114 controls on measures on the following measures of the CVLT-C: recall, recognition, and use of learning strategies. Results demonstrated that the group with dyslexia learned the list item more slowly, recalled fewer words on the last learning trial and delayed trials, and performed less well on the recognition condition. For learning strategies, post hoc analyses revealed that the controls recalled a higher proportion of words from the middle region than dyslexics, which Kramer et al. presumed to reflect more efficient rehearsal and encoding. Because recognition paradigms aid retrieval and the RD group was impaired on this measure, Kramer et al. concluded that in children with RD, poor recall is not likely to be related to a retrieval deficit. The lack of differences between the groups in their rate of forgetting indicated that the primary mechanism underlying deficits in verbal memory in RD is in the acquisition of new information. Children with RD have less efficient rehearsal and encoding mechanisms, resulting in deficient encoding of new information, but normal retention and retrieval. The authors suggested that both reading disability and poor verbal memory stem from underlying verbal processing deficiencies in reading disability.

Kibby (2009) evaluated the nature of the memory deficits in 18 children with dyslexia and 18 controls using the CVLT-C. Kibby hypothesized that group differences would not be present on the CVLT-C as the measure fostered semantic coding. As will be explained in a later section, in a different study by Kibby they found that children with dyslexia were impaired on phonological short-term memory tasks and not on semantic short-term memory tasks. Kibby evaluated immediate memory, short-term memory, and long-term memory using a variety of measures from the CVLT-C.

In general, children with dyslexia scored in the average range on all CVLT-C measures, which Kibby (2009) interpreted as an intact semantic short and long-term memory. The results from this study, combined with the results from a different study by Kibby suggested that the primary memory deficit in children with dyslexia is poor phonological short-term memory, with the rest of memory functioning being spared. Kibby concluded that the store for material phonetically encoded is likely affected in dyslexia, whereas the store for material semantically encoded is likely intact.

Overall, performance on the CVLT-C measures revealed that verbal memory deficits in children with ADHD is most likely due to difficulties in retrieval of information even after initially learning the same amount of words as controls. Whereas verbal memory deficits in children with RD are most likely due to factors other than retrieval and retention. Deficits in rehearsal strategies, encoding, and phonological processing, have all been implicated as factors.

Wide Range Assessment of Memory and Learning (WRAML). The WRAML consists of a variety of subtests that assesses various aspects of memory. The Verbal Learning test includes a seven to nine item word list. The list is presented in multiple trials, for each trial the participant is asked to recall as many words as possible without receiving feedback on accuracy, this portion of the subtest measures encoding, learning, and retrieval of information. Free recall and recognition of the list are evaluated following a 20- minute delay, this portion of the subtest measures retention and retrieval of information.

WRAML in RD. As reviewed in the previous section, Kibby (2009) conducted a study to evaluate the nature of memory deficits in children/adolescents with dyslexia. For this particular study, 20 children with dyslexia and 20 controls, ages 9-13 were tested with numerous subtests of the WRAML. Kibby was particularly interested in the debate on short-term memory deficits in dyslexia, which is if deficits are accounted for by deficits in phonological processing.

Group performance was comparable on Verbal Learning, a semantic measure, while group performance on phonetic decoding subtests significantly differed. Results also revealed that children with dyslexia performed worse than controls on the phonological short-term memory subtests. Phonological short-term memory was also moderately to highly correlated with word identification and decoding skills and in contrast correlations between semantic short-term memory and basic reading measures were small.

WRAML in ADHD/RD. Research is limited in studies that examine ADHD no RD, RD no ADHD, and combined ADHD/RD groups on verbal learning tasks. However, Kaplan, Dewey, Crawford, & Fisher (1998) used the WRAML to assess memory deficits in children (53 ADHD, 63 RD, 63ADHD + RD, and 112 controls). Multiple subtests from the WRAML were used to provide a standard score for Verbal Memory, Visual Memory, a Learning Index, and an overall General Memory Index.

Results indicated that on Verbal Learning, which contributes to the Verbal Memory Index, the RD and the ADHD + RD group scored significantly lower than controls. The RD group also scored significantly lower than the ADHD group and ADHD +RD group. One conclusion was that children with RD and ADHD +RD consistently perform at a similar yet clinically impaired range on some parts of the WRAML, but consistently perform poorer than the ADHD group and controls on verbal memory and learning indices.

Overall, according to one study, performance on the WRAML in children with RD suggests a deficit in phonological short-term memory as opposed to semantic short-term memory (Verbal Learning) (Kibby, 2009). In another study examining the deficits in verbal memory between controls, ADHD, RD, and ADHD +RD group, they found that RD and ADHD + RD consistently performed poorer than the ADHD group and controls on verbal memory and learning indices (Kaplan et al., 1998). The results of these two studies do not support one another. A potential reason for the lack of findings in the RD group for Kibby (2009) may be the use of small sample sizes and the mild severity of dyslexia for the RD group, while Kaplan et al. (1998) included a larger sample size and a fairly inclusive group of children with varying severities in reading deficits.

Rey-Auditory Verbal Learning Test (R-AVLT). The R-AVLT includes a 15-item word list. The list is presented over five trials, for each trial the participant is asked to recall as many words as possible without receiving feedback on accuracy, this portion of the subtest measures encoding, learning, and retrieval of information from short-term storage. Following the first list a second 15 item word list (distractor) is administered, followed by a recall of the original list, this allows for measurement of retention and retrieval of information.

R-AVLT in RD and ADHD. Felton, Wood, Brown, Campbell, & Harter (1987) investigated verbal memory and naming deficits in 98 children with word level reading disabilities (dyslexia) and children without word level reading disabilities who were characterized according to the presence or absence of ADD (45 RD (26 ADHD, 19 non-ADHD (NADHD)), 53 non reading disabled (13 ADHD, 40(NADHD)). An array of assessment instruments was used, including the R-AVLT. Results revealed a significant main effect of the ADHD group only for free recalls on the first and fifth trials and postdistractional trial of the (R-AVLT). In contrast to results of many previously mentioned studies, Felton et al. concluded that a distinctive pattern exists where the ADHD effect appears to be on tests of verbal learning and the RD effect is on test of naming.

Vakil, Blachstein, Wertmna-Elad, & Greenstein (2012) examined the effects of ADHD, LD, and the combined effects of both on the learning and memory processes in thirty children ranging from 11 to 17 years (30 ADHD, 18 LD, and 64 ADHD/LD) and 28, 18, and 62 matched controls, respectively. Several verbal memory processes were evaluated using a variety of R-AVLT measures. Results revealed that the ADHD group did not differ from matched controls on any of the measures, indicating similar encoding, storage, and retrieval processes. The LD group was impaired compared to controls in the overall amount of words learned in the first consecutive learning trials. Finally, the ADHD + LD group showed impairment similar to the group with LD only. In addition, the advantage of recognition versus delayed recall was larger in the combined group than in the control group, reflecting retrieval deficits. Vakil et al. suggested several reasons for lack of differences in the ADHD group, including several identical presentation trials and the use of an older age group whose memory was less dependent or associated with attention, thereby enabling ADHD participants to function similarly to healthy controls. This study did not run analyses based on individual learning disabilities (e.g., reading disability, arithmetic disability).

Overall, studies evaluating performance of R-AVLT suggested various outcomes, which are difficult to compare and interpret across studies due to the use of different populations. One study associated ADHD with poor performance on verbal learning tests, specifically in encoding and retrieval of information. Another study found that ADHD does not differ from controls on any measure of the R-AVLT, while the LD and ADHD + LD group show impairment in some measures of the R-AVLT, including overall amount of words learned in the first consecutive learning trials (encoding) and retrieval efficiency.

Selective Reminding Task (SRT). The Selective Reminding Task (SRT) consists of a list of words read to the participant. The participant recalls as many of the words as possible. Subsequent learning trials involve only presenting the items that were not recalled during the immediately preceding trial (Strauss, Sherman, & Spreen, 2006). An item is believed to be in long-term storage when it is recalled twice without presentation. Consistent Long Term Retrieval involves consistent recall on subsequent trials without any further presentation at all.

Currently, there is minimal research investigating performance on the SRT in children with ADHD and RD. However, one study evaluated performance on the SRT in children with learning disabilities while another study evaluated performance on the SRT in children with two different subtypes of ADHD.

Selective Reminding in RD. Fletcher (1985) used selective reminding procedures to evaluate verbal and nonverbal memory in normal achieving children and four groups of disabled learners including: 16 controls, 10 reading-spelling disabled, 38 reading-spelling-arithmetic disabled, 10 spelling-arithmetic disabled, and 13 arithmetic disabled. Children received one memory task for verbal material (animal names). The tasks were administered through the use of selective reminding procedures that allowed for the separation of storage and retrieval aspects of memory.

Results revealed that subjects with reading and spelling deficits did not significantly differ from controls on a storage measure, but performed significantly less well on a retrieval measure. However, patterns of results showed that the reading-spelling subgroup had the lowest mean performance on total recall, long-term storage, long-term retrieval, and consistent long-term retrieval in comparison to all groups, including controls. Fletcher (1985) concluded that memory performance of children with RD varies according to the type of learning problem, the nature of the stimuli, and the aspect of memory being assessed.

Selective Reminding in ADHD. Barkley, DuPaul, & McMurray (1991) used selective reminding procedures to evaluate the effects of methylphenidate (e.g. Ritalin, Concerta) in 23 children with ADHD-H/I with and 17 children with ADHD-I. Children received a verbal learning and memory test adapted from Buschke’s Selective Reminding during pretreatment and at the end of each drug condition; they were evaluated on total recall, long-term storage, and consistent long-term retrieval.

Results revealed that children with ADHD-I were significantly more impaired in their consistent long-term retrieval of verbal information across all drug conditions compared with those with ADHD- H/I. Barkley et al. (1991) concluded that children with ADHD-I exhibit attention problems that is not likely due to vigilance or impulsivity, but may reside more in a different component of attention. This study did not compare performance to that of a control group.

Overall, studies evaluating performance on selective reminding tasks suggest that children with RD exhibit deficits in storage and retrieval, while children with ADHD-I experience a deficit only in retrieval, relative to ADHD-H/I.

Rationale for Present Study

Past research examined memory functioning in children with word level reading disabilities as well as children with ADHD. The ability to learn, retain, and recall information is critical for children's success in school (Cutting et al. 2003; Swanson & Zheng, 2013). Therefore, the mechanisms underlying verbal learning are an important area of research. Previous studies, however, have not carefully disentangled RD and ADHD, and have not addressed the comorbidity issue. Thus, there are conflicting results across studies of RD, ADHD, and comorbid groups. It is not clear whether verbal memory deficits are more specific to RD or ADHD, or whether this domain represents a correlated liability.

There are multiple assessment tools that aid in discovering the mechanisms behind verbal learning. Past research has used various tests such as the PAL, CVLT-C, WRAML, R-AVLT, and the SRT. However, most of these studies compare one group (ADHD or RD) to a control group versus comparing the groups to one another and including a comorbid group. Studies that include a comorbid group often combine various learning disabilities into one group, making it difficult to identify which learning disability is most closely associated with a particular deficit. Cutting et al. (2003) suggested that future studies may want to consider including other measures of memory and examining differences in performance on the CVLT-C (used in their study) between ADHD, RD, and ADHD-RD groups.

It may be that performance is impaired on verbal memory tasks for different reasons. As previously indicated, deficits in executive functions are indicated in both ADHD and RD groups, but more so in association with ADHD. Language-based functions are clearly associated with RD. Verbal learning tasks place demands on many aspects of language and executive functions.

The Selective Reminding Test is useful because it allows for the participant to demonstrate retrieval from long-term storage by recalling an item which was not presented on that trial. The Selective Reminding test also uniquely assesses for the quality of retrieval, by evaluating if the participant consistently retrieved the words or exhibited random retrieval. Short-term storage may be strongly related to language and working memory skills, with difficulties in these areas leading to weaknesses encoding information into a long-term storage. Retrieval processes are heavily influenced by attention and executive processes, with difficulties in these skill domains interfering with consistent long-term retrieval. Overall, the Selective Reminding Test provides a comprehensive measurement of specific verbal learning and memory skills, including the evaluation of various memory stores that have been indicated in multi-store models. In this study I propose the use of the Selective Reminding Test in differentiating between ADHD, RD, and ADHD/RD.

My hypothesis was:

1. There would be a significant Group x Task (memory indices) interaction consistent with relatively greater retrieval problems in children with ADHD only and relatively greater encoding deficits in children with RD only and ADHD/RD that affect their performance on retrieval indices.
    a. Children with ADHD only would perform significantly higher than children with RD only on encoding (Long Term Storage). Children with ADHD would not perform significantly different from children with RD only on retrieval (Consistent Long Term Retrieval), due to their difficulties with retrieval.
    b. Children with RD only would perform significantly lower than children with ADHD only on encoding, due to their language deficits. Children with RD only would not perform significantly different from children with ADHD only on retrieval, because both would perform poorly on this measure. This would reflect encoding deficits in children with RD only that inevitably affects their performance on retrieval.
    c. Children with ADHD/RD would exhibit the greatest severity of deficits amongst the three groups on both encoding and retrieval due to the presence of deficits associated with reading and inattention. The pattern of performance in children with ADHD/RD would be similar to the pattern of performance in children with RD only with low scores on both encoding and retrieval when compared to the ADHD only group.

In order to test this hypothesis, I controlled for the effects of age, medication, sampling variability, and the potential role of sleep problems, using secondary exploratory hypotheses.

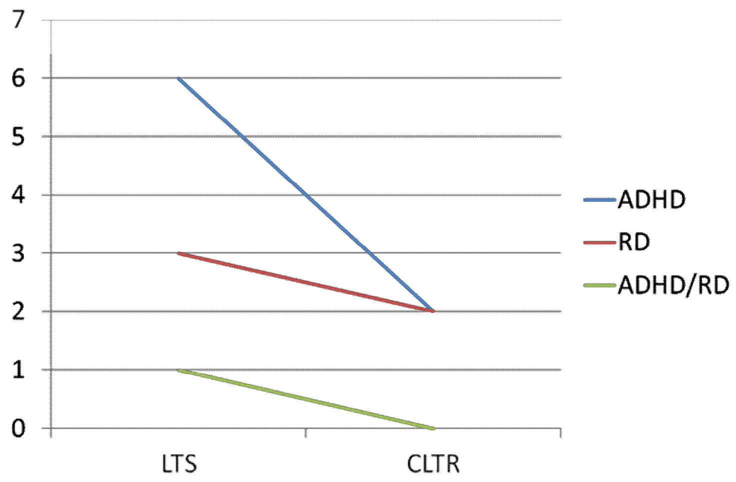

Figure 2. Expected Pattern of Results on Group x Indices ANOVA'S

Methods

Participants

Participants were selected from two sources. The first source was a pre-existing database of over 250 children who underwent assessments to evaluate the presence of learning disabilities and/or ADHD. Few of these children (n = 5) had only RD, which is not unusual because clinical samples need to be referred because of the behavioral issues associated with ADHD. In order to have an adequate number of children in the RD group, a second source of data was collected from children who were evaluated in the Houston Independent School District in order to increase the number of children with reading deficits. Participants with RD from the Houston Independent School District were in a study where they received intervention in Grade 4 and were being followed in Grade 5.

To obtain the sample, children ages 7-12 years, identified with ADHD, RD, or ADHD/RD, were selected. The criteria for ADHD was based on clinical consensus, using individual semi-structured interviews which integrated sources such as the Child Behavior

Checklist (CBCL), SWAN, and Swanson, Nolan and Pelham-IV (SNAP-IV) which is based on *DSM-IV-TR* (2000) criteria. Due to the lack of evidence of differences in cognitive functions between ADHD subtypes (Nigg et al., 2002), this study included all three subtypes under the label of ADHD.

The criterion for Reading Disability was based on performance at or below the 25^{th} percentile on the Woodcock Johnson-III (WJ-III) Basic Reading Composite, which is composed of the Letter – Word Identification and Word Attack subtests. Children that met either of these criteria or both were selected as participants for this study. A priori power analyses using indicated that a sample size of 36 would be sufficient to detect a medium effect (.23) with a power of .82 and alpha of .05 (G* Power 3; Faul, Erdfelder, Lang, & Buchner, 2007).

Exclusion Criteria

This study excluded children who had a Composite IQ that was below 70 based on norms from the Wechsler Abbreviated Scale of Intelligence (WASI; The Psychological Corporation, 1999) or the Kaufman Brief Intelligence Test, Second Edition (KBIT-2; Kaufman & Kaufman, 2004). Children with anxiety and other primary emotional disorders were excluded based on the CBCL and clinical interview. In addition, children with acquired brain injuries or a history of Autism or a Pervasive Developmental Disorder were excluded.

Table 1 contains demographic, IQ, achievement, and ADHD rating scale characteristics of the three groups. This study included 88 participants who received an evaluation through an assessment clinic at the University of Houston (n = 74) or who were evaluated in the Houston Independent School District (n = 14). Reflecting the nature of the referrals, participants in the sample were predominantly Caucasian in the clinic group, but the RD group, which came largely from the HISD, was more diverse. There were 60 males and 28 females in the study. There are clear gender differences among the groups with a significantly large representation of males within the ADHD only and ADHD/RD groups. Race differences were not statistically evaluated because of the low numbers in some groups, but clearly showed different patterns.

The mean age of participants was 116.15 months (SD= 17.98). There were significant differences between the groups $F(2, 85) = 8.99$, $p<.0001$, with children from the RD group significantly older than children from the ADHD only and ADHD/RD groups, which did not differ.

The mean Full Scale IQ for all participants was 99.26 (SD=15.54). One participant's Full Scale IQ was not available; however, the participants score on the nonverbal section of the KBIT revealed intellectual functioning in the average range and therefore it was not necessary to exclude this participant. Consistent with previous research, there were significant differences between groups on Full Scale IQ, $F(2, 84) = 14.36$, $p <.0001$, with the ADHD only group showing a significantly higher IQ score than the RD only group and the ADHD/RD group. There were no significant differences between the RD only group and the ADHD/RD group.

The mean word reading score of the participants was 99.43 (SD =14.03). One participant's word reading score was not available, although previously recorded data placed this participant in the RD only group. As expected, there were significant differences between groups on word reading, $F(2, 84) = 67.80$, $p<.0001$, with the ADHD only group showing a significantly higher word reading score than the RD only group and the ADHD/RD group, consistent with how the groups were formed. There was not a significant difference between the RD only group and ADHD/RD group.

Teacher/tutor ratings were used for all analysis because parent ratings were not available for the 14 participants from the Houston Independent School District. The mean for teacher ratings of Hyperactivity/Impulsivity on SNAP for all participants was 1.22 (SD=.87). As expected there were significant differences between groups on this measure, $F(2, 85) = 3.42$, $p < .04$. There was a significant difference between the ADHD only group and the RD only group, with the ADHD only group showing significantly higher ratings. However, there was not a significant difference between the ADHD only and ADHD/RD group or the RD only group and ADHD/RD group. It was expected that the ADHD/RD combined group would have significantly higher ratings of Hyperactivity/Impulsivity than the ADHD only or RD only group; however, the ADHD/RD only group had the smallest sample size, which may have contributed to lower scores on Hyperactivity/Impulsivity and subsequently the lack of significance seen between the groups when using ADHD/RD as a comparison. The mean teacher ratings of Inattention on SNAP for all participants was 1.76 (SD= .77). As expected there were significant differences between groups on this measure, $F(2, 85) = 13.87$, $p<.0001$. The ADHD only and ADHD/RD group had significantly higher ratings than the RD only group. There was not a significant difference between the ADHD only and ADHD/RD groups.

Measures

Measures to Determine Group Membership

Intelligence. For some participants (n = 40), the WASI (The Psychological Corporation, 1999) was used as a measure of verbal and nonverbal intelligence. The Vocabulary subtest is a 42- item task that requires the child to either verbally name pictures or to define words that have been presented orally and visually. The Matrix Reasoning subtest consists of 35 incomplete gridded patterns that the examinee must complete by pointing to or stating the correct choice, from five possible choices. The scores on the Vocabulary and Matrices subtest are combined to yield the FSIQ-2. Children with FSIQ-2 below 70 were excluded from the study. The reliability coefficient for children from ages 6 to 12 ranges between .92 and .95 for the FSIQ-2. The WASI has a statistically significant correlation of .81 with the Wechsler Intelligence Scale for Children (WISC-III) for the FSIQ-2.

For other participants (n =46), the K-BIT-2 (Kaufman & Kaufman, 2004) was used as a measure of verbal and nonverbal abilities. The Verbal Knowledge subtest is a 60-item measure of receptive vocabulary and range of general information about the world; it requires the examinee to point to a picture that shows the meaning of a word or the answer to a question, given by the examiner. The Matrices subtest consists of 46-items that require the examinee to have an understanding of relationships among the stimuli, and point to correct response or say its letter, out of six possible choices. The Riddles subtest, consist of 48 items that measure verbal comprehension, reasoning, and vocabulary knowledge. The examinee says a single word response that answers the riddle given by the examiner. The scores on the Verbal Knowledge and Riddles subtest are combined to yield a Verbal sum. The score on the Matrices subtest reveals a Nonverbal score. Combining the Verbal and Nonverbal score yield's an IQ Composite. Children with an IQ Composite below 70 were excluded from the study. The internal consistency reliability for the IQ composite for ages 6-12 ranges from .91-.94. The KBIT-2 IQ Composite correlates .81-.90 with the WASI Full Scale IQ based on four subtests and slightly lower with the two-subtest FSIQ.

Inattentive behavior. The SNAP-IV (Swanson, Nolan, and Pelham, 1992) is an 18-item norm-referenced teacher and parent rating scale of behavioral inattention and other psychological disorders. Behaviors associated with the criteria for ADHD as well as other disorders from the *DSM-IV-TR* (2000) are rated on four point categorical scale, the ratings range from zero to three, with higher scores corresponding with a higher frequency of the behavior. In the present study, ratings completed by the parent in which the child falls at or below the 5% cutoff or at or above 1.78 on the ADHD- Inattentive subscale (2.56, if completed by the teacher) and/or above 1.44 on the Hyperactive Impulsive subscale (1.78 if completed by the teacher) were considered to have significant levels of behaviors associated with ADHD. A review of the psychometric properties of the Parent and Teacher SNAP-IV Ratings of Attention Deficit Hyperactivity Disorder Symptoms revealed internal consistency for inattention and hyperactivity/impulsivity to be at .90 and .79 for parents, respectively. Internal consistency for inattention and hyperactivity/impulsivity was at .96 and .92 for teachers, respectively (Bussing et al., 2008).

The Strengths and Weaknesses of ADHD symptoms and Normal Behavior rating scale (SWAN) is an 18-item norm referenced teacher and parent rating scale of behavioral inattention, hyperactivity, and impulsivity. Behaviors associated with the criteria for ADHD from the *DSM-V* (2013) are rated on a seven point categorical scale, the ratings range from +3 to -3, with higher scores corresponding with below average presentation of the behavior. In the present study, ratings completed by the teacher in which the child falls at are below the 5% cutoff or at or above 2.11 for ADHD-C, 2.48 for ADHD-I, and 2.00 for ADHD-HI were considered to have significant levels of behaviors associated with ADHD. Lakes, Swanson, and Riggs (2012), found an internal consistency of .95 for the SWAN. Convergent validity was assessed with the Strengths and Difficulties Questionnaire which also aims to measure attention and hyperactivity in children; the correlation between the two measures was .54 ($p<.01$).

Another rating scale assessment available on the clinical sample was the Child Behavior Checklist (CBCL) for the parent and the Teacher Report Form (TRF) for the teacher (Achenbach & Rescorla, 2001). The CBCL and the TRF allows the parent or teacher to rate a child's problem behaviors and competencies. The first section of the questionnaire consists of 20 competence items and the second section consists of 118 items on behavior or emotional problems during the past six months. Behaviors rated on a 3-point Likert scale; ranging from not true to often true of the child. The internal consistency of the CBCL ranges from .78-.97. The CBCL has been shown to significantly correlate with analogous scales of other instruments as well as with *DSM-IV-TR* (2004) criteria (Achenbach & Rescorla, 2001).

Parental report of sleep problems. Sleep problems have consistently been shown to affect memory processes, such as encoding and working memory, in children and adolescents (Carskadon, Harvey, & Dement, 1981; Kopasz et al., 2010; Mitru, Millrood, &Mateika, 2002; Sadeh, Gruber, & Raviv, 2002; Steenari et al., 2003). Mitru et al. (2002) also suggested that clinical evidence supports the association between sleep and ADHD. In order to assess potential effects of sleeping problems across the three groups and across the selected measures of the Selective Reminding Test, parents of participants were asked to rate their child's problems with sleep based on seven questions related to sleep from the CBCL. As explained in the previous section, the behaviors were rated on a 3- point Likert scale; ranging from not true to often true of the child. The seven questions were as follows: 1) Do you have nightmares? 2) Are you overtired without good reason? 3) Do you sleep less than most children? 4) Do you sleep more than most children during the day/night? 5) Do you talk or walk in your sleep? 6) Do you wet the bed? 7) Do you have trouble sleeping?   Item ratings were added together for a total sleep problems score for each individual and for each group.

Academic achievement. The WJ-III (Woodcock, McGrew, & Mather, 2001) is used as a measure of academic achievement. The Letter- Word Identification subtest requires identifying and reading isolated letters and words by recognition and pronunciation. The Word Attack subtest requires pronouncing phonologically regular pseudowords. Basic Reading is a composite of these two subtests. The reliability for Letter Word Identification for children from age 6-12, ranged from .90-.98. The reliability for Word Attack, ranged from .85-.94. For the composite, Basic Reading skills, reliability ranged from .93-.97. The correlations of the WJ-R ACH clusters with other measures of achievement are typically in the .60s and .70s for Grades 1 through 8 (Woodcock, McGrew, & Mather, 2001).

Current Study Measures

Verbal Memory. The Selective Reminding Test (SRT) is a measure of several components of memory and learning in verbal free recall (Buschke, 1973). This test measures verbal learning and memory using a multiple-trial list-learning paradigm. The two measures used in this study were Long Term Storage and Consistent Long Term Retrieval from the children's version of the Selective Reminding Test. In children ages 5 to 8 the test retest reliability ranged from .55 to .66 (Morgan, 1982). Based on adult data, modest correlations have been demonstrated among the SRT and other tests of verbal learning and memory, such as the CVLT, R-AVLT, and WMS (Wechsler Memory Scale) (Strauss et al., 2006).

The Selective Reminding Task involves reading to the child a list of words and then having the child recall as many of the words as possible. Subsequent learning trials involve only presenting the items that were not recalled during the immediately preceding trial (Strauss et al., 2006). An item is believed to be in long-term storage when it is recalled twice without presentation. Consistent Long Term Retrieval involves consistent recall on subsequent trials without any further presentation at all. To test the hypothesis in this study, I analyzed the raw scores and z-scores for the Long Term Storage measure and the Consistent Long Term Retrieval measure across all three groups. The z -scores were computed from a local sample of children 6-12 years of age collected many years ago to serve as a comparison group in a study of children with traumatic brain injury.

Procedures

Data from participants in this study was based on archival data from Dr. Fletcher's clinic as well as current data from students with reading disabilities in the Houston Independent School District. I selected participants from the files who met the criteria outlined above. A coding sheet was developed and participant data was then input into a statistical program. Participants were divided into three different groups (ADHD, RD, and ADHD/RD) based on their performance across measures used in this study. Analyses were performed to determine group differences across the Long Term Storage and Consistent Long Term Retrieval measures of the Selective Reminding Test.

Methods of Analysis

Prior to statistical analysis, the distribution of scores across subtests were assessed for outliers on the Long Term Storage and Consistent Long Term Retrieval measures. Outliers were defined as scores that fall more than 3 SD from the group mean. The three groups (ADHD, RD, and ADHD/RD) were compared using the mean of group raw scores and z-scores on the Long Term Storage measure and the Consistent Long Term Retrieval measure.

Alternate form reliability study. In order to evaluate the reliability of the Selective Reminding Test a small alternate form reliability study was conducted using participants from the Houston Independent School District. The participants administered counterbalanced alternate forms (Form A and Form B) of the Selective Reminding Tests; one form directly followed by the alternate form. No participant was given the same form twice. A reliability coefficient was calculated using Pearson's correlation and comparing the differences on Long Term Storage and Consistent Long Term Retrieval across Form A and Form B.

Primary analyses. The hypotheses were analyzed using a 3 x 2 mixed model ANOVA that controlled for age (through either z scores or by treating age as a covariate for the raw scores) because the Group with RD only was significantly older. I also conducted exploratory analyses to control for sampling variability and for the effects of gender, medication use, and parental report of sleep problems. Lastly, I evaluated correlations for sleep, inattention, and hyperactivity-impulsivity with Long Term Storage and Consistent Long Term Retrieval.

Results

Alternate Form Reliability Study

In order to evaluate the reliability of the Selective Reminding Test, a small alternate form reliability study was conducted using 14 participants (12 RD, 2 ADHD/RD) from the Houston Independent School District (H.I.S.D.). The participants were administered counterbalanced alternate forms (Form A and Form B) of the Selective Reminding Tests; one form directly followed by the alternate form. No participant was given the same form twice. Table 2 provides the means and standard deviations for performance on the Long Term Storage and Consistent Long Term Retrieval Measure, based on administration order. A reliability coefficient was calculated using Pearson's correlation; differences on the z- scores for Long Term Storage and Consistent Long Term Retrieval were compared across Form A and Form B. In this sample of children the alternate form reliability was .45 for Long Term Storage and .60 for Consistent Long Term Retrieval. Further review of the data revealed an order effect, with children performing lower on the form that was administered second, without respect of Form A or Form B. As a result of higher performance on the first form administered, data was analyzed using participant's performance on the first form administered. See Table 2 for order effects.

One Sample Z-tests

A series of one-sample z-tests were conducted to evaluate whether groups significantly differed from the normative sample. For the ADHD only group, the mean of the Long Term Storage z-score (*M* = -.30, *SD* = 1.00) was significantly different from the normative sample, $z(53) = -2.20$, $p = .013$; the mean of the Consistent Long Term Retrieval z-score (M= -.63, SD= 1.09) was also significantly different from the normative sample $z(53) = -4.63$, p=<.0001.

For the RD only group, the mean of the Long Term Storage z-score (M= -.72, SD=1.26) was significantly different from the normative sample, $z(16) = -2.97$, p= .0014; the mean of the Consistent Long Term Retrieval z-score (M= -.57, SD= 1.02) was also significantly different, $z(16) = -3.42$, p= .0003.

For the ADHD/RD group, the mean of the Long Term Storage z-score (M= -.57, SD=1.02) was significantly different from the normative sample, $z(16) = -2.35$, p= .0094; the mean of the Consistent Long Term Retrieval z-score (M= -.96, SD= .81) was also significantly different, $z(16) = -3.95$, p= <.0001.

Overall, this indicates that all three groups perform significantly lower than the normal population on tasks that require encoding and retrieval skills.

Primary Analyses

Long Term Storage and Consistent Long Term Retrieval. A Pearson's correlation prior to primary analyses indicated a significant correlation between the z-scores for Long Term Storage and the Consistent Long Term Retrieval (r =.64, p = <.0001). For the raw scores, the correlation was (r = .63, p= <.0001). Although these are moderate correlations, they do suggest that the two indices may be measuring somewhat different aspects of memory and are sufficiently reliable to share common variability.

Results Based on Raw Scores. Outcome variables (Long Term Storage raw scores and Consistent Long Term Retrieval raw scores) were entered as dependent variables, with group membership as the independent variable and age as a covariate. Table 3 provides the results from the analyses. The interaction effect for Group x Task $F(2, 82) = .17$, $p<.85$, was not significant. The effect for Group was not significant when controlling for age $F(2, 82) = .61$, $p<.55$. The effect for Task was not significant when controlling for age $F(1, 82) = 2.07$, $p<.15$. Overall, this was not consistent with the hypothesis that performance on Long Term Storage and Consistent Long Term Retrieval would be differentiated by groups.

Results Based on z- scores. Outcome variables (Long Term Storage z-scores and Consistent Long Term Retrieval z-scores) were entered as dependent variables, with group membership as the independent variable. Table 3 provides the results from the analyses. The interaction effect for Group x Task $F(2, 85) = .17$ $p<.85$, was not significant. The effect for Group was not significant, $F(2, 85) = 1.69$, $p<.19$. The effect for Task was not significant, $F(1, 85) = 2.26$, $p<.14$. Overall, this was not consistent with the hypothesis that performance on Long Term Storage and Consistent Long Term Retrieval would be differentiated by groups.

Effect sizes. Partial eta squares were calculated for Group, Task, and Group x Task interaction. Tables 4 and 5 provide the results from the calculations for raw scores and z-scores. Results indicated very low effect sizes. Task accounted for the largest percentage of variance relative to Group or Group x Task. The low effect size estimates suggest an absence of meaningful differences and suggest that the study was adequately powered to detect meaningful differences, which were not apparent. Additionally, Cohen's *d* was calculated to provide the effect sizes for pair-wise comparisons across groups. Effect sizes for pair-wise comparisons were calculated for Long Term Storage and Consistent Long Term Retrieval. Table 6 and 7 provide the results from the calculations for raw scores and z-scores. Results generally indicated low effect sizes. However, when considering z-scores for Long Term Storage, Table 7 indicated a small to medium effect size (*d*= .38) for the comparison of the ADHD only (M= -.30; SD= 1.00) versus RD only group (M= -.72; SD= 1.26), with the ADHD only group scoring higher than the RD only group. Additionally, Table 7 indicated a small effect size (*d*=.25) for the comparison of the ADHD only (M= -.30; SD= 1.00) versus ADHD/RD group (M= -.57; SD=1.02), with the ADHD only group scoring higher than the ADHD/RD group. When considering the z-scores for Consistent Long Term Retrieval, Table 7 indicated a fairly small effect size (*d*=.29) for the comparison of the ADHD only (M= -.63; SD= 1.09) group versus the ADHD/RD group (M= -.95; SD= .81), with the ADHD only group scoring higher than the ADHD/RD group. This suggests that the ADHD only group generally exhibits higher performance than the RD only group for Long Term Storage and higher performance than the ADHD/RD group for Long Term Storage and Consistent Long Term Retrieval.

The results of Cohen's *d* are consistent with some portions of the hypothesis, including that the ADHD only group would perform higher than the RD only group for Long Term Storage and not for Consistent Long Term Retrieval. Additionally, partially consistent with the hypothesis, the ADHD/RD group performed lower than the ADHD only group for Long Term Storage and Consistent Long Term Retrieval; however negligible effect sizes were indicated for the comparisons of RD and ADHD/RD. In this study, partial eta squares and Cohen's *d* were calculated to estimate effect sizes.

However, literature supports the use of eta square or partial eta square when calculating effect sizes for various types of ANOVA's (Levine & Hullett, 2002).

Secondary Analyses

Medication. Twenty-seven children (23 ADHD, 4 ADHD/RD) who were on medication at the time of the evaluation were included in this study. Using z-scores, there was not a significant difference in medicated children (M= -.28, SD=.97) versus non-medicated children (M= -.54, SD= 1.06) on Long Term Storage $t(67) = -.62$, $p<.54$. There also was not a significant difference in medicated children (M= -.44, SD=1.05) versus non-medicated children (M= -.85, SD= 1.00) on Consistent Long Term Retrieval $t(67) = -1.26$ $p<.21$. Therefore, there were no significant differences between children who were on medication at the time of the evaluation versus children with ADHD only who were not on medication at the time of the evaluation.

H.I.S.D. sample versus clinic sample. Due to the variability in the recruitment of the sample (e.g. pre-existing clinical database, school district), an analysis was conducted to compare scores between the two groups and across the two selected measures of the Selective Reminding Test (Long Term Storage and Consistent Long Term Retrieval). This analysis included 20 children who were a part of the pre-existing clinical database (5 RD only, 15 ADHD/RD) and 14 children who were recruited from H.I.S.D. (12 RD only, 2 ADHD/RD). Recruitment of participants in the H.I.S.D. sample did not include children with ADHD only. Therefore, when comparing the pre-existing clinical database, which included an ADHD only group, to the H.I.S.D. sample, the ADHD only group was not considered and analyses were conducted using the RD only and ADHD/RD groups. Outcome variables (Long Term Storage z-scores and Consistent Long Term Retrieval z-scores) were entered as dependent variables, with group membership (clinic vs. H.I.S.D.) as the independent variable.

There was not a significant difference in H.I.S.D. (M= -.82, SD=1.36) versus clinic (M= -.56, SD= 1.07) means on Long Term Storage $t(32) = -.64$, $p<.53$. There also was not a significant difference in H.I.S.D. (M= -.82, SD= .91) versus clinic (M= -.98, SD= 1.09) means on Consistent Long Term Retrieval $t(32) = .44$, $p<.66$. Therefore, no significant differences were found between children selected from the pre-existing clinical database and children selected from the school district on Long Term Storage and Consistent Long Term Retrieval.

Parental report of sleep problems. Of the 88 participants, sleep data was available for 68 participants from the ADHD only group and the ADHD/RD group. A 3x2 mixed model procedure was conducted across Long Term Storage and Consistent Long Term Retrieval z-scores while controlling for sleep scores. Outcome variables (Long Term Storage and Consistent Long Term Retrieval) were entered as a within subject variable (task), with Group (ADHD and ADHD/RD) entered as the independent variable, and sleep score as a covariate. Based on the data from those 68 participants, using Long Term Storage and Consistent Long Term Retrieval z-scores, the Sleep x Group x Task interaction was not significant, $F(1, 63) = .09$, $p<. 76$. The remaining interactions and main effects were not significant. Additionally, an analysis was conducted to compare mean scores for parental report of sleep problems between participants with ADHD only and ADHD/RD. Outcome variable (parental report of sleep of problems) was entered as a dependent variable, with Group as an independent variable (excluding the RD only group).

There was not a significant difference in the ADHD only group (M= 2.49, SD=2.19) and the ADHD/RD group (M= 2.54, SD= 1.66) for parental report of sleep problems $t(62) = -0.07$, $p<.94$.

Gender. Due to a significantly higher number of male participants versus female participants in the sample, analyses were conducted to compare scores between males and females across the two selected measures of the Selective Reminding Test (Long Term Storage and Consistent Long Term Retrieval). The analyses included 60 males and 28 females. Outcome variables (Long Term Storage z-scores and Consistent Long Term Retrieval z- scores) were entered separately as dependent variables, with gender entered as the independent variable.

There was not a significant difference in male (M= -.47, SD= 1.06) and female means (M= -.37, SD= 1.07) on Long Term Storage $t(86) = -.41$, $p<.69$. There was also not a significant difference in male (M= -.78, SD=1.02) and female (M= -.63, SD= 1.10) means on Consistent Long Term Retrieval $t(86) = -.60$, $p<.55$. Additionally, a 3x2 mixed model procedure was conducted across Long Term Storage and Consistent Long Term Retrieval z-scores while controlling for gender. Outcome variables (Long Term Storage z-score and Consistent Long Term Retrieval z-score) were entered as a within subject variable (task) with Group (ADHD and ADHD/RD) entered as the independent variable, and gender as a covariate. Based on the data from the participants, using Long Term Storage and Consistent Long Term Retrieval z-scores, the Gender x Group x Task interaction was not significant $F(2,82) = 1.23$, $p<.30$. The remaining interactions and main effects were not significant.

Correlations of sleep, inattention, and hyperactivity-impulsivity for long term storage and consistent long term tetrieval. A series of Pearson's correlations were conducted to evaluate the strength of relations for sleep, inattention, and hyperactivity-impulsivity with z-scores from the Long Term Storage and Consistent Long Term Retrieval measures. The results indicated weak correlations between parental report of sleep problems and Long Term Storage (r= .003, p=.98) and parental report of sleep problems and Consistent Long Term Retrieval (r=.09, p=.50). The results indicated weak correlations between inattention and for Long Term Storage (r= .11, p= .31) and inattention and Consistent Long Term Retrieval (r= -.11, p=.29). The results indicated weak correlations between hyperactivity-impulsivity and Long Term Storage (r=.16, p=.12) and hyperactivity-impulsivity and Consistent Long Term Retrieval (r=.20, p= .05). These results suggest that parental report of sleep problems, inattention, and hyperactivity-impulsivity do not have strong relations with Long Term Storage or Consistent Long Term Retrieval.

Discussion

Past research has examined memory functioning in children with word level reading disabilities as well as in children with ADHD using a variety of verbal memory measures. However, these studies have not carefully disentangled RD and ADHD, and have not addressed the comorbidity of the two disorders. Thus, there are conflicting results across studies of RD, ADHD, and comorbid groups and it is not clear whether verbal memory deficits are more specific to RD or ADHD, or whether this domain represents a correlated liability.

The Selective Reminding Test provides a theoretically-based measurement of specific verbal learning and memory skills, including the evaluation of various memory stores that have been indicated in multi-store models. The purpose of this study was to evaluate the use of the Selective Reminding Test in differentiating memory performance between ADHD only, RD only, and ADHD/RD.

Long Term Storage and Consistent Long Term Retrieval

I hypothesized that children with ADHD only would perform significantly higher than children with RD only on encoding (Long Term Storage) and that children with ADHD only would not significantly differ from children with RD only on retrieval (Consistent Long Term Retrieval). I also hypothesized that children with ADHD/RD would exhibit the greatest severity of deficits amongst the three groups on both encoding and retrieval due to the presence of deficits associated with reading and inattention. The analyses were conducted using raw scores and age as covariate, as well as using z-scores based on local normative data and therefore did not require control for age.

Results from the mixed model analyses based on both raw scores and z-scores demonstrated that the groups did not significantly differ from one another across the two indices (Long Term Storage and Consistent Long Term Retrieval). However, effect sizes using Cohen's *d* suggested a clinically meaningful difference between ADHD only and RD only performance for Long Term Storage, with the RD group performing lower than the ADHD only group. Additionally, the pattern of performance considering z-scores, demonstrated that children with RD only and ADHD/RD had lower means than children with ADHD only for both indices. This finding is similar to the pattern of results from Fletcher (1985), which indicated that the reading-spelling subgroup had the lowest mean performance on long term storage, consistent long-term retrieval, total recall, long-term storage, and long-term retrieval in comparison to all groups, including controls. However, Fletcher (1985) did not compare deficits in children with RD only to deficits in children with ADHD only or ADHD/RD. Barkley et al. (1991) found that children with ADHD-I experienced a deficit in retrieval on the Selective Reminding Test, but this was only compared to children with ADHD- H/I.

There is additional literature addressing encoding and retrieval strategies in the three populations used in this study; however, this literature makes use of different verbal memory paradigms (CVLT-C, WRAML, R-AVLT, etc.) and does not compare ADHD only, RD only, and ADHD/RD groups to one another. Findings from multiple studies using the CVLT-C, suggests that verbal memory deficits in children with ADHD are most likely due to difficulties in retrieval of information, while verbal memory deficits in children with RD is most likely due to factors other than retention and retrieval, including rehearsal strategies, encoding, and phonological processing (Crocker et al. 2011; Cutting et al. 2003; Kibby, 2009; Kramer et al., 2000). This pattern was not apparent in the present study, but may reflect the correlation of the two indices (Long Term Storage and Consistent Long Term Retrieval), which begs the question of how separable memory processes are really evaluated by the selective reminding procedure.

Findings from two studies that used the WRAML were inconsistent, with one study suggesting that children with RD did not significantly differ from controls on verbal learning even though they found differences on phonological short-term memory (Kibby, 2009) and the other study finding that RD and ADHD/RD consistently performed poorer than the ADHD group and controls on verbal memory and learning indices (Kaplan et al., 1998). Although the current study did not find statistically significant differences consistent with the Kaplan et al. results for verbal learning, the pattern of results were similar to findings of Kaplan et al. in that the z-score means of the RD only group were lower in comparison to the ADHD only group. Also similar to the results of Kaplan et al., the z-score means of the ADHD/RD group was lower than the mean of the ADHD only group in this study. Therefore, the results are consistent with Kaplan's et al. conclusion that children with RD and ADHD + RD consistently perform at a similar yet clinically impaired range on some aspects of verbal learning, and consistently perform poorer than the ADHD group on verbal memory and learning indices.

Findings from the studies that used the R-AVLT were also inconsistent, with one study associating ADHD with poor performance on encoding and retrieval (Felton et al., 1987) and another study finding that children with ADHD did not differ on any measures of the R-AVLT, but rather the LD and ADHD + LD group showed impairment in some measures including encoding and retrieval (Vakil et al., 2012). As previously stated, although the current study did not find statistically significant differences consistent with the results of Vakil et al., the pattern of results was similar to their findings.

The absence of differences does not mean that the groups were not impaired on the Selective Reminding Test. All three groups scored significantly below the normative sample means, indicating poorer memory performance associated with both reading difficulties and ADHD.

When considering mean differences in scores from the Long Term Storage measure and the Consistent Long Term Retrieval measure, all three groups had lower performance on Consistent Long Term Retrieval, which is expected. Although the pattern of the means is consistent with past findings in literature, it is not consistent with a portion of the hypothesis which stated that children with ADHD/RD would exhibit the greatest severity of deficits amongst the three groups due to the deficits associated with reading and inattention. While the ADHD/RD group score on Consistent Long Term Retrieval was well below age expected levels, it was not significantly lower than the RD or ADHD only group. However, effect sizes using Cohen's *d* suggested a clinically meaningful difference between ADHD only and

ADHD/RD performance for Long Term Storage and Consistent Long Term Retrieval, with the ADHD/RD group performing lower than the ADHD only group.

When considering the consistency of the findings of this study when compared to past studies, it must be noted that many of the past studies used typically developing comparison groups for comparisons to ADHD or RD groups. By incorporating one sample z-tests I was able to evaluate whether the groups significantly differed from the normal population on tasks that require encoding and retrieval skills. Results demonstrated that all three groups significantly differed from the normal population on both Long Term Storage (encoding) and Consistent Long Term Retrieval (retrieval). This reflects that all groups exhibit some difficulties on these measures relative to the normal population which may indicate deficits in encoding, retrieval, or another factor.

Taken together the results suggest that deficits for Long Term Storage and Consistent Long Term Retrieval are both associated with RD and ADHD; however, they are not differentially associated based on statistical tests using conventional levels of alpha ($p < .05$).

Medication

The effects of medication in the ADHD population have been known to impact performance on neuropsychological measures, with noted improvement in domains such as attention, memory/working memory, and additional domains (Pietrzak, Mollica, Maruff, & Snyder, 2006). Due to the potential for medicated children with ADHD only or ADHD/RD to have significantly higher performance, I used a secondary exploratory analysis to further evaluate the possible role of medication. Although medicated children with ADHD only or ADHD/RD had a higher mean performance than non-medicated children with ADHD only or ADHD/RD on both indices, this difference was not statistically significant. The lack of significant findings between the medicated and non-medicated participants is likely due to the nature of referrals from the clinical sample. Referrals from the clinical sample were likely attributable to concerns about learning problems and not behavior problems, suggesting that problems with attention were not severe. This should not be taken to mean that stimulant medication does not influence performance on the Selective Reminding Test because no effort was made to control type of stimulant, dosage, or when it was administered. Overall, for this study medication likely did not play a significant role in outcomes.

Parental Report of Sleep Problems

As previously mentioned, sleep behaviors have been shown to affect memory processes, such as encoding and working memory (Carskadon, Harvey, & Dement, 1981; Kopasz et al., 2010). Furthermore, evidence has supported the association between sleep and symptoms of ADHD (Mitru, Millrood, &Mateika, 2002). Secondary exploratory analyses did not indicate a significant Sleep x Group x Task interaction. However, there are potential explanations for this finding. First, this study evaluated parental report of 'sleep problems' and did not manipulate sleep or directly measure the effects of 'sleep behavior' (e.g., quality of sleep) on performance. Second, the measure used to evaluate sleep problems in this particular study was comprised of retrospective and subjective information regarding specific sleep problems. It is possible that a more sensitive measure of 'sleep behaviors' may have resulted in an alternate outcome. Furthermore of the 88 participants within the study, only 68 participants from the ADHD only and ADHD/RD groups were included in the analysis. It was also not possible to determine whether both groups were impaired in sleep problems because of the absence of normative data for the ad hoc measure used in this study.

Comorbidity

The strongest evidence of comorbidity is the correlated liabilities framework (Pennington, 2006). The patterns seen in this study appear to be consistent with the correlated liabilities hypothesis, which states that ADHD and RD share a common subset of weaknesses that varies from that of the normal population. In this study, children with ADHD only, RD only, and ADHD/RD exhibited deficits on verbal learning and memory. Although all three groups exhibited deficits for encoding and retrieval, the nature of the deficits may be due to different reasons that are unique to each group. Children with reading difficulties may exhibit poor performance on retrieval measures due to poor performance on encoding measures, while children with ADHD may exhibit poor performance on retrieval due to poor rehearsal strategies. In fact, research has clearly indicated that ADHD and RD have cognitive/behavioral functions that have not been identified as correlated liabilities, such as phonological awareness and impulsivity that is specific to RD and ADHD, respectively. This study sought to differentiate the types of deficits in verbal learning between ADHD only, RD only, and ADHD/RD, which was not strongly apparent.

Utility and Validity of the Selective Reminding Test

The Selective Reminding Test was used because many verbal memory tests have been modeled after it and also because it allows for the participant to demonstrate retrieval from long-term storage as well as assess for the quality of retrieval. Thus, it allows for the evaluation of various memory components that have been indicated in multi-store models.

On average, children with attention difficulties or reading difficulties will likely not perform well on the Selective Reminding Test. Therefore, it is important to assess the pattern of performance in order to gather additional information concerning the nature of the deficit. Evaluation of the pattern of performance provides information regarding the potential breakdown of various memory stores or processes that may take place in between the memory stores (e.g., rehearsal strategies). Identifying the area in which the 'breakdown' occurs is necessary because it determines the stage of the memory process in which intervention is warranted.

In the educational setting, this informs interventionists of the cause of verbal memory deficits in children with reading difficulties or attention difficulties so that intervention may be better targeted towards improving the skills that contribute to the child's verbal memory performance and subsequently other areas of learning. For example, children with reading difficulties who exhibit poor performance on a verbal memory task may require intervention that improves their ability to initially encode words while children with attention difficulties who exhibit poor performance on a verbal memory task may require intervention at the level of rehearsal to improve rehearsal strategies and support performance on retrieval. As a result of targeted intervention, it is possible that performance for verbal memory (encoding or retrieval) would increase for both populations and would result in improved learning and academic performance. In the clinical setting, differences in performance between Long Term Storage and Consistent Long Term Retrieval (when combined with performance on other measures and taking into account relevant history) may provide support for diagnostic decision making.

A clear pattern of deficits between children with reading difficulties and attention difficulties was not apparent in this study. Overall, this study tended to implicate both encoding and retrieval problems in both populations, though possibly for different reasons.

The results of this study have implications for multi-store models in ADHD and RD. The results did not indicate a statistically significant interaction between the groups on the two indices (Long Term Storage and Consistent Long Term Retrieval). However, the patterns of means suggested that all three groups performed lower on the Consistent Long Term Retrieval measure than the Long Term Storage measure. Intuitively, poor encoding of information or poor performance on Long Term Storage will negatively affect retrieval of information. If an individual does not encode and store the information, this reduces the likelihood of successful retrieval of the same information. Therefore, these two measures (Long Term Storage and Consistent Long Term Retrieval) are highly related. This idea is further supported by the high correlation of the two indices (Long Term Storage and Consistent Long Term Retrieval), which does not support the idea that separate processes are being measured.

Alternatively, the difference in performance on Long Term Storage and Consistent Long Term Retrieval across groups may reflect a breakdown in some portion of the cognitive process that takes place between encoding and retrieval; this could include phonological processing/analysis, rehearsal strategies, or even phonological output, all which have been processes included in well-known multi-store models of memory (Baddeley, 2003) and are likely relevant to the performance of children with ADHD and RD. Furthermore, it could be argued that Long Term Storage is represented by the ability to recall a higher number of items consistently and that items remembered twice in a row does not establish the requirement for Long Term Storage. These are all factors which could possibly affect the sensitivity of the

Selective Reminding Testing in differentiating the cognitive processes involved in verbal learning and memory for ADHD only, RD only, and ADHD/RD.

Limitations

In the present study, children with ADHD only, RD only, and ADHD/RD were all impaired in their performance on two indices of the Verbal Selective Reminding Test. However, there was no evidence of differential impairment and the two indices did not interact with group membership. One limitation of this study is the significantly higher age of the RD only group when compared to the ages of the ADHD only and ADHD/RD groups. The significant difference in their age may be due to the tendency for reading difficulties to be detected at a later age than attentional difficulties (Catts, Compton, Tomblin, & Bridges, 2012; Visser et al., 2014). Nevertheless, considering children and adolescents, as age increases so does the capacity to hold information over time, which can be contributed to more efficient use of rehearsal strategies. However, age was entered as a covariate to control for its potential effects and I also used local normative data for comparison purposes.

Additionally, the majority of participants in the RD only group were from a sample of students evaluated in H.I.S.D while the majority of participants in the ADHD only and ADHD/RD groups were from a pre-existing assessment clinic database. To address this limitation an additional analysis was conducted and results did not indicate significant differences across participants with RD only and ADHD/RD from H.I.S.D. or the clinic database, on either of the measures. Nonetheless, the sample was older, more female, and more likely to be racially diverse. Although low socioeconomic status was not evaluated in this study, it is associated with lower levels of school achievement and intelligence (Bradley & Corwyn, 2002) Furthermore, while the ADHD only and ADHD/RD groups were comprised of more males than females, the RD only group was comprised of more females than males. These group characteristics potentially contribute to the study outcomes and in the future warrant further investigation.

This study also included the analysis of archival data. Although there are some advantages of using archival data, the use of archival data also limited the control of what type of data was collected. For example, this study was limited by the inability to review the quality of errors. If this information were available, data may have supported what past research has found, that there are significant differences in qualitative errors versus differences in overall scores. Therefore, while there may not be significant findings on overall scores, qualitative errors may provide additional information regarding differential performance of the three groups (Douglas & Benezra, 1990).

This study did not include a typically developing comparison group which represented a potential limitation. However, z-tests were performed to compare performance of the three groups to expected performance of the normal population; the z-scores of all three groups were significantly lower than the normative population for Long Term Storage and Consistent Long Term Retrieval.

The DSM-V was developed and released during the time of this study and changes were made in the diagnosis criteria for ADHD. However, these changes were minimal and likely would not have affected the diagnosis of participants within this study, neither would it have impacted the results. Subsequently, this was not a major issue.

Finally, the Selective Reminding Test does not have particularly high reliability; however, this is characteristic of most learning tasks. A more relevant limitation of the Selective Reminding Test is the high correlation of the Long Term Storage and Consistent

Long Term Retrieval measures, which can make differences between the two measures difficult to detect.

Conclusions and Future Directions

Despite these limitations, the patterns of results in this study yield's information that warrants further investigation of verbal learning and memory deficits using the Selective Reminding Test or an alternative verbal learning task. Based on these results, two indices of the Verbal Selective Reminding Test have not proven to be differentially sensitive to encoding and/or retrieval deficits in ADHD only, RD only, and ADHD/RD groups. Additionally, results of the alternative form reliability study indicated poor to acceptable reliability of the Long Term Storage and Consistent Long Term Retrieval indices. These results are similar to results found by Morgan (1982). Reduced reliability is not particularly an uncommon characteristic of a learning task, due to factors such as practice effects, order effects, and subtle differences that may exist between various forms.

Future studies should include a larger sample size across all three groups, with children of similar ages. Evaluation of group performances on other measures of the Selective Reminding Test may also provide alternative explanations. For example, examining qualitative errors may yield additional information regarding performance. Future studies may utilize alternative measures of memory such as the Wide Range Assessment of Memory and Learning-II or the Children's Memory Scale. With these measures it is possible to compare performance between verbal memory and visual memory from the same normative sample. Amongst children with attention difficulties or reading difficulties, this would provide a broad view of the types of memory deficits they may encounter as a result of their attention or reading difficulties. Future studies should also explore the role of alternative correlated liabilities (e.g., processing speed, working memory, etc.) on memory processes. For example, to assess processing speed and its' impact on verbal or visual memory, the amount of time given to the participant to respond may vary throughout the memory task. Finally, there are many factors that were not included in this study and warrant further investigation. These factors include but are not limited to: the effects of socioeconomic status, gender, and race.

Table 1. Sociodemographic and Group Formation Information by Group

	Group		
	ADHD	RD	ADHD/RD
N	54	17	17
Age (months: M ± SD)	111.94±16.07 [a]	131.29±14.13 [b]	114.35±19.89 [a]
Gender- N Male Female	 45 9	 7 10	 15 2
Word Reading Score (M ± SD)	107.98 ± 9.20 [a]	84.44 ±10.15 [b]	86.35±5.26 [b]
Full Scale IQ (M ± SD)	105.31±14.61 [a]	87.75±11.48 [b]	90.88±11.72 [b]
SNAP Hyperactivity Score (M ± SD)	1.38 ±.97 [a]	.76±.43 [b]	1.23 ±.75 [a,b]
SNAP Inattention Score (M ± SD)	1.92 ±.68 [a]	.99 ± .58 [b]	2.05 ±.79 [a]

[a,b] Means with the same letter are not significantly different

Table 2. Means and Standard Deviations of Long Term Storage and Consistent Long Term Retrieval by Order of Form Administration

Long Term Storage

Form A Administration 1 (M±SD)	Form B Administration 2 (M±SD)
-1.12(1.62)	-1.46(1.24)

Form B Administration 1 (M±SD)	Form A Administration 2 (M±SD)
-.52(1.56)	-.82(.70)

Consistent Long Term Retrieval

Form A Administration 1 (M±SD)	Form B Administration 2 (M±SD)
-.96(1.26)	-1.51(.87)

Form B Administration 1 (M ±SD)	Form A Administration 2 (M ±SD)
-.68(.42)	-.1.19(.89)

Table 3. Means and Standard Deviations Based on Age Adjusted Raw Scores and Z-scores for Long Term Storage and Consistent Long Term Retrieval

	ADHD only	RD only	ADHD/RD
Long Term Storage Raw (M)	68.01	68.75	65.14
Consistent Long Term Retrieval Raw (M)	43.60	45.52	37.46
Long Term Storage Z-Score (M ± SD)	-0.30 ± 1.00	-.72 ± 1.26	-.57 ± 1.02
Consistent Long Term Retrieval Z-Score (M ± SD)	-0.63 ± 1.09	-0.83 ± 1.10	-.95 ± .81

Table 4. Effect Sizes (*partial* η^2) for Primary Analysis by Raw Scores

Task/Measure	*partial* η^2
Group	.007
Task	.012
Group x Task	.002

Table 5. Effect Sizes (*partial* η^2) for Primary Analysis by Z-Scores

Task/Measure	*partial* η^2
Group	<.0001
Task	.012
Group x Task	.001

Table 6. Effect Sizes (*d*) for Long Term Storage and Consistent Long Term Retrieval (CLTR) using Pair-Wise Comparisons and Raw Scores

Task/Measure	ADHD-RD	ADHD- ADHD/RD	RD- ADHD/RD
Long Term Storage	-.003	.01	.01
CLTR	-.008	.02	.03

Table 7. Effect Sizes (*d*) for Long Term Storage and Consistent Long Term Retrieval (CLTR) using Pair-Wise Comparisons and Z-scores

Task/Measure	ADHD-RD	ADHD- ADHD/RD	RD- ADHD/RD
Long Term Storage	.38	.25	-.16
CLTR	.18	.29	.11

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