THE IMPACT OF VISUAL MEMORY DEFICITS

ON ACADEMIC ACHIEVEMENT IN

CHILDREN AND ADOLESCENTS

by

Jessica Maria Larsen

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STATEMENT OF DISSERTATION APPROVAL

The dissertation of **Jessica Maria Larsen**

has been approved by the following supervisory committee members:

Lora Tuesday-Heathfield	, Chair	**12/13/10** Date Approved
Michael K. Gardner	, Member	**12/13/10** Date Approved
Daniel E. Olympia	, Member	**12/13/10** Date Approved
Janiece L. Pompa	, Member	**12/13/10** Date Approved
Brenda S. Van Gorder	, Member	**12/13/10** Date Approved

and by **Elaine Clark** , Chair of

the Department of **Educational Psychology**

and by Charles A. Wight, Dean of The Graduate School.

ABSTRACT

Memory assessment can often alert practitioners and educators to learning problems children may be experiencing. Results of a memory assessment may indicate that a child has a specific memory deficit in verbal memory, visual memory, or both. Deficits in visual or verbal modes of memory could potentially have adverse effects on academic achievement. Past research in the area of memory and academics have shown mixed results, with some studies showing correlations between visual or verbal memory deficits and patterns of academic achievement and other studies showing evidence there is not a predictable pattern. The purpose of the present study was to examine the effects of visual memory deficits upon children's academic achievement in reading, spelling, and arithmetic.

Archival data of children's comprehensive neuropsychological evaluations conducted at a private neuropsychology clinic were reviewed and analyzed to determine if children who showed evidence of deficits in visual memory differed significantly on academic achievement measures from a comparison group of children who did not have visual or verbal memory deficits. Overall, the results of this study found that individuals with visual memory deficits showed significantly weaker performance in arithmetic achievement compared to children without memory deficits. Children with visual memory deficits did not differ significantly from children without memory deficits on reading or spelling achievement.

TABLE OF CONTENTS

LIST OF TABLES

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INTRODUCTION

Despite an ever-changing conceptualization of human memory throughout history, several definitions have emerged regarding this vast concept. Tulving and Craik (2000) refer to memory as the process by which people can remember and refer to past experiences. Another definition regards memory as a storehouse for information, as if memory were a location or thing that holds information (Spear & Riccio, 1994). Another way in which memory is conceptualized or characterized is as a memory trace that holds the content of our experiences. This conceptualization views memories more as mental representations (Radvansky, 2006). Possibly the most common view of memory is as a dynamic process by which we learn, store, and retrieve information (Baddeley, 1998; Brown & Craik, 2000; Spear & Riccio, 1994; Sternberg, 2006).

The concept of memory has inspired philosophers and researchers throughout history and has stimulated research for hundreds of years. Interest in human memory can be traced back to the ancient philosopher Aristotle, who theorized that memories were composed of associations among various stimuli or experiences (Radvansky, 2006). British empiricists also influenced current conceptualizations of memory by their theories that viewed memories as interconnections between various ideas and concepts.

Ebbinghaus was one of the first scholars to study the measurement of memory by examining how people learn and forget things, using himself not only as the experimenter but also as a human subject (Baddeley, 1998; Radvandksy, 2006). Ebbinghaus used nonsense syllables as stimuli and discovered many important concepts, such as the learning curve, that are commonly referred to today in the study of memory.

Children's memory has also been of interest to developmental theorists and psychologists for many years. Piaget contributed to the field of cognitive and memory assessment by studying children's thinking abilities through interview techniques. Although Piaget is not known for his study of memory per se, he is recognized for including memory in his studies of children by focusing on children's ability to conserve previously learned information (Barry, 2006). Throughout the years, other researchers have also shown interest in children's memory as a cognitive ability and how memory develops. There has been considerable research regarding memory in infancy and the development of memory throughout childhood and adolescence. Developmental research on children's memory has generally found that different components of memory appear to develop at different rates. The more basic forms of memory, such as procedural knowledge of how to do things, and nondeclarative knowledge, such as familiarity with different stimuli, are present as early as infancy. More complex forms of memory, such as semantic and episodic memory, show rates of development that are associated with rates of brain development (Radvansky, 2006). Regarding semantic memory, which refers to encyclopedic-type knowledge or knowledge of facts, children show evidence of schemas and scripts as early as 3 years of age (Radvansky, 2006). Development in episodic memory can be recognized over time as children improve in the ability to structure and organize information in the retrieval process. As children become older, they develop more memory-enhancing skills and meta-memory skills such as monitoring and rehearsal of information to improve recall (Sternberg, 2006). One of the most notable changes to children's memory is metamemory awareness, which allows them to be aware of their use of different strategies to prevent forgetting and recognize when they need to use such strategies (Radvansky, 2006). Despite this growing field of research in children's memory, there are still many unanswered questions regarding children's memory and how it functions.

There are several ways in which memory has been conceived. Some general ways in which memory is conceptualized include distinctions between working memory, short-term memory, and long-term memory, though there are various definitions and conceptualizations of each of these concepts. For the purposes of this study, the following models of memory will be used as a reference for defining these aspects of memory.

The Modal Model of Memory

One of the first theories of memory, the modal model, was proposed by Atkinson and Shiffrin (1968). The modal model of memory is considered a standard model of memory, is frequently referred to in the study of memory, and has played an essential role in stimulating further research into the understanding of memory. Atkinson and Shiffrin's model is comprised of four components: sensory registers, short-term memory, control processes, and long-term memory (Radvansky, 2006). The sensory registers include touch, taste, smell, sight, and hearing and make up a collection of memory stores that hold information for brief periods of time. They allow a constant changing flow of information to be taken in and allow an individual to dismiss and attend to information as needed (Radvansky, 2006). Short-term memory represents a storage system that is less transient than the information acquired through the sensory registers, but also is timerestricted. This system generally retains information for less than a few minutes if it is not actively processed. This active processing constitutes another component of the modal model, the control processes, which actively manipulate information through rehearsal and the transfer of information back and forth from short-term store to long-term store (Radvansky, 2006). Some memory theorists have identified this component as a working memory system, which will be discussed in more detail later. The last component, long-term memory, represents more permanent information and has large storage capabilities. Long-term memory is composed of a variety of different types of long-term knowledge and associations (Radvansky, 2006). Neuropsychological and psychological assessments try to capture and measure aspects of these memory components, including a person's short-term memory and long-term memory. This is often accomplished through tasks that require an individual to be presented with stimuli and asked to recall information immediately after it was presented or recall information after a short delay (see Figure 1).

In neuropsychological and psychological assessment, other modes of memory have also been distinguished, such as visual memory and verbal memory. Visual memory is generally defined as any memory in which information is acquired and stored via the visual modality (Hollingworth & Luck, 2008). Baddeley (1998) describes the visual memory system in more detail by identifying three components that make up the visual system. These components include iconic memory, short-term visual memory, and long-term visual memory. Iconic memory is a rapidly decaying sensory trace that individuals experience when first exposed to a visual stimulus. This iconic memory is thought to feed into a more concrete visual storage system: short-term visual memory.

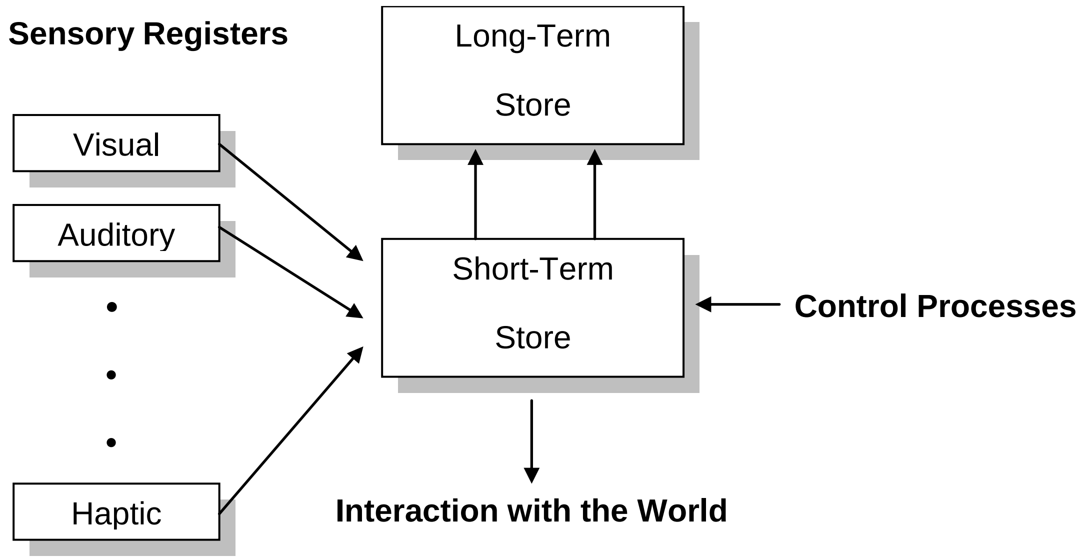

Figure 1. Modal model of memory.[1]

[1] From Radvansky (2006) Copyright 2006 by Pearson Education, Inc. Adapted with permission of Pearson Education, Inc.

Short-term visual memories are thought to be stronger than iconic memories, being comprised of limited amounts of information that are retained for a relatively short amount of time. Long-term visual memory is thought to have greater storage capabilities and includes visual material that has been held for longer periods of time (Baddeley, 1998).

Verbal or auditory memory is a type of memory in which information is acquired verbally or a person utilizes the auditory modality to encode information into memory (Baddeley, 1998). Similar to Baddeley's explanation of visual memory, he also explains memory by the sensory storage system of audition. Verbal memory is made up of three systems: echoic memory, auditory short-term memory, and auditory long-term memory (Baddeley, 1998). Echoic memory is a sensory storage system that represents the persistence of a sound and possibly lasts milliseconds, auditory short-term memory is believed to hold information from 5 to 10 seconds, and auditory long-term memory represents the least transient storage system, holding auditory information for longer periods of time than auditory short-term memory (Baddeley, 1998).

The Working Memory Model

One aspect of memory that has gained considerable attention in the field of psychology is working memory. As mentioned previously, Atkinson and Shiffrin (1968) did not identify working memory in their early model; however, many theorists have interpreted their conceptualization of short-term memory as an early predecessor to the concept of working memory (Baddeley, 1996). The term working memory generally refers to a temporary storage system that allows individuals to receive information and hold onto it momentarily while also manipulating other information (Baddeley, 1998). A system such as this allows us to be able to learn, reason, and comprehend. Baddeley and Hitch (1974) proposed a working memory model that illustrates how visual and auditory memory systems are related. Baddeley (2001) described a model of the memory system comprised of a central executive, visual-spatial sketchpad, episodic buffer, and phonological loop. The central executive is thought to be a key component in memory and represents a supervisory system with limited attentional capacity that controls cognitive processes with the assistance of two subsidiary memory systems: the visual-spatial sketchpad and phonological loop (Baddeley, 2003). The visual-spatial sketchpad is involved in the temporary storage and processing of visual and spatial information. It is thought to be comprised of two components: the visual cache for static visual information and an inner scribe for dynamic spatial information (Pickering, Gathercole, Hall, & Lloyd, 2001). The phonological loop is also thought to be comprised of two subsystems, the phonological store and articulatory process. The phonological store handles information that is verbal or auditory. One important aspect to note regarding the phonological store is that visual information can also be converted into phonological information via verbal rehearsal and be stored through this system. The phonological loop includes the articulatory process, also known as the subvocal rehearsal process, which allows information to be repeated in an auditory loop to prevent decay. Baddeley (2001) added a fourth element to the working memory model, the episodic buffer. This process is thought to be involved in linking information across the visual-spatial sketchpad and phonological loop to create an integrated representation in memory which includes both visual and auditory components. Additionally, the episodic buffer is thought to integrate or link multidimensional representations from long-term memory, creating a unitary and coherent representation, which is thought to contribute to long-term memory storage (Baddeley, 2000; Dehn, 2008) (see Figure 2).

The Visual-Spatial Sketchpad

In Baddeley and Hitch's model of working memory, the focus would be primarily upon the contribution of the visual-spatial sketchpad in memory. Although the visual-spatial sketchpad is only one of two slave systems in Baddeley and Hitch's working memory model, it performs numerous tasks that contribute to human memory. One of the main tasks of the visual-spatial sketchpad is the role it plays in the construction, maintenance, and manipulation of mental images (Radvansky, 2006). Similar to the phonological loop, mental images must be maintained and rehearsed or they decay. Another commonly recognized role of the visual-spatial sketchpad is to act as a

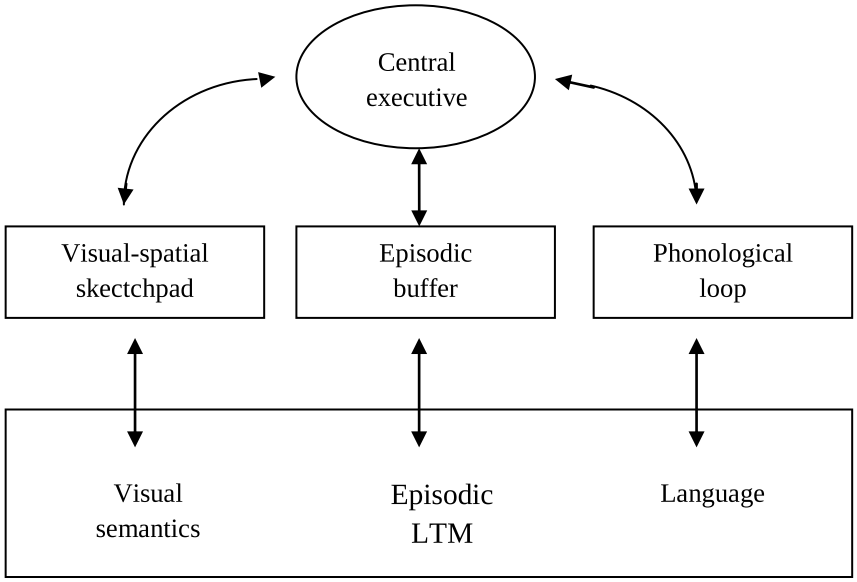

Figure 2. Multicomponent working memory model revision.[2]

[2]From Baddeley (2003) Copyright 2003 by Macmillan Publishers, Ltd. Adapted with permission of Macmillan Publishers, Ltd.

replacement for physical reality (Radvansky, 2006). This is apparent in an individual's ability to visualize objects or locations when not in their presence. Our mental visual scanning abilities are sophisticated to the extent that our visual-spatial sketchpad will attempt to imitate the visual and spatial processes that operate when we actually experience an event. Intons-Peterson and Roskos-Ewoldsen (1989) illustrated this in a study using a mental scanning task. In this study, college students were asked to visualize themselves going from one location to another on their college campus. Interestingly, their response times increased when students were required to mentally travel longer distances and their response times increased when they had to imagine carrying heavy items (Intons-Peterson & Roskos-Ewoldsen, 1989). Another process recognized as a task performed by the visual-spatial sketchpad is mental rotation. This allows individuals to mentally turn objects. This type of skill may be used when seeing something oriented upside-down, when comparing similarities or differences in objects, or understanding whether something will fit together. Research has shown that mental rotation attempts to simulate what one would observe if he or she were actually physically rotating objects. These are only a few of many recognized skills the visual-spatial sketchpad possesses, illustrating some of the ways in which the visual-spatial sketchpad is utilized to assist overall memory.

Baddeley (2003) affirms that the visual-spatial sketchpad may serve several crucial functions in providing semantic knowledge about the appearance of objects and the function of objects, assisting in visualizing complex systems, as well as providing understanding of spatial orientation and geography. Understanding the ability to hold, manipulate, and recall visual-spatial representations may have implications for an individual's success in fields like architecture and engineering (Baddeley, 2003). For children, deficits in this particular system of memory could potentially have adverse effects on academic performance by impairing their ability to match symbols, discriminate between different symbols, learn new symbols, and recognize and recall important symbols such as numbers and letters that are used in school learning tasks (Bavin, Wilson, Maruff, & Sleeman, 2005). Additionally, deficits in visual-spatial memory could impair a child's ability to use imagery to solve math equations, puzzles, read maps, navigate hallways, remember placement of objects, and spatially organize information (Bavin et al., 2005). A question that the present study attempts to explore is how the modality of visual memory relates to children's academic performance and whether one can accurately distinguish a deficit in this particular modality of memory.

The following chapter reviews the contemporary research literature regarding memory and academic performance, with additional focus upon studies examining visual memory and the role of the visual-spatial sketchpad. The review concludes with a summary and critical analysis of the literature reviewed, followed by discussion of specific research questions and hypotheses suggested by the review and examined in the present study.

LITERATURE REVIEW

Aspects of Learning

Before one can understand and measure memory, the topic of learning must be addressed first. Information must be learned in order for memory to be measured and understood. Two methods of learning that are commonly considered in the study of memory are intentional learning and incidental learning (Radvansky, 2006). Intentional learning is often the goal of teachers, who directly teach students information with the hope that students will respond by trying to learn. Memory assessments also attempt to tap this type of learning through tasks that teach new information to examinees before asking them to recall or recognize the information previously taught. The tasks on the California Verbal Learning Test (CVLT-C; Delis, Kramer, Kaplan, & Ober, 1994) provide a good example of using intentional learning to assess verbal memory. On the CVLT-C, the examiner reads the examinee a list of words that he or she is asked to remember; immediately after the list is read, the examinee is asked to recall as many words from the list as possible.

The other type of learning, incidental learning, is information that people acquire without intentional effort and often occurs in day-to-day activities through observation and being exposed to different information (Radvansky, 2006). In memory testing, memory acquired through incidental learning may be assessed by exposing examinees to information without prompting them that they will need to recall it at a later time. The Rey-Osterrieth Complex Figure Task (RCFT; Osterrieth, 1944) examines visual-motor integration, perceptual organization, and visual memory, and provides a good example of assessing memory through incidental learning (Meyers & Meyers, 1995). On the initial copy trial, the examinee is exposed to a stimulus card and asked to copy the image. Later, for the immediate recall trial, the examinee is given a blank piece of paper and asked to reproduce the image on the stimulus card he or she was exposed to during the copy trial. Individuals are never instructed during first exposure to the stimulus card that they will later be asked to recall the figure, which forces them to recall what they learned through incidental learning.

Learning Problems and Memory Deficits

Memory is a required part of learning. For learning to occur, working memory must function to manipulate information, interact with long-term memory, and process information (Dehn, 2008). Long-term memory must function to store knowledge and experiences so that information can be used and retrieved (Dehn, 2008). Children spend a majority of their time in school in pursuit of learning. Educational and psychological research has provided substantial evidence that working memory processes underlie individual differences in learning ability (Dehn, 2008). In classroom settings, working memory skills and long-term memory skills are required when listening to teachers while trying to take notes, remembering and following complex instructions, decoding unfamiliar words, writing sentences from memory, and using mental arithmetic. Each of these scenarios requires memory skills of the learner to process new information, integrate previously learned information, and store information. If children experience learning difficulties in school, parents, teachers, and clinicians may refer to these difficulties as they apply to particular academic subject areas like reading, math, and written expression (Semrud-Clikeman, Fine, & Harder, 2005). In the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR), the American Psychiatric Association (APA, 2000) prescribes a certain number of symptoms for a diagnosis of a Learning Disorder (LD). According to APA, LD is defined so that an individual's "learning problems significantly interfere with their academic achievement or activities of daily living that require reading, mathematical, or writing skills and an individual's achievement is substantially below that expected for age, schooling, and level of intelligence" (APA, 2000, p. 49). APA (2000) indicates that the estimated prevalence of LD may range from 2% to 10% of the population. The U.S. Department of Education (2006) determines eligibility for special education services under the category of specific learning disabilities when

> a child…does not achieve adequately for the child's age or meet state-approved grade-level standards in one or more areas including: oral expression, listening comprehension, written expression, basic reading skills, reading fluency skills, reading comprehension, mathematics calculation, and/or mathematics problem solving when provided with learning experiences and instruction appropriate for the child's age or state-approved grade-level standards. (U.S. Department of Education, p. 46786)

According to the Office of Special Education and Rehabilitative Services of the U.S. Department of Education (2006), approximately 5.5% of the school-age population receives special education for a specific learning disability.

These two definitions of learning disabilities are relatively similar; however, APA defines LD by the core academic subjects of reading, written language, and mathematics, and allows the nonspecific diagnostic category of Learning Disorder Not Otherwise Specified to capture other variants of LD. Additionally, APA and the U.S. Department of Education differ slightly in how they determine inadequate achievement. APA indicates that LD is determined in relation to an individual's age, school experience, and intelligence, whereas the U.S. Department of Education specifies that LD be determined according to the child's age and grade level. These slight differences in definition can sometimes lead to differences in how information is gathered through assessment in clinical versus school settings. Other assessment tools are better suited for clinic settings and specifically focus upon ruling in or ruling out different symptoms of diagnoses based upon criteria specified in the DSM-IV-TR. Some assessment tools are designed to gather information that is helpful to psychologists and educators working in school settings by providing information that can be applied to school functioning and instructional needs. Additionally, ethical codes, professional standards, and legal documents affect assessment practices in different settings (Jacob & Hartshorne, 2003). For example, in school settings, the Individuals with Disabilities Education Improvement Act (IDEIA) outlines legal requirements for evaluation procedures, and this affects which assessment tools psychologists and educators use in this setting (Jacob & Hartshorne, 2003).

Rather than viewing memory deficits as learning disabilities, more often memory problems are recognized as processing or cognitive deficits that can have more global impacts beyond particular academic subject areas (Krener, 1996). Memory problems can also occur as a result of brain injuries and insults such as closed head injuries, brain infection, and exposure to toxic levels of drugs and alcohol (Sheslow & Adams, 2003). However, this does not mean that memory problems are not associated with LD. In children and adolescents, learning disabilities and developmental delays are frequently associated with memory deficits (Sheslow & Adams, 2003). Torgesen (1982) found specific memory impairments in a substantial proportion of children with learning disabilities and Swanson and Berninger (1996) have found that children with all types of learning disabilities display poor working memory performance. Additionally, a study by Maehler and Schuchardt (2009) was conducted to see if memory performance in children with LD was affected by intellectual functioning. Maehler and Schuchardt's study involved examining three groups of children. One experimental group was made up of children with LD who had average intellectual functioning, another group was made up of children with LD and low intellectual functioning, and a third group was made up of typically developing children with average school achievement and average intellectual functioning. Results of their study found that children with LD, irrespective of their intellectual functioning level, showed significantly lower working memory than typically developing children.

Teachers and professionals working in education settings are often very familiar with LD and specific learning disabilities; however, they sometimes are not aware of memory problems or how memory problems affect academic skills. If a strong link does exist between memory deficits and learning problems, providing teachers with information regarding a student's memory skills could be beneficial in identifying whether memory is a factor in a student's academic difficulties and could guide teachers and professionals working in schools to use more effective education interventions and strategies.

The aim of the present study is to further explore how memory deficits and more specifically, visual memory deficits, affect academic learning. Are memory problems frequently comorbid with particular academic achievement deficits? For example, are individuals with visual memory impairments more likely to have learning difficulties in mathematics than in reading? If the outcomes of the present study suggest a relationship between visual memory impairment and specific academic achievement deficits, future research can address how to improve teaching techniques to address each of these problems effectively.

Learning Disorders Associated with Visual Spatial Memory Deficits

Although memory deficits are not synonymous with LD as defined within classification systems such as the DSM-IV-TR or education classification systems as described in IDEIA, there are particular disorders that are characterized by poor visual-spatial skills that should be considered when examining the relationship between visual memory and learning, such as nonverbal learning disorder (NVLD).

Although knowledge regarding this classification of learning disorder is still emerging (Little, 1999), NVLD is estimated to affect approximately 1 in 10 children with LD (Rourke, 1995). NVLD is a fairly new and recent addition to the compendium of learning disorders and has a somewhat controversial origin and definition (Forrest, 2004). The existence of NVLD is still debated, and it is not identified as a learning disorder in the DSM-IV-TR. The phenomenon of NVLD was originally proposed by Johnson and Myklebust (1967), who found distinct differences between children who had deficits in verbal versus nonverbal processing skills. Rourke (1995) later proposed a more widely accepted definition and pattern of symptoms associated with the disorder. According to Rourke (1995), children with NVLD have high verbal cognitive intelligence, and strengths in rote verbal learning, phonemic awareness, verbal fluency, and verbal classification skills. In contrast, these children show low visual-spatial skills and struggle on cognitive tasks that require visual-spatial organization, perceptual motor skills, and nonverbal problem solving skills. In school settings, children identified with NVLD show a pattern of contrasting academic abilities, often with advanced skills in phonemic spelling and word recognition in the face of severe mathematical difficulties (Rourke, 1995). In addition to having this unique academic profile, children with NVLD often have social deficits due to their poor visual-spatial abilities, which affect their ability to read social and visual cues such as gestures and facial expressions. According to Rourke, these children often become further alienated from peers by their unusual language and social characteristics.

Another disorder associated with poor visual and spatial cognition is Williams syndrome, a rare genetic disorder with a unique cognitive profile in which individuals show strengths in expressive language skills but severe deficits in spatial cognition (Wang & Bellugi, 1994). Wang and Bellugi found that the superior language ability of individuals with Williams syndrome was accompanied by significantly better performance on a verbal short-term memory task compared to a visual-spatial short-term memory task. Conversely, they also found that individuals with Down Syndrome performed significantly better on a visual-spatial short-term memory task than a verbal short-term memory task. They concluded from their study that there is neurogenetic evidence for distinctions between visual-spatial short-term memory and verbal short-term memory. One question of interest regarding the present study is to further explore if there is a direct link between visual-spatial processing skills and visual-spatial memory. Could clinicians expect children with deficits in specific domains, such as visual-spatial memory skills, to experience similar patterns of academic struggles, such as those found in individuals with NVLD, or is this academic profile a result of other cognitive deficits associated with this disorder? Understanding more about the link between visual-spatial skills and academic performance could help explain some of the learning difficulties experienced by children with NVLD and children experiencing visual-spatial memory problems.

Memory and Cognition

The literature clearly suggests that a link appears to exist between memory and learning, but how does memory specifically relate to cognitive functioning? One assumption regarding the role of memory in cognition is that memory assists the performance of cognitive tasks like learning, comprehending, and reasoning (Baddeley, 1998). Working memory is also thought to play a role in maintaining and manipulating information during cognitive tasks (Baddeley, 2002). Many theoretical approaches include memory as a factor in models of intelligence or cognitive functioning (Dehn, 2005). For example, a highly recognized and prominent intelligence theory, Cattell-Horn-Carroll (CHC) theory, proposes a trilevel hierarchical model of g, or general intelligence, with 10 broad abilities (McGrew, 2005). The 10 broad abilities include fluid intelligence, quantitative intelligence, crystallized intelligence, reading and writing, short-term memory, visual processing, auditory processing, long-term storage and retrieval, processing speed, and decision/reaction time/speed (McGrew & Woodcock, 2001). Interestingly, short-term memory and long-term storage and retrieval are recognized as 2 of the 10 major factors. The influence of the CHC theory can be seen in many assessments of intelligence and cognitive functioning by their inclusion of short-term memory or working memory as a factor within the overall assessment of cognitive skills

(Dehn, 2008). For example, The Wechsler Intelligence Scale for Children (WISC-IV; Wechsler, 2003c) and the Stanford-Binet Intelligence Scales (SB5; Roid, 2003), common cognitive and intelligence assessments for children, both include a measurement of memory. Including memory tasks as part of a cognitive skills assessment makes sense considering that an individual's memory allows him or her to predict cause and effect of behavior, learn new information, and reason effectively. To have a deficit in memory could cause an individual to struggle in following conversations, planning activities, accessing his or her environment independently, and completing daily tasks (Makatura, Lam, Leahy, Castillo, & Kalpakjian, 1999). Past research has also shown evidence that moderate correlations exist between cognitive ability and memory ability, making it difficult to separate memory from cognitive functioning ability. A study about the genetic covariance of reading, intelligence, and memory by Van Leeuwen, Van den Berg, Peper, Hulshoff Pol, and Boomsma (2009) illustrates this point further. This study was conducted using sets of twins to examine the genetic relationship among reading performance, IQ, verbal and visual-spatial working memory, and short-term memory. The results of their study found that genetic variation accounted for 83% of the variation in reading performance, and that most of the genetic variance was explained by variation in an individual's intelligence quotient (IQ) and memory performance. Further, Van Leeuwen et al. concluded that there is a common set of genes which account for the correlation between working memory, short-term memory, IQ, and reading performance.

Assessment Practices

Assessment is a frequent practice in school and clinical settings as a methodical way to gather information about individuals. It informs professionals of children's cognitive and psychological strengths, weaknesses, and current state of functioning. It allows professionals to make educated decisions so they can recommend appropriate treatment and/or provide needed interventions. Memory assessment is frequently used in clinical settings, and the need may be apparent, considering that Eliason and Richman (1987) report that children with LD and memory deficits represent a substantial percentage (55%) of the clinic population from 1982-1987.

Cognitive and intelligence assessments are very popular and frequently used in both clinic and school settings. Dehn (2008) explains the memory tasks included in comprehensive cognitive and intellectual assessment tools should not be considered less valid than recognized memory assessment batteries. However, Dehn (2008) cautions that the drawback of using the memory tasks in cognitive assessments is that they often are based on traditional memory models rather than more prominent memory models, such as Baddeley and Hitch's working memory model. Therefore, the structure of short-term and working memory assessed within cognitive assessments may not adequately reflect the functioning of some components of memory structures such as the phonological loop and visual-spatial sketchpad.

It is possible that more frequent and comprehensive assessment of memory in schools is warranted, since several studies have linked memory performance to academic or achievement performance in children. In school settings, memory assessment could potentially serve as a useful tool for teachers and school professionals working with children. Memory assessment results could inform teachers and other educational staff of techniques and strategies that could best assist a child in school. For children receiving special education services, knowledge of memory functioning could help determine what skills and goals are addressed in the child's individualized education plan (I.E.P.).

Some psychologists gather additional information regarding children's memory either through observation and interview and/or through standardized comprehensive memory assessment tools, and use this information in their overall assessment of children with learning difficulties. According to Dehn (2008), some commonly used memory assessment tools for children and adolescents include the Luria-Nebraska Neuropsychological Battery Memory Scale (LNNB-M; Golden, Hemmeke, & Purisch, 1980), the Wide Range Assessment of Memory and Learning (WRAML2; Sheslow & Adams, 2003), Children's Memory Scale (CMS; Cohen, 1997), Test of Memory and Learning (TOMAL-2; Reynolds & Voress, 2007), the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001), the California Verbal Learning Test – Children's Version (CVLT-C; Delis et al., 1994), and the Rey-Osterrieth Complex Figure Task (RCFT; Osterrieth, 1944). In addition to providing an overall memory score, many of these memory assessments allow for the measurement of particular types of memory such as short-term recall and delayed recall, and some assess learning over multiple trials with repetition of information.

One common factor in each of the memory assessment tools listed above is the division of memory performance into indices of verbal and/or visual memory. Perhaps this reflects the influence, again, of the CHC theory on the development of assessment tools. Referring back to CHC theory and the 10 broad abilities, visual processing and auditory processing are recognized as separate cognitive factors. This and the delineation of most memory assessments into modalities of verbal and visual memory suggest that the differentiation of these memory modalities provide potentially useful information to clinicians regarding differences in memory. However, little is known regarding how differentiation in performance on these modalities of memory specifically affects individuals and their learning environments or informs clinicians in practice. More research is needed to learn about the constructs of visual and verbal memory and how deficits in these areas might affect children's academic performance or provide information concerning children's learning styles and cognitive abilities. Learning more about visual and verbal memory constructs may aid clinicians in analyzing memory assessment results and also assist clinicians in making effective treatment recommendations.

Memory Functioning and Academic Achievement

Since there appears to be a link between memory and learning, it is not surprising that several studies have revealed links between working memory and academic performance (Andersson, 2008; Bull & Scerif, 2001; McLean & Hitch, 1999; Swanson, Cochran, & Ewers, 1990). Some research suggests that the working memory abilities of students can limit or contribute to students' academic performance. Andersson (2008) conducted a study examining the contribution of visual-spatial and phonological working memory and the central executive upon children's arithmetic skills. The central executive, as mentioned in the Introduction, refers to a supervisory system that controls cognitive processes with the assistance of the visual-spatial sketchpad and phonological loop (Baddeley, 2003). Results of Andersson's research found children's arithmetic skills could be constrained by their general working memory capacities and central executive skills.

Other studies indicate that measures of working memory may assist in predicting academic performance. Hainlen (1995) found verbal memory indices to be predictive of reading and math achievement in adolescents and visual memory indices to be predictive of reading achievement in young children. Bull and Scerif (2001) conducted a study examining the influence of central executive skills and working memory skills in predicting mathematics ability. Results of their study found that when children's IQ was controlled for, working memory span and central executive functions (perseveration, inhibition, and efficiency) predicted a significant amount of variance in written arithmetic performance.

Some studies suggest working memory may differentiate between different levels of academic performance. McLean and Hitch (1999) conducted a study of students with arithmetic learning difficulties and found that children with poor arithmetic skills differed from age-matched and ability-matched peers on their performance on spatial working memory tasks and executive functioning tasks that involved processes of switching retrieval plans. McLean and Hitch used measures that assessed switching retrieval plans to test participants' speed and accuracy in alternating between numerical and alphabetical sequences. Additionally, Swanson et al. (1990) found that there were distinct differences in working memory between subtypes of academic achievement. They used factor analysis to demonstrate that a battery of memory measures could be used to subdivide children into ability groups. Although other subtypes of individuals were included in the analysis, only those who were categorized as individuals with learning disabilities (having a significant discrepancy between cognitive and achievement performance), slow learners (individuals with achievement scores between the 35th and 50th percentiles), and average achievers (individuals with achievement above the 50th percentile) showed significant differentiation between memory functioning, with individuals categorized as having learning disabilities performing lowest on working memory tasks. Cain (2006) also conducted a study examining the memory and reading comprehension of individuals identified as "good comprehenders" versus "poor comprehenders." Results indicated that individuals who were categorized as poor comprehenders demonstrated deficits on working memory tasks that involved the simultaneous storage and processing of verbal stimuli. Additionally, results indicated that poor comprehenders had difficulties inhibiting intrusions or ignoring irrelevant information in context. Surprisingly, individuals who were categorized as poor comprehenders did not have an impaired ability to store and recall words, which Cain hypothesized may indicate that although they appear to have working memory deficits, their ability to store and retrieve words is not affected.

The findings from these studies highlight the importance of considering memory functioning in relation to children's academic performance. Although these studies indicate that a link exists between memory and academic achievement, more specific research concerning how different modes of memory are related to academic achievement could have useful implications for professionals working in clinical settings and school settings. Historically, there has been considerably more research examining the phonological loop and how limitations in verbal working memory are linked to deficits in reading and other cognitive abilities; less research has focused specifically upon the visuospatial sketchpad (Cornoldi, Vecchia, & Tressoldi, 1995). The intent of the present study is to contribute to a knowledge base of information regarding how children's visual memory impacts academic achievement.

Modes of Memory and Academic Achievement

Limited research has been conducted examining the relationship between verbal and visual memory and their relationship to children's achievement. However, some research is available to inform clinicians in hypothesizing patterns of academic achievement that may be expected given certain memory difficulties. Ozols and Rourke (1988) conducted a study examining groups of children with particular academic achievement patterns and their performance on visual-perceptual or auditory-perceptual tasks. They formed three experimental groups of children based upon their performance on the Wide Range Achievement Test (WRAT; Wilkinson, 1993). The first group exhibited deficient performances in reading, spelling, and arithmetic. The second experimental group presented with a pattern of deficiencies in reading and spelling, but performed significantly higher in arithmetic, and the third group performed higher in spelling and reading, but their performance in arithmetic was significantly lower. Results of their study indicated that there was a difference in how the groups performed on visual-perceptual and auditory-perceptual tasks. The group with specific deficits in arithmetic performed more poorly on visual-perceptual tasks, while the children with deficits in all their subjects and the children with deficits in reading and spelling performed significantly poorer on tests involving auditory-perceptual abilities. Although visual and verbal memory tests were not specifically used, this research does indicate that the differences between individuals' performance in visual and verbal modalities of information processing are important to examine regarding children and their learning.

Additionally, the results of Ozols and Rourke (1988) suggest that if children experience specific academic deficits, their performance on visual and verbal tasks may differ.

In a study examining the academic and memory profiles of children, Silver, Ring, Pennett, and Black (2007) predicted that children with isolated arithmetic disabilities would have a memory profile indicative of short-term visual memory deficits. Contrary to their hypothesis, they found that children with isolated arithmetic disabilities did not show a significant deficit in their visuo-spatial memory abilities. However, results of their research did indicate that children with comorbid disabilities in reading and math were more likely to experience verbal memory deficits. Although their original hypothesis was not confirmed, the research of Silver et al. suggests that memory assessment in both visual and verbal modalities can be an informative tool when evaluating children with learning deficits.

Another important study examining the relationship between academic performance and memory was conducted by Catroppa and Anderson (2007), who examined the memory functioning and academic success of individuals recovering from traumatic brain injury (TBI). In Catroppa and Anderson's study, children who had sustained a mild, moderate, or severe TBI were given cognitive, memory, adaptive, and academic testing at 6, 12, and 24 months postinjury. Results of their study showed that short and long-term memory difficulties in both verbal and visual modalities were present up to 24 months postinjury for individuals with moderate or severe brain injury. They also found that performance in arithmetic and listening comprehension had a dose-response relationship, showing significant differences dependent upon injury severity and task demands. Additionally, they found that pre-injury academic ability and postinjury verbal memory performance were the best predictors of academic success (Catroppa & Anderson, 2007). Although Catroppa and Anderson's study specifically focused upon a population of individuals with TBI, it demonstrated how knowledge about memory functioning can be used as an important indicator of academic performance and success.

Hainlen (1995) also used children's performance on a memory measure to predict academic achievement in school-age children. Hainlen administered the Wide Range Assessment of Memory and Learning (WRAML; Sheslow & Adams, 1990) and the Broad Math and Broad Reading clusters from the Woodcock-Johnson Revised Tests of Achievement (WJR-ACH; Woodcock & Johnson, 1989) to determine if memory scores could predict academic achievement. Results of her research found positive and moderately high correlations between the memory indices on the WRAML and reading and math achievement on the WJR-ACH. More specifically, the Verbal Memory Index was highly predictive of both reading and math achievement.

<u>Visual Memory and Academic Performance</u>

Lufi and Cohen (1985) examined short-term visual memory and its implications for academic performance. In their study, Lufi and Cohen were interested in understanding whether children with Attention Deficit Disorder (ADD) (currently referred to in the DSM-IV-TR as Attention Deficit Hyperactivity Disorder or ADHD), show differences in their short-term visual memory and whether these differences may be related to academic deficits that are typically seen in children with ADD. Lufi and Cohen determined participants had a diagnosis of ADD if the child displayed inappropriate attention, impulsivity, and hyperactivity according to the criteria specified in the third edition of the DSM (DSM-III). In their study, Lufi and Cohen administered the Wechsler

Intelligence Scale for Children-Revised (WISC-R; Wechsler, 1974) to a clinic sample of children and divided them into two groups. One group contained only children with a diagnosis of ADD, while the comparison group included children with emotional problems. Children in both of the experimental groups had average IQ scores. To assess short-term visual memory, Lufi and Cohen used a Coding Recall subtest on the WISC-R, in which children were asked to draw abstract symbols they had previously been asked to copy after a short delay. Results of their study indicated that children with ADD performed significantly worse on the visual memory subtest than children with emotional problems. Lufi and Cohen theorized that children with ADD perceived the symbols as geometric shapes rather than associating them with letters or attaching verbal meaning to them, which could have assisted them in recalling the symbols. This research is important because it suggests there may be a link between short-term visual skills and the academic struggles that are commonly seen in children with ADHD.

Bavin et al. (2005) conducted a study examining the visual-spatial memory of children with specific language impairments (SLI). Bavin et al. described a significant literature base supporting the fact that children with SLI are more likely to exhibit verbal memory impairments. However, Bavin et al. were interested in understanding if children with SLI also exhibited visual-spatial impairments. Specifically, these researchers hypothesized that if children with SLI had verbal memory limitations, that there might also be deficits in visual-spatial memory. They tested this hypothesis by comparing children with SLI to a matched sample of children without SLI. Results of their study found that children with SLI showed significant differences in their performance on visual-spatial memory tasks of pattern recognition and paired associates learning. Pattern recognition tasks assessed if participants could remember and recognize a pattern previously presented to them and paired associates learning tasks determined how well participants matched a stimulus to a particular location. Children with SLI performed significantly poorer on both of these tasks. Interestingly, they did not find that children with SLI showed differences in their information processing speeds or working memory, which others have hypothesized as reasons for their memory deficits. Professionals often may presume that children with SLI require interventions focused solely on addressing verbal impairments; however, Bavin et al. (2005) illustrated the importance of also considering visual memory impairments or more global memory impairments as a possible source of difficulty for children with SLI, resulting in a need for additional interventions.

Samuels and Anderson (1973) were also interested in the role of visual memory in associational learning and whether children with reading difficulties were more likely to have visual memory deficits. In their study, Samuels and Anderson examined two groups of children who were identified as either “good readers” or “poor readers.” They administered both visual recognition memory tasks and paired-associate learning tasks. In the visual recognition memory task, a participant was exposed to a stimulus card with a design and was later shown a series of similar designs and asked to choose the stimulus they had been shown earlier. Samuels and Anderson hypothesized that children who were “good readers” would demonstrate higher performance than students who were considered “poor readers” on visual recognition memory and paired associates tasks. Results of their research found that children who were “good readers” performed significantly higher than “poor readers” on visual recognition tasks. Additionally, the children with high visual recognition scores also tended to perform well on paired associates tasks. Samuels and Anderson concluded that children's learning is heavily influenced by their perceptual learning abilities. They further proposed that teachers could enhance children's visual memory abilities by implementing strategies focused on improving children's selective attention, perceptual learning, and coding skills.

Kulp, Edwards, and Mitchell (2002) conducted a study that specifically examined the relationship of visual memory performance to academic achievement in school age children. In their study, Kulp et al. were interested in determining not only if visual memory abilities could be linked to specific academic areas of reading and math, but how they might affect overall achievement. They administered a visual-perceptual skills/visual memory test and academic achievement assessments with second through fourth grade students. Results of their research found there was a positive trend between children's visual memory score and performance on reading decoding, math, and overall academic achievement. The Test of Visual and Perceptual Skills (TVPS; Gardner, 1988) was used as a measure of visual memory (scores ranged from 0-16). Results of their analysis found that for every unit increase (1.0) on the TVPS standard score, children's odds of having a below average reading-decoding score decreased by 18.4%. For math, their odds decreased by 15.4 %, and for overall achievement, their odds of below average performance decreased by 21.1%. Kulp et al. concluded that poor visual memory scores were associated with an increased likelihood of poor performance globally in academic achievement. One interesting finding from this research was that although they predicted that a significant correlation would be present based upon a study conducted by Halliwell and Solan (1972), reading comprehension and visual memory were not significantly correlated. Halliwell and Solan had found that when reading instruction was supplemented with perceptual instruction to improve visual memory, children's reading abilities showed greater improvement compared with a group of children who received regular reading instruction and special reading assistance, and compared with a control group. Kulp et al. hypothesized that their finding, which did not support Halliwell and Solan's findings, may have been due to the young age of their participants and that older children may be more likely to use visual memory to comprehend, organize, and remember mental images of a story when reading. Future research is needed that examines the differences across age groups. Kulp el al. also proposed that future research should examine the usefulness of visual memory therapies on academic achievement.

Simmons, Singleton, and Horne (2008) examined the influence of the visual-spatial sketchpad and phonological awareness upon arithmetic attainment in young children. Simmons et al. predicted that visual-spatial sketchpad skills would be highly predictive of arithmetic attainment, based on past findings by Rasmussen and Bisanz (2005), who had found that visual-spatial functioning correlated highly with preschoolers' arithmetic achievement. Rasmussen and Bisanz (2005) further theorized that as children approach school age, they become more reliant upon phonological loop functioning and visual-spatial sketchpad skills are less influential. Simmons et al. also based their hypothesis on the research of Hecht, Torgesen, Wagner, and Rashotte (2001), who demonstrated that phonological awareness tasks predict arithmetic performance independently of memory tasks. As a synthesis of these past findings, Simmons et al. (2008) conducted a study to specifically look at visual-spatial sketchpad skills and phonological awareness in predicting arithmetic performance while controlling for three other covariates: vocabulary, nonverbal reasoning, and reading. Their results indicated that visual-spatial sketchpad functioning and phonological awareness were significant independent predictors of children's arithmetic attainment. Additionally, they found that phonological awareness was a significant independent predictor of reading attainment. They concluded that while phonological awareness can be linked to both reading and arithmetic, the functioning of the visual-spatial sketchpad primarily impacts arithmetic development.

Although many of these studies suggest a correlation between visual memory performance and academics, other studies have found results contrary to these findings. Giles and Terrell (1997) conducted a study comprised of two experiments examining visual sequential memory and spelling ability. Giles and Terrell compared children ranging in age from 12 to 16 who were identified as either "good spellers" or "poor spellers," and compared their performance on visual sequential memory tasks. They hypothesized that children who were good spellers would perform significantly better than poor spellers on visual sequential memory tasks. The visual sequential memory tasks included two tests, one which allowed participants to use verbal coding to assist in recall and one task which did not allow verbal coding. In both tasks, participants were presented with a row of pictures in connected boxes for approximately 5 seconds, and after a 3-second delay, were presented again with a row of empty boxes and a single box with a picture from the previous display. Participants were instructed to indicate in which box the picture had originally been displayed. The trial that allowed for verbal coding used pictures of animals, which presumably allowed participants to assign verbal labels to the pictures to assist in recalling the answer. The task did not allow for verbal labeling used triangles of varying size, form, and orientation. Giles and Terrell theorized this condition would not allow participants to use labeling, because the triangles all would be too similarly labeled and this would prevent verbal coding from assisting in the memory of visual information. Results of the first experiment found that on the visual sequential memory task that did not allow verbal coding, visual sequential memory performance did not differentiate between the groups of children who were poor at spelling or good at spelling. This is contrary to the hypothesis they proposed, suggesting that poor spellers do not have a specific deficit in visual memory for sequences. However, on the task in which verbal coding was permitted, there was a significant difference between the visual sequential memory performance of "good spellers" and "poor spellers," with "good spellers" having significantly higher scores. Giles and Terrell theorized that children who have poor spelling skills may be less adept at using verbal strategies to enhance memory performance. In a second experiment, Giles and Terrell attempted to replicate these findings; however, in their second experiment, they matched participants on IQ scores. In the second experiment, they found that when participants were matched on IQ, neither of the visual sequential memory tasks revealed significant differences between the groups, whether verbal coding was permitted or not. As a result, they concluded that the findings from the first experiment were likely invalid due to heterogeneity of IQ in the first sample and the outcomes of the second experiment were more likely valid, suggesting that good and poor spellers cannot be differentiated by visual sequential memory scores.

Purpose of the Study

Studies in the area of memory and academics have shown mixed results, with some studies showing correlations between impairment in memory and specific academic performance patterns and other studies showing evidence that there is not a predictable pattern of academic performance. Memory assessment can be an important component of a comprehensive psychoeducational or neuropsychological assessment, particularly for children and adolescents experiencing learning difficulties. Results of memory assessment may indicate that a child has a specific memory deficit in either verbal and/or visual memory. Psychologists must then make inferences regarding how different memory deficits may impact a child's performance in an academic setting. The purpose of the present study was to specifically examine the relationship between visual memory deficits and children's academic achievement. This study examined whether visual memory impairment was associated with a specific pattern in children's academic performance and whether visual memory impairment can be linked to lower performance in particular academic subject areas. Additionally, this study attempted to inform clinicians who use memory assessment as part of their comprehensive psychoeducational or neuropsychological assessments of children and adolescents.

Research Questions and Hypotheses

Ultimately, the goal of this study was to investigate the following research questions and hypotheses:

> Research Question: Do children with visual memory impairments show differences in their academic profiles in comparison to children without visual memory deficits?

Research Hypothesis: Children with visual memory impairments will have lower performances in reading, spelling, and arithmetic compared to children without visual memory impairments. Visual memory appears to be involved in the learning and production of skills in reading, spelling, and arithmetic; therefore, children with visual memory impairments will exhibit deficits in all areas when compared to children without memory impairments.

Null Hypothesis I: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of reading achievement.

Null Hypothesis II: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of spelling achievement.

Null Hypothesis III: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of arithmetic achievement.

METHODOLOGY

Design

The design of this study involved a between-group comparison. Archival data collection was used to gather data on the participants' performance on cognitive, memory, and academic measures. Participants were assigned to one of two groups based upon their performance on a standardized memory assessment. The two groups formulated were referred to as either the visual memory deficit group or the nondeficit comparison group.

Participants

Participants included a clinical sample of 70 children and adolescents between the ages of 6 to 16. Participants were identified through archival data collection of client files. A record review was conducted for clients who completed a neuropsychological evaluation at a private neuropsychology clinic between the dates of January 2007 through July 2009. The private clinic is located in a central urban township in a Western state. Clients seen prior to data collection typically were referred for neuropsychological evaluation due to concerns regarding academic and/or psychological difficulties. Individual files selected for inclusion in the study were those of children identified as having a visual memory deficit as measured by a standardized, norm-referenced memory assessment, and comprised the visual memory deficit group. In addition, a clinical comparison group was selected of individuals who showed average or above average performance on the same memory assessment. Due to the average memory performance of individuals in this group, they have been labeled the non-deficit comparison group. All individuals included in the data analysis completed an evaluation with standardized, norm-referenced assessments of cognitive functioning, memory, and academic achievement. Table 1, 2, and 3 display demographic information for participants included in this study.

Visual Memory Deficit Group

The visual memory deficit group was comprised of individuals identified as having a visual memory deficit as measured by the Wide Range Assessment of Memory and Learning, Second Edition (WRAML2; Sheslow & Adams, 1990). Information regarding the individuals' performance on the Visual Memory Index and Verbal Memory Index of the WRAML2 were collected to determine group assignment. Participant data for inclusion in the visual memory deficit group were indicated by a deficit score on the Visual Memory Index and an average score on the Verbal Memory Index of the WRAML2. A deficit in visual memory was defined as any standard score that was less than or equal to 85, which represents one standard deviation below the mean (M = 100, SD = 15). For the purposes of this study, an average score on the Verbal Memory Index was defined as any score that was equal or greater than a standard score of 93. This cutoff was chosen because it represents a difference of more than one-half standard deviation above the deficit cutoff score and also represents a standard score that falls within the average range.

Table 1

Demographic Information of Participants by Group Membership

	Group Membership	
	Visual Memory Deficit (*n* = 32)	Non-deficit Comparison (*n* = 38)
Male	23	21
Female	9	17
Mean Age	9:9	11:7
Mean Grade Level	4	6
Receiving Special Education	43.8%	26.3%

Table 2

Age Ranges of Participants by Group Membership

	Age Groups			
Group	6 to 8 (*n* = 20)	9 to 11 (*n* = 24)	12 to 14 (*n* = 16)	15 to 17 (*n* = 10)
Visual Memory Deficit	6	13	13	6
Nondeficit Comparison	14	11	3	4

Table 3

Ethnicity of Participants by Group Membership

	Group Membership	
Ethnicity	Visual Memory Deficit (n = 32)	Nondeficit Comparison (n = 38)
African American	6.3%	2.6%
American Indian	3.1%	5.3%
Asian American	3.1%	5.3%
Biracial	6.3%	2.6%
Caucasian	78.1%	78.9%
Latin American	0.0%	2.6%
Other	3.1%	0.0%

Nondeficit Comparison Group

A nondeficit comparison group was comprised of individuals with average performance on memory measures. Individuals selected for inclusion in this group had average or above average performance on both the Visual Memory Index and the Verbal Memory Index of the WRAML2. An average or nondeficit memory score was defined as a Memory Index score that is equal or greater than a standard score of 93 (M = 100, SD = 15). Similar to the definition for average memory performance used for inclusion criteria established to define the visual memory deficit group, this cutoff score for inclusion in the comparison group was selected because it represents a score that is considered to fall within the average range of functioning, but also represents a difference of more than one-half standard deviation above the individuals who comprised the visual memory deficit group. Individuals in the comparison group had both Visual and Verbal Memory Indices greater than or equal to a standard score of 93 to qualify for inclusion in the nondeficit comparison group.

Exclusions

Archival data that were excluded for the purposes of this study included participant data that did not fit the specified age ranges of 6 to 16 years of age. This age range was specifically chosen due to the age restriction of the cognitive measure used. Additionally, individuals with a visual memory standard score that was greater than or equal to 84 and less than or equal to 92 could not be included because they fell outside the parameters defined for group assignment to either the visual memory deficit group or the nondeficit comparison group. No other considerations for exclusion were used in this study.

Measures

All participants had been administered a cognitive measure, a memory measure, and an academic achievement measure as part of a larger psychoeducational or neuropsychological battery. All cognitive, memory, and achievement measures were norm-referenced and were administered using standardized procedures. Each participant was administered all three assessment tools in one session at a private neuropsychological private practice by a trained professional.

Cognitive Assessment

The Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003a) is a norm-referenced standardized test that measures general intellectual abilities in children and adolescents aged 6 to 16. The WISC-IV uses verbal and performance tasks to derive a global Full Scale Intelligence Quotient (FSIQ). Additionally, four factor-based indices are obtained: Verbal Comprehension, Perceptual Reasoning, Working Memory, and Processing Speed (Wechsler, 2003a). Index scores on the WISC-IV are converted from raw scores to standard scores with a mean of 100 and standard deviation of 15. Wechsler (2003b) reports the WISC-IV to have adequate reliability and validity indices. Information obtained from test-retest reliability data indicates that the average corrected FSIQ stability coefficient was .93. Wechsler (2003b) has also reported several indicators of validity, including content validity, convergent validity, and discriminant validity. Content validity was established through feedback by reviewers and experts. In test development, they created content similar to existing content and established tests to expand the evaluation base. The response process was examined as well, with multiple choice formats to detect common errors, having examinees explain their responses to highlight alternate acceptable answers, and alter stimuli as a result. Convergent validity was established by examining the subtest intercorrelations. These correlations revealed a pattern in which all subtests showed some degree of correlation with each other. Additionally, it was generally found that subtests assessing similar functions correlated more highly with each other in comparison to subtests measuring different types of functioning (Wechsler, 2003b). Discriminant validity was established through a factor analysis. Results showed each subtest had factor loadings above .60 with their own Index and had considerably lower loadings on the other Indices. The only exception was Picture Concepts, which loads .45 on the Perceptual Reasoning Index, with .19 being the next highest loading with any other

Index. The FSIQ score on the WISC-IV was included in the analyses for this study as a covariate to determine the amount of variance that is accounted for by cognitive ability that cannot be attributed to memory ability alone.

Memory Assessment

The Wide Range Assessment of Memory and Learning – Second Edition (WRAML2; Sheslow & Adams, 2003) is a norm-referenced standardized assessment used to assess memory and learning in individuals aged 5 to 90 years old. Standardization of the WRAML2 was conducted with a well-represented normative sample. Scores from the WRAML2 are considered highly reliable (Haynes, 2005). Measurements of internal consistency report Cronbach's coefficient alphas ranging from .82 to .96 on core subtests. Test-retest reliability indicated a substantial learning effect from one test time to another, whereby individuals gained one point on scaled scores for subtests. Interrater reliability was also high at .98, which is impressive, considering that a few subtests require some level of subjectivity to score items (Haynes, 2005). Several measures of validity were documented by Sheslow and Adams (2003). Internal validity was tested through item content, subtest intercorrelations, exploratory factor analyses, confirmatory factor analysis, and differential item functioning. For item content, separation reliabilities were documented as .98 to 1.00. Intercorrelations for Indices and subtests were high. Results from factor analytic studies support the internal validity of the WRAML2. External validity was confirmed through investigations of convergent validity by comparing similar subtests of the WRAML2 with subtests on other memory assessments (Wechsler Memory Scale- III, Children's Memory Scale, Test of Memory and Learning, and the California Verbal Learning Test-Children's Version). Moderate correlations were noted. Discriminant validity was also examined by comparing WRAML2 with cognitive assessments (Wechsler Adult Intelligence Scale, Third Edition; WAIS-III and Wechsler Intelligence Scale for Children, Third Edition; WISC-III) and achievement tests (Wide Range of Achievement Test, Third Edition; WRAT3 and Woodcock-Johnson Tests of Achievement, Third Edition). Moderate correlations were also found between these comparisons.

The WRAML2 is considered a comprehensive memory assessment tool. Six core subtests including Story Memory, Verbal Learning, Design Memory, Picture Memory, Finger Windows, and Number/Letter are administered and provide an overall global measure of an individual's memory performance, referred to as general memory. The main indexes acquired in the standard administration of the WRAML2 yield scores for the Verbal Memory Index, Visual Memory Index, and Attention and Concentration Index. There are 11 optional subtests in the WRAML2 that can be administered to measure an individual's ability in delayed recall, recognition, and working memory in both visual and verbal domains of memory. A benefit of the WRAML2 is that it allows comparisons of an individual's visual versus verbal memory performance, as well as semantic versus rote information (Adams & Reynolds, 2009). For the purposes of this study, only the Visual Memory Index Score and Verbal Memory Index Scores were used to determine group assignment regarding the independent variable. Adams and Reynolds (2009) indicate that when interpreting the Visual Memory Index on the WRAML2, a low score may predict difficulties in remembering new visual information. For example, individuals with low scores on the WRAML2 may have difficulties finding their way to new locations, or remembering different routes, or remembering information presented in graphs, maps, tables, or figures in a textbook.

WRAML2 Visual Memory Index Subtests

Subtests that make up the Visual Memory Index of the WRAML2 include Design Memory and Picture Memory. The Design Memory subtest of the WRAML2 is intended to measure short-term retention of visual information (Adams & Reynolds, 2009). Administration requires that the examinee look at a card with simple geometric shapes on it for approximately 5 seconds. The card is then removed from sight, and after a 10-second delay, the examinee is asked to draw the designs he or she remembers (Sheslow & Adams, 2003). The scoring is based upon the number of correctly recalled shapes, as well as the placement or position of the drawings. The Design Memory subtest also has a brief copying task available for test administrators to use with younger children and with other individuals to rule out the influence of visual motor problems (Adams & Reynolds, 2009). Poor performance on the Design Memory subtest may be attributable to poor visual memory, spatial deficits, visual field neglect, or impaired visual acuity.

The Picture Memory subtest of the WRAML2 requires the examinee to detect changes in features or details in a picture that shows meaningful scenery. The administration briefly exposes the examinee to the picture for 10 seconds. The card is then removed from the examinee's sight and he or she is given a response sheet with similar scenery. The examinee is told that the proceeding picture is similar, but things have been "changed, moved, or added" (Sheslow & Adams, 2003, p. 40) and he or she is asked to identify the details or features that changed. The scoring for the Picture Memory subtest is based upon the number of correctly identified changes in the picture. Low scores on the Picture Memory subtest may be indicative of poor visual memory, spatial skills deficits, visual field neglect, and impairment in visual acuity.

Academic Achievement Assessment

The Wide Range Achievement Test – Third Edition (WRAT3; Wilkinson, 1993) is a norm-referenced achievement measure used in the assessment of academic skills of individuals between the ages of 5 to 75. TheWRAT3 is known for being an achievement measure that is considered simple and time-efficient to administer, two features that likely have sustained the popularity of this assessment across time (Stetson, Stetson, & Sattler, 2001). The WRAT3 measures an individual's basic academic skills in reading, spelling, and arithmetic (Stetson et al., 2001). The Reading subtest includes the recognition and naming of letters and reading of a list of words. The Spelling subtest requires the examinee to write his or her name, and to write letters and words as they are dictated. The Arithmetic subtest involves two parts. The first part involves counting, reading number symbols, solving oral math problems, and solving simple arithmetic problems presented orally. In the second part, the examinee is given a time limit to solve arithmetic problems through written computation. The types of arithmetic tasks in this section include adding and subtracting single-digit and double-digit numbers, division, multiplication, converting decimals to fractions, and reducing algebraic functions (Stetson et al., 2001). Scores obtained from the WRAT3 yield an absolute score, a norm-referenced standard score, percentiles, and approximate grade equivalents regarding an individual's achievement in the three academic areas. For the purposes of the present study, the standard scores for the Reading, Spelling, and Arithmetic subtests were used to examine the relationship between visual memory and academic performance.

Unfortunately, one of the weaknesses of the WRAT3 is that it lacks adequate psychometric properties (Ward, 1995). One notable concern expressed by Ward (1995) in her review of the WRAT3 is the lack of diversity in the populations sampled. She notes that although the proportions of ethnic groups are acceptable for establishing norms, she cautions that they are not sufficient to determine whether the test is culturally biased. Another concern regarding the WRAT3 is the fact that it lacks proper construct definition and therefore does not provide sufficient evidence of construct validity (Ward, 1995). However, internal consistencies are reportedly high. Median alternate forms reliability was reported as $> .89$, and test-retest reliability was reported as $\geq .91$ (Wilkinson, 1993). Content validity has not been adequately documented, although item statistics analyses indicate that the structure of the subtests in the WRAT3 range in difficulty from easy to hard.

Procedure

Prior to the archival review and collection of participant data, all assessments had been administered at a local private neuropsychology clinic. Clients at the neuropsychological clinic included mostly school-age children who were referred for academic, social-emotional, or neuropsychological concerns. Clients who received a neuropsychological evaluation through the clinic were administered assessments under similar testing conditions. All participants were administered measures in the same testing room and assessment was conducted across the length of one 7-hour day. All assessments were administered using standardized procedures by one of either two graduate students in school psychology or a psychologist under licensed supervision of a neuropsychologist. At the conclusion of the neuropsychological evaluation, clients' data were archived.

Participant data for the present study were collected through file review of archived neuropsychological files between the dates of January 2007 through July 2009. Assessment data that fit the study's inclusion criteria were included in a Microsoft Excel© file. To protect privacy and confidentiality, participants were assigned a random identification number. All research-related data, including demographic information and performance on cognitive, memory, and academic testing, were linked with the participant's identification number in this database. The clinic director had sole access to a separate file linking the participants' names to their identification numbers; this file was password-protected and stored on a computer that was password-protected and located in the neuropsychological clinic. The principal investigator had access to a separate file containing identification numbers linked to demographic information, including age and grade level at time of testing, status in special education at the time of testing, diagnoses given at the conclusion of the participant's evaluation, and participants' scores on cognitive, memory, and academic measures for data analysis. At the conclusion of the study, the password-protected file that links participant names and identification numbers will be destroyed by the director of the neuropsychology clinic. In addition, the file containing the data sheet of identification numbers and participants' test data will be deleted from the principal investigator's mass storage device at the conclusion of the study.

RESULTS

MANOVA

A multivariate analysis of variance (MANOVA) was selected to analyze the data for this study, due to the design's capability of handling several dependent variables (Tabachnick & Fidell, 2007). For this study, the correlation between the independent variable needed to be considered in relation to the three dependent variables: achievement in reading, spelling, and arithmetic. Another advantage of using a MANOVA was that it is known for emphasizing mean differences between groups (Tabachnick & Fidell, 2007). In this case, understanding the differences between the nondeficit comparison group and visual memory deficit group were important in understanding the potential implications of having a visual memory deficit. Additionally, the MANOVA was a preferred model for this study because there were multiple dependent variables and a MANOVA test can improve the chances of determining if dependent variables are correlated with differences in the independent variable (Tabachnick & Fidell, 2007). This was significant for the purposes of determining if group membership in either the nondeficit comparison group or visual memory deficit group would reveal differences in academic achievement in reading, spelling, and arithmetic. Another advantage in using a MANOVA test was its reputation for protecting against the inflation of Type I error that can occur when multiple analyses of variance (ANOVA) are conducted and dependent variables are likely to be correlated (Tabachnick & Fidell, 2007). Construct validity information provided by the WRAT3 manual reports intercorrelations between the Reading, Spelling, and Arithmetic subtests (dependent variables) as follows: .87 for Reading and Spelling, .66 for Reading and Arithmetic, and .70 for Spelling and Arithmetic (Wilkinson, 1993).

MANOVA Results

The MANOVA was performed on three dependent variables: reading achievement, spelling achievement, and arithmetic achievement (as measured by the WRAT3). Table 4 displays the descriptive statistics for the MANOVA. The independent variable was group membership in either the visual memory deficit group or nondeficit comparison group. The visual memory deficit group included 32 participants with Visual Memory scores ≤ 85 and the nondeficit comparison group included 38 participants with Visual Memory and Verbal Memory scores > 93 (as measured by the WRAML2). The assumptions of normality and linearity were all met within reasonable boundaries (see Table 5) and there were no univariate outliers at the z = |3.3| criterion. Levine's *t* tests showed homogeneity of variance between groups on all dependent variables (see Table 6) and a test of homogeneity of variance-covariance matrices was also not significant (see Table 7).

Omnibus MANOVA

The omnibus MANOVA revealed that there were significant differences between the group of children with visual memory deficits and the nondeficit comparison group when all of the dependent variables (reading, spelling, and arithmetic achievement) were considered as a group. It made no difference which of the four tests were run, as all tests yielded the same *F* value and significance level, $F(3, 66) = 5.129$, $p = .003$; partial eta

Table 4

Descriptive Statistics for MANOVA

Group	Reading	Spelling	Arithmetic
Visual Memory Deficit			
Mean	96.31	96.13	88.44
SD	17.611	16.955	18.141
Nondeficit Comparison			
Mean	95.68	93.39	99.71
SD	16.860	14.904	15.920

squared effect size = .189 indicated that 18.9% of the variance was accounted for by group membership. The observed power of .907 indicated that the high positive correlations between dependent variables (see Table 8) did not diminish the power of this analysis to detect the effect.

Stepdown Analysis

The specific null hypotheses were tested using the Roy-Bargmann stepdown analysis, which tests each dependent variable while controlling for the others (Tabachnick & Fidell, 2007). Use of this analysis was intended to address the question of whether the presence or lack of a visual memory deficit predicted academic achievement through stepwise multiple regressions. The results of this analysis showed that children

Table 5

Test of Normality of Assumptions

Group	Reading	Spelling	Arithmetic
Visual Memory Deficit			
Skewness	-.243	1.314	-.645
Std. Error of Skewness	.414	.414	.414
Kurtosis	-.102	3.429	-.716
Std. Error of Kurtosis	.809	.809	.809
Nondeficit Comparison			
Skewness	-.299	.189	.923
Std. Error of Skewness	.383	.383	.383
Kurtosis	.507	-.997	1.258
Std. Error of Kurtosis	.750	.750	.750

Table 6

Levine's Tests of Homogeneity of Variance

Dependent Variables	*F*	Sig.
Reading	0.039256	0.843533
Spelling	0.043665	0.835102
Arithmetic	1.556880	0.216402

Table 7

Box's Test of Equality of Covariance Matrices

Box's M	*F*	*df* 1	*df* 2	Sig.
5.278	.837	6	30890.938	.541

in the visual memory deficit group differed significantly on their performance on the arithmetic achievement measure, F (1, 68) = 7.67, p =.007 compared to the nondeficit comparison group (see Table 9). However, the two groups did not differ significantly on their performance on either reading or spelling achievement measures. When applied to the hypotheses stated in the Methodology chapter, the results of this analysis suggest failure to reject the null for statements concluding that there will be no differences between participants in the visual memory deficit group and children in the nondeficit comparison group on measures of reading and spelling achievement. However, there is evidence to suggest that the null hypothesis is rejected regarding the statement that there

Table 8

Omnibus MANOVA

Effect	Value	*F*	Hypothesis *df*	Error *df*	Sig	Partial η^2	Noncent. Parameter	Observed Power
Intercept								
Pillai's Trace	0.978	958.15(b)	3	66	.000	0.978	2874.454	1.000
Wilk's Lambda	0.022	958.15(b)	3	66	.000	0.978	2874.454	1.000
Hotelling's Trace	43.552	958.15(b)	3	66	.000	0.978	2874.454	1.000
Roy's Largest Root	43.552	958.15(b)	3	66	.000	0.978	2874.454	1.000
Group								
Pillai's Trace	0.189	5.129(b)	3	66	.003	0.189	15.388	.907
Wilk's Lambda	0.811	5.129(b)	3	66	.003	0.189	15.388	.907
Hotelling's Trace	0.233	5.129(b)	3	66	.003	0.189	15.388	.907
Roy's Largest Root	0.233	5.129(b)	3	66	.003	0.189	15.388	.907

Table 9

MANOVA Stepdown Analysis

Source	*SS*	*df*	*MS*	*F*	Sig.	Partial η^2	Observed Power
Group							
Reading	6.86	1	6.86	0.02	0.879		0.0526
Spelling	129.49	1	129.49	0.51	0.476		0.1089
Arithmetic	2207.58	1	2207.58	7.67	0.007	0.101	0.7792

will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on a measure for arithmetic achievement. This analysis suggests that there were significant differences between children with visual memory deficits versus those without on their arithmetic performance, but not on reading or spelling achievement.

Null Hypothesis I: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of reading achievement. Fail to Reject Null.

Null Hypothesis II: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of spelling achievement. Fail to Reject Null.

Null Hypothesis III: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of arithmetic achievement. Reject Null.

Supplementary MANOVA

A supplementary MANOVA analysis was conducted that included additional groups as independent variables. This MANOVA was run such that the independent variables included a visual memory deficit group (n=32), a verbal memory deficit group (n=11), a combined memory deficit group (both visual and verbal memory deficits) (n=8), and a nondeficit comparison group (n=38). The formation of the verbal memory deficit group and combined memory deficit group were based upon similar criteria used to form the visual deficit memory group. Individuals in the verbal memory deficit group included individuals who scored less than or equal to a standard score of 85 on the Verbal

Memory Index of the WRAML2 and showed average or nondeficit scores on the Visual Memory Index. Average or nondeficit scores were equal to or greater than a standard score of 93. Individuals in the combined memory deficit group included individuals with standard scores of ≤ 85 on both the Visual and Verbal Memory Indices of the WRAML2. The supplementary MANOVA was performed using the same dependent variables of reading achievement, spelling achievement, and arithmetic achievement. The results were the same as for the initial comparison of the visual memory deficit group with the nondeficit comparison group, resulting in a significant omnibus MANOVA as tested by Wilks' Lambda, $F(9, 202) = 3.497$, $p < .001$. The step-down analysis was also similar with significant differences between each memory deficit group and the nondeficit comparison group for arithmetic achievement, $F(3, 85) = 7.327$, $p < .001$. There were no significant differences between the memory deficit groups and nondeficit comparison group for reading or spelling achievement (see Tables 10, 11, and 12). Planned contrasts showed that when each group was compared against the nondeficit comparison group, there were significant differences in arithmetic achievement for all comparisons and no significant differences in reading or spelling achievement for any comparisons.

Table 10

Descriptive Statistics with Additional Independent Variables

Group		*n*	*Minimum*	*Maximum*	*Mean*	*SD*
Visual Memory Deficit	Reading	32	55	134	96.31	17.611
	Spelling	32	72	155	96.13	16.955
	Arithmetic	32	50	112	88.44	18.141
Verbal Memory Deficit	Reading	11	79	113	93.55	9.501
	Spelling	11	77	101	88.27	7.577
	Arithmetic	11	66	101	84.00	10.780
Visual+Verbal Memory Deficit	Reading	8	53	105	83.25	16.645
	Spelling	8	53	104	84.75	16.360
	Arithmetic	8	50	93	74.13	17.133
Nondeficit Comparison	Reading	38	47	128	95.68	16.860
	Spelling	38	67	123	93.39	14.904
	Arithmetic	38	74	149	99.71	15.920

Table 11

Supplementary Omnibus MANOVA Analysis

	Effect	Value	*F*	Hypothesis *df*	Error *df*	Sig.
Group						
	Pillai's Trace	0.316	3.333	9	255.000	.001
	Wilk's Lambda	0.703	3.497	9	202.151	.000
	Hotelling's Trace	0.396	3.589	9	245.000	.000
	Roy's Largest Root	0.317	8.992(b)	3	85.000	.000

Table 12

Supplementary MANOVA Stepdown Analysis

	Source	*SS*	*df*	*MS*	*F*	Sig.
Group						
	Reading	1180.867	3	393.622	1.456	0.232286
	Spelling	1108.638	3	369.546	1.604	0.194376
	Arithmetic	5895.052	3	1965.017	7.327	0.000199

DISCUSSION

In children and adolescents, memory deficits are often associated with learning problems and other developmental disabilities. Memory deficits are also among a myriad of cognitive functions that are commonly affected in cases where individuals experience trauma to the brain (Sheslow & Adams, 2003). The assessment of memory aims to gather further information about how individuals learn and retain information. Understanding strengths and weaknesses of children's memory skills may assist professionals working with children to improve instructional planning, programming decisions, treatment recommendations, and accommodations to benefit their academic success. Although memory assessments are widely used in neuropsychological clinics and clinical psychology disciplines, their use in school settings is not as prominent, despite various studies linking memory and academic achievement. Braden (2003) reports that the majority of cognitive assessment tools used in school settings are individually administered intelligence tests. Although intellectual assessment measures frequently include subtests that measure some component of memory as a factor contributing to general intelligence, memory skills are not often assessed comprehensively within cognitive and intelligence assessments instruments (Dehn, 2008). As mentioned in the literature review, one possible reason schools primarily use cognitive and intellectual assessments, but not comprehensive memory assessments, may be due to legislation that influences evaluation practices in school settings (Jacob &

Hartshorne, 2003). The aim of the present study was to examine if memory deficits, identified by performance on a standardized memory assessment tool, affect children's performance on measures of academic achievement in reading, spelling, or arithmetic.

Results of MANOVA

Results of the MANOVA analysis indicated that overall, there were significant differences in academic performance between the visual memory deficit group and the nondeficit comparison group. Additionally, results of this study found that children with visual memory deficits showed significant differences in their performance on the Arithmetic subtest of the WRAT3. These findings are consistent with past research by Simmons et al. (2008), who found that functioning of the visual-spatial sketchpad was not a significant independent predictor of reading; however, it did independently predict arithmetic achievement.

This analysis would suggest clinicians should be attentive to possible struggles in arithmetic when visual memory deficits are detected. If a child appears to have difficulties with visual memory, including a measure of arithmetic performance in addition to other measures could help in gaining a comprehensive assessment of the child's academic struggles. Likewise, when struggles in arithmetic are detected, additional testing in visual memory may be helpful in understanding if visual memory may be a contributing factor.

Recognizing the role of the visual-spatial sketchpad in Baddeley and Hitch's working memory model regarding arithmetic calculations can help clinicians to provide appropriate accommodations and design or recommend interventions to assist individuals who experience deficits in visual-spatial memory skills. Solving arithmetic problems involves three stages (McCloskey & Macaruso, 1995). First, the individual must be able to encode the presented information. Second, the individual must be able to perform the calculation, which includes processes such as retrieving information from memory, counting, and remembering rules and algorithms. Finally, the person produces a response, either verbal or written. When performing mental arithmetic, the visual spatial sketchpad and phonological loop are most likely involved in the processes of encoding information, either visually or phonologically, and maintaining the information through visualization (e.g., mental blackboard) and/or verbal rehearsal (DeStefano & LeFevre, 2004). This illustrates how a visual memory deficit could influence arithmetic skills. Children with low visual-spatial memory skills may have inadequate strategies to visualize numbers, sequences, and calculations. Additionally, they may not use visualization to assist in maintaining arithmetic operations, which would influence their ability to successfully solve arithmetic problems (Dehn, 2008).

Dehn (2008) identifies several working memory strategies that could be used as interventions for deficits in visual memory. For individuals who have visual memory deficits but adequate verbal memory skills, utilizing verbal rehearsal strategies can be an effective technique for remembering visual information. Verbal rehearsal involves prompting individuals to verbalize what they see. There are several other verbal working memory interventions that can be used for individuals with visual or verbal memory deficits such as paraphrasing, chunking, elaborative rehearsal, and semantic rehearsal (Dehn, 2008). Regarding arithmetic instruction, teachers could use this strategy in several ways by prompting students to verbally repeat math facts, calculations, talk through equations, and think of solutions out loud. A visual-spatial memory intervention called visual mnemonics is another strategy that could be taught to individuals to improve their visual-spatial skills (Dehn, 2008). This strategy trains individuals to create a visual image of verbal information. For individuals who struggle to visualize images, this training can assist by suggesting or providing useful visual stimuli, which will allow the person to formulate helpful images. Individuals are given time to visualize and then asked to describe the visual image, which creates opportunities for both visual and verbal representations of the information (Dehn, 2008). Often educators can use visual aids such as blocks to represent one-to-one ratios of numbers. Finding other visual images and visual models that help individuals understand the operations that occur within arithmetic would be another useful tool to individuals with visual memory deficits. If individuals with visual memory deficits struggle to remember the images they create, having them draw the images could also be useful (Dehn, 2008). Aside from writing calculations on paper, students with visual memory deficits could draw their understanding of math concepts using pictures, graphs, and pie charts. Students could also draw any tangible objects their instructor used to teach arithmetic concepts. Understanding more about how memory strategies could be used to improve academic performance could be helpful to professionals making treatment recommendations and academic interventions for individuals with memory deficits. Future research should continue to explore the implications of teaching memory strategies and memory interventions for individuals with memory deficits.

Results of Supplementary MANOVA

A supplementary analysis was performed similar to the first MANOVA; however, additional independent variables were included by adding a group of individuals with verbal memory deficits, and individuals with a combination of visual and verbal memory deficits (combined memory deficit group). The outcomes of this analysis were very similar to the results found in the first MANOVA. Results revealed that each group (visual memory deficit, verbal memory deficit, and combined memory deficit) showed significant differences in their arithmetic performance when compared to the nondeficit comparison group; however, no significant differences were found regarding reading or spelling achievement. These results were quite interesting because a different academic pattern did not emerge as might be expected for individuals with verbal memory deficits compared to individuals with visual memory deficits or individuals with combined memory deficits in both modalities. These results may suggest that despite the modality of memory (visual or verbal) that is adversely affected, arithmetic skills may be vulnerable to the impact of memory deficits. However, some caution should also be warranted in any conclusions drawn from this supplementary analysis. Unfortunately, the sample sizes of the verbal memory deficit group and the combined memory deficit group were small and may not have been sufficient to represent a larger population of individuals with verbal memory deficits or combined visual and verbal memory deficits. Subsequently, these results should be considered exploratory in nature.

Synthesis of Results

The results of the MANOVA may imply to clinicians that when individuals have deficits in visual memory, there is a possibility that these individuals will also show lower achievement scores in arithmetic. Additionally, the results of the supplementary MANOVA found that individuals with verbal memory deficits and a combination of visual and verbal memory deficits also showed lower arithmetic achievement than individuals in the nondeficit memory group. Although the supplementary MANOVA results should be interpreted with caution due to the small sample size of the verbal memory deficit and combined memory deficit groups, these results suggest to clinicians that they should also be attentive to potential struggles in arithmetic when deficits in either modality of memory are detected.

Another possible consideration regarding the current study's results is to explore the contribution of the central executive in Baddeley and Hitch's working memory model. The central executive is possibly the most complex and most ambiguous component of Baddeley and Hitch's working memory model (Baddeley, 1996). Baddeley (1996) explains that although there are hypothesized roles the central executive plays, the entire range of its role in the working memory model is not fully known or understood. The hypothesized core executive functions described by Baddeley (2006) include the ability to attend to relevant information and inhibit irrelevant information; the ability to switch or coordinate tasks concurrently; the ability to select and execute plans; the capacity to allocate resources to the other systems of working memory; and the capacity to retrieve, hold, and manipulate information from long-term memory. In a classroom setting, individuals who show deficits in central executive working memory skills may struggle to stay on-topic or inhibit irrelevant information, have difficulty switching between different types of operations, such as switching from addition to subtraction problems, and have difficulty doing concurrent activities such as taking notes and listening. Additionally, they may have difficulty using appropriate learning strategies, recognizing when learning strategies are needed, and avoiding inefficient learning strategies (Dehn, 2008). Research further supports the role the central executive may plan in memory. Regarding arithmetic specifically, DeStefano and Lefevre (2004) theorize that the central executive may be responsible for tasks such as keeping track of which parts of a calculation a person has already performed. An interesting question regarding the central executive and the present study's results might be, "to what extent does the central executive play a role in children's memory and academic performance and can this functioning be discriminated from the performance of the other slave systems of Baddeley and Hitch's working memory model?" Indeed there is research implying that there are discriminable differences in the role and function of the central executive, phonological loop, and visual-spatial sketchpad. Gathercole, Pickering, Ambridge, and Wearing (2004) have demonstrated that this three-component structure of working memory is present in children as early as 6 years of age. A study conducted by Bull and Scerif (2001) supports the possibility that central executive skills play a significant role in arithmetic performance. Andersson (2008) found that three tasks tapping the central executive and one task tapping skills of the phonological loop accounted for 59% of the variance in children's written arithmetic skills. The different central executive functions Andersson theorized as having the most significant contribution were coordination of concurrent processing and storage of numerical information, shifting, and retrieval of information from long-term memory. Regarding the functioning of working memory systems, Dehn affirms that, "Executive processing efficiency impacts the functioning and capacity of nearly all working memory operations and makes more resources available for different types of storage" (2008, p. 69). Future research should examine the influence of the central executive and whether deficits in the central executive can be measured and correlated with patterns in children's academic performance, particularly arithmetic.

Limitations

Several limitations should be considered when examining the results of this study. One potential limitation concerns the small sample size of children used in this study. Although the sample size had moderate levels of power, having a small sample was a potential threat to the generalization of results to larger populations. Future researchers who have access to large databases of information regarding individuals' performance on cognitive, memory, and achievement assessments could greatly contribute to the literature in this area by exploring similar analyses to see if the results are replicated in larger samples of children.

An additional consideration regarding the sample was the use of a clinical comparison group. There are some advantages and disadvantages to using a clinical comparison. In this study, the advantage in using a clinical sample was that it potentially prevented the influence of some confounding factors from being considered in the analyses. For example, if a nonclinical comparison group were used, one might conclude that differences seen could be attributed to the presence of other psychological factors (e.g., anxiety, depression, ADHD); however, since the comparison group was made up of individuals who were also referred to a clinic for academic, social, and psychological concerns, the likelihood of this confound is less probable. The potentially disadvantageous consequence of using a clinical sample is that characteristics of the sample may not be representative of a heterogeneous group of individuals. The private neuropsychology clinic from which the data for this study were collected had a particularly high level of referrals for individuals suspected of traumatic brain injury, fetal alcohol syndrome and effects, and eating disorders. This may indicate that some of the outcomes of this study could be attributable to the heterogeneity of the individuals referred to this clinic. Another limitation in the use of a clinic-referred sample as a comparison group is that the results may not be generalizable to nonreferred, nonclinical populations of individuals. Future research could aim to resolve potential sampling problems by using a clinical comparison group that is formed using data from multiple clinics or psychoeducational and neuropsychological assessment providers to minimize the possibility of using a heterogeneous sample. Future research may also consider using a nonreferred, nonclinical population as a comparison group; a group such as this might provide a more representative sample of individuals with typical memory functioning.

Another possible limitation in this study was the diverse age ranges of the sample of participants. Research has generally found that as children become older, their memory skills become more complex. Children develop more neural connections as they age. Frontal lobe maturation in children has been associated with age-related differences in the ability to focus attention, resist interference from the environment, and inhibit inappropriate thoughts and behavior (Bjorklund, 1987). Maturation in these skills also affects memory performance. Additionally, as children become older, they acquire metamemory skills, or awareness of their own memory skills and the ability to think about their memory and how to use it (Sternberg, 2006). As children become more aware of how their memory works, they are more likely to employ memory strategies such as rehearsal or mnemonic strategies. This suggests that if children become aware of memory struggles they are having, they may have more awareness and skill in utilizing memory strategies to compensate for memory difficulties. Therefore, memory performance may vary in children depending on the extent to which they have developed metamemory skills.

Regarding visual and verbal modalities of memory, there is research suggesting that a developmental shift occurs in younger children. This developmental shift reflects how younger children primarily use visual memory strategies and then switch to a reliance upon verbal memory strategies at later ages. A study conducted by Rasmussen and Bisanz (2005) supports this hypothesis with findings that visual-spatial sketchpad functioning in preschool-aged children is correlated with performance on verbal and non-verbal arithmetic problems, but is not predictive of the arithmetic performance of school-aged children. McKenzie, Bull, and Gray (2003) conducted a study investigating the cognitive processes involved in mental arithmetic and found that younger children, aged 6 to 7, showed a lowering in their performance on arithmetic tasks when placed in a condition in which there was concurrent visual-spatial disruption. This also occurred with older children aged 8 to 9, but a smaller effect was observed. They found that younger children were unaffected under conditions where phonological disruptions occurred. However, older children were affected by phonological disruptions. As a result, McKenzie et al. concluded that younger children almost exclusively used visual-spatial strategies when performing mental arithmetic. In contrast, they concluded that older children used a mixture of visual-spatial and verbal strategies, which accounted for their lowered performance under both conditions. The current study was limited to a relatively small sample of individuals with a broad age range. Because some research suggests that younger children utilize visual spatial skills more readily, research on the influence of visual memory deficits at younger ages in comparison to older adolescents could have important implications for intervention strategies. Future research examining memory deficits associated with more specific age groups could significantly contribute to the current literature base.

Another potential limitation to this study was the use of a pre-existing database. Although the database used was an excellent source of clinical data and offered an adequate sample of assessment information from a clinic-referred population, the measures used to assess memory, academic achievement, and cognitive functioning were predetermined. This is an important factor to consider for several reasons. The outcome measure, the WRAT3, was not optimal for measuring children's academic achievement in reading, spelling, and arithmetic. The WRAT3, although very popular amongst clinicians, is brief and considered a screener for academic achievement (Stetson et al., 2001). As an academic screener, the disadvantage of this measure is that it lacks more thorough and specific assessment of different academic areas. For example, the WRAT3 Arithmetic subtest only yields a general arithmetic score; it does not provide analysis of more specific skills in arithmetic such as addition, subtraction, multiplication, division skills, knowledge for math concepts, algebra, geometry, understanding of ratios, measurements, etc. Similarly, the composite scores for Reading and Spelling on the WRAT3 are very broad and ambiguous in their definitions of reading and spelling skills. Therefore, the implications regarding the influence of visual memory deficits upon academic performance are very broad and nonspecific. Knowing how more specific academic skills are affected within academic areas could be particularly helpful to teachers who are working with students on learning different academic skills.

Another possible limitation of using pre-existing data concerns the measure used to assess visual and verbal memory performance. Ideally, the assessment of visual memory should reflect only visual memory strategies or skills, such as those of the visual-spatial sketchpad, as proposed by Baddeley and Hitch. Likewise, the assessment of verbal memory should reflect only verbal memory strategies and skills, such as those of the phonological loop. Unfortunately, separating modalities of memory in performing cognitive tasks is somewhat difficult, considering that the systems are likely interactive and integrative. In Baddeley's definition of working memory, the phonological loop often is described as having the capability of assisting the visual-spatial sketchpad through verbal repetition and rehearsal. Additionally, other factors that can potentially affect visual and verbal memory scores need to be considered. Adams and Reynolds (2009) note that when individuals perform poorly on Design Memory, a subtest of the Visual Memory Index of the WRAML2, this score can reflect not only problems with visual and spatial memory but also perceptual-motor skill deficits. Additionally, poor performance on Picture Memory, the other subtest included in the Visual Memory Index of the WRAML2, can reflect problems with attention and impulsivity (Adams & Reynolds, 2009). Although the WRAML2 is recognized as a very carefully constructed memory assessment tool and the design of the WRAML2 shows respectable psychometric properties, the indices of the WRAML2 are not necessarily a reflection of the independent functioning of the phonological loop or the visual-spatial sketchpad. The Verbal Memory Index of the WRAML2 represents an individual's performance on tasks that are delivered verbally by the examiner and also request a verbal response from the examinee; unfortunately, this does not guarantee that the performance by the examinee is a reflection of only verbal memory abilities. Likewise, the Visual Memory Index of the WRAML2 represents tasks in which the examinee is presented with visual stimuli and the examinee responds in a nonverbal form (e.g., drawing, placing an "x" on the answer). Often verbal memory skills can assist in the recall of visual stimuli and alternatively, visual imagery can assist in the recall of verbal information. Unfortunately, the WRAML2 was not designed to control the influence of which modalities of memory, visual or verbal, are utilized by the examinee. Use of a memory assessment tool that better captures the separate functioning of modalities of memory could improve understanding of memory functioning. The Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001) is currently the only norm-referenced battery specifically designed to separately measure the functioning of the phonological loop, visual spatial sketchpad, and central executive skills as conceptualized by Baddeley and Hitch (Dehn, 2008).

Another strategy used by some researchers to control the influence of different modalities is to design memory tasks where strategies such as verbal rehearsal or visualization cannot be utilized by the examinee. For example, Giles and Terrell (1997) were interested in examining visual sequential memory and spelling ability. To prevent participants from using verbal coding to assist in recall of visual information, researchers created a condition in which participants were exposed to visual stimuli that looked dissimilar (e.g., size and presentation) but had the same verbal label (e.g., triangle) to minimize the possibility of the examinee using verbal labeling or coding to assist their visual memory skills. Future research that is interested in the functioning of modalities of memory, such as visual and verbal memory, would benefit by using measurement tools better designed to assess visual and verbal memory while controlling the influence of other modalities.

Future Research Directions

The purpose of the present study was to further explore the link between children's memory and academic performance. The results raised several areas of inquiry in regards to deficits in modalities of memory and the usefulness of memory assessment in the prediction of academic performance. The present study found mixed outcomes, with some evidence suggesting that individuals with visual memory deficits may display lower functioning in arithmetic achievement. Future research investigating interventions for memory deficits should investigate several factors. There have been promising findings regarding the effects of memory interventions upon the improvement of memory strategies (Conners, Rosenquist, Arnett, Moore, & Hume, 2008; Klingberg, Forssberg, & Westerberg, 2002; Van der Molen, Van Luit, Van Der Molen, Klugkist, & Jongmans, 2010). Future research should investigate whether memory interventions can also significantly improve functioning in specific modalities of memory. For example, can improvements be seen in the functioning of an individual's visual-spatial sketchpad following intervention? If improvements can be seen from interventions in modalities of memory, another possible area for future research would be to explore whether memory interventions could also have a beneficial impact upon academic performance. Can individuals who receive intervention for visual memory deficits, for example, also show improvement in their arithmetic achievement?

The current study focused upon the effects of visual memory deficits. Although some supplementary analyses were run to include data from individuals with verbal memory deficits and individuals with a combination of deficits in both verbal and visual modalities, the results were limited due to the small samples of participants available for inclusion. Future research investigating memory deficits in other modalities, such as verbal memory, and individuals with a combination of deficits in both visual and verbal memory, could further contribute to the understanding of how deficits in various modalities of memory differentially affect academic achievement. Understanding more about memory deficits in different modalities could provide valuable information to educators designing instruction for students and clinicians making treatment recommendations.

Another concern regarding the sample of this study was the impact of age in the consideration of functioning of the visual-spatial sketchpad. Past literature has indicated that younger children are more reliant upon the use of visual memory strategies rather than verbal memory strategies (Rasmussen & Bisanz, 2005). This may suggest that memory deficits could differentially affect different age groups. Young children, such as preschool-aged children, could be particularly disadvantaged by a deficit in visual memory. Future research studying the impact of deficits in modalities of memory should also examine the impact of these deficits at different ages.

Another consideration for future research could include the use of different memory assessment measures to identify deficits in memory. One limitation in the use of the WRAML2 was that it was not specifically designed to measure the components of Baddeley and Hitch's conceptualization of the working memory model. Future research may aim to use a memory assessment tool that is more specifically designed to measure the functioning of the phonological loop and visual-spatial sketchpad when studying

Baddeley and Hitch's working memory model and applying it to children's academic achievement. One assessment purported to measure memory based on this model is the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001). For researchers investigating memory deficits in relation to Baddeley and Hitch's working memory model, consideration of an assessment that taps the functioning of the central executive may also be beneficial. There is evidence suggesting that the central executive plays a crucial role in successful academic functioning (Andersson, 2008). Future research examining the central executive, visual-spatial sketchpad, phonological loop, and their impact upon academic achievement would contribute greatly to understanding the practical implications of Baddeley and Hitch's working memory model.

Another consideration in selecting a memory assessment tool may focus on an assessment tool that can control the influence of other modalities of memory so a more pure measurement of each modality can be attained. Although the WRAML2 is considered an adequately reliable and valid comprehensive measure of memory, the memory tasks making up the Visual and Verbal Memory Indices were not designed to control for the influence of other modalities of memory. For example, on the Design Memory subtest (a visual memory subtest on the WRAML2), the examinee could use verbal rehearsal to assist his or her performance on this task, even though the task is intended to tap an individual's visual memory skills. Future research may benefit by ensuring modalities of memory are more clearly defined and measured. Isolating the modalities of memory may allow practitioners to better understand the influence of each specific system.

For researchers interested in using the WRAML2, another consideration for future research might be to examine other indices of the WRAML2 as predictors of academic achievement. The present study focused solely upon the Visual and Verbal Memory Indices and defined participant inclusion based on memory deficits as measured by criterion scores of these indices. Perhaps deficits in other indices of memory on the WRAML2, such as the Attention-Concentration Index or performance on Recognition Subtests, can provide better predictors of academic achievement patterns and can further inform practitioners of how to address deficits in memory functioning given WRAML2 results.

Dehn (2008) explains that the working memory scales included in cognitive assessment batteries can also be used to glean information regarding children's memory. For researchers interested in understanding more about the use of different assessment tools in predicting academic outcomes, they may consider comparing comprehensive memory assessment tools to the memory subscales found in more frequently administered cognitive assessments. One question to explore might be, "Can comprehensive memory assessment compared to memory subscales of cognitive assessments provide unique information in the prediction of academic achievement?"

The outcome measure used in this study was a noteworthy limitation. Future research replicating this study with a stronger outcome measure could provide educators and clinicians with more comprehensive and specific information about academic skills that may be affected in individuals with memory deficits. Two more commonly used comprehensive academic achievement measures include the Wechsler Individual Achievement Test, Second Edition (WIAT-II; Wechsler, 2002) and the Woodcock-

Johnson Achievement Tests, Third Edition (WJ-III; Woodcock, McGrew, & Mather, 2001). The outcome measure used in this study, the WRAT3, only provided general outcomes measures of participants' achievement in reading, spelling, and arithmetic. In contrast, the WIAT-II provides composite scores for Reading, Mathematics, Language, and Writing (Stetson et al., 2001). Each of these composites is made up of subscales showing more discrete academic skill sets. For example, the Mathematics Composite score of the WIAT-II includes subtests in Mathematics Reasoning and Numerical Operations (Stetson et al., 2001). Future research replicating this study and using a more comprehensive outcome measure may allow practitioners to more narrowly define academic skills areas that may be affected in individuals with visual memory deficits.

Conclusions

The present study aimed to gather more information regarding the influence of modalities of memory deficits upon children's academic performance. The results of this study found implications that individuals with visual memory deficits may show significantly lower arithmetic performance. Additionally, exploratory findings examining deficits in visual memory, verbal memory, and combined memory deficits brought into question the importance of the modality of memory when examining the impact of deficits in memory upon academic achievement patterns. Overall, the present study took steps to examine memory deficits in children and the potential impact memory functioning can have upon academic achievement. Although the limitations of this study prevent definitive conclusions, hopefully this study can inspire future researchers to think critically about the use of memory assessments and how the information gained can lead practitioners to make useful recommendations and provide effective treatment.

APPENDIX

SUPPLEMENTARY STATISTICAL ANALYSES

MANCOVA

A multivariate analysis of covariance (MANCOVA) was selected to further analyze the data for this study. Similar to the design of a MANOVA, a MANCOVA has the capability of handling several dependent variables (Tabachnick & Fidell, 2007). However, the design of a MANCOVA allows for the control of supplementary continuous independent variables, or covariates, which can have an effect upon the dependent variables (Tabachnick & Fidell, 2007).

MANCOVA Results

A one-way MANCOVA was performed on three dependent variables (reading, spelling, and arithmetic achievement) with an adjustment made for the covariate of cognitive performance as measured by the Full Scale Intelligence Quotient on the WISC-IV (FSIQ). The question posed by this analysis was, "does the effect of group membership on the three academic achievement variables remain significant when FSIQ is controlled for?" The answer was that the omnibus effect remained significant, $F(3, 65) = 4.209$, $p = .009$; partial eta squared effect size = .163, but the pattern of significant results for the individual dependent variables was reversed. Once FSIQ was used as a covariate, differences in arithmetic achievement based on group membership became nonsignificant, $F(1, 67) = .958$, $p = .331$. The differences in reading achievement, $F(1, 67) = 5.596$, $p = .02$, and spelling achievement, $F(1, 67) = 7.68$, $p = .007$, both became significant (see Tables 13 and 14).

When FSIQ was held constant, the results were contrary to the former MANOVA analysis, and imply an opposite outcome regarding the null hypotheses. This analysis suggests rejection of the null for statements concluding that there will be no differences

Table 13

Descriptive Statistics for MANCOVA

Group		*Mean*	*SD*	*n*
Nondeficit Comparison	Reading	95.68421	16.86049	38
	Spelling	93.39474	14.90427	38
	Arithmetic	99.701053	15.92025	38
Visual Memory Deficit	Reading	96.3125	17.61128	32
	Spelling	96.125	16.95487	32
	Arithmetic	88.4375	18.14091	32

Table 14

MANCOVA with FSIQ as Covariate

Source	*SS*	*df*	*MS*	*F*	Sig.
Group					
Reading	1089.5084	1	1089.5084	5.596522	0.020897
Spelling	1361.9956	1	1361.9956	7.680363	0.007219
Arithmetic	179.7998	1	179.7998	0.957515	0.331334

between participants in the visual memory deficit group and children in the nondeficit comparison group on measures of reading and spelling achievement. There is failure to reject the null regarding the statement that there will be no differences between children in the visual memory deficit group and the nondeficit comparison group on a measure of arithmetic achievement. This analysis suggests that when FSIQ was held constant, there were significant differences between children with visual memory deficits versus those without on measures of reading and spelling achievement, but not on arithmetic achievement.

Null Hypothesis I: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of reading achievement. Reject Null.

Null Hypothesis II: There will be no differences between children in the visual memory deficit group and children in the nondeficit comparison group on measures of spelling achievement. Reject Null.

Null Hypothesis III: There will be no differences between children in the visual memory deficit group and children in the nondeficit memory group on measures of arithmetic achievement. Fail to Reject Null.

Supplementary MANCOVA

One emphasis of the present study was the conceptualization of memory in terms of verbal and visual modalities. Similar to memory assessment tools, cognitive assessment tools such as the WISC-IV are also commonly dichotomized into modalities of verbal and visual-spatial or perceptual composite scores. The WISC-IV yields four major index scores: Verbal Comprehension Index (VCI), Perceptual Reasoning Index (PRI), Working Memory Index (WMI), and Processing Speed Index (PSI). The VCI includes the Vocabulary, Similarities, and Comprehension subtests. These tasks are designed to assess verbal comprehension by posing tasks in verbal form and requiring the examinee to provide a verbal response. The PRI includes the Block Design, Picture Concepts, and Matrix Reasoning subtests. The PRI subtests were designed to assess an individual's perceptual reasoning by presenting tasks visually to the examinee and requesting the examinee to manipulate materials or allow the examinee to respond in a nonverbal form (e.g., pointing). To incorporate the potential influence of VCI and PRI, supplementary MANCOVA analyses were run using these cognitive scores as covariates. The first supplementary MANCOVA was run using VCI as a covariate and included the same independent variables and dependent variables used in the previous MANCOVA. The independent variables were group membership in the visual memory deficit group or the nondeficit comparison group, and the dependent variables included academic achievement in reading, spelling, and arithmetic. The question posed by this analysis was "does the effect of group membership on the three academic achievement variables remain significant when VCI is controlled for?" Results of the omnibus MANCOVA with VCI as the covariate revealed that there were significant differences between the visual memory deficit group and the nondeficit comparison group when all the dependent variables were considered as a group, $F(3, 65)= 4.17$, $p =.009$, partial eta squared =.161 (Wilks' Lambda). These results indicated that the nondeficit comparison group outperformed the visual memory deficit group on the outcome variable of academic achievement in reading, spelling, and arithmetic. A step-down analysis looking at each dependent variable, with the others controlled for, showed that the results were significant for arithmetic achievement $F(1, 67) = 4.336$, $p = .041$, partial eta squared .06. There were no significant differences on reading or spelling achievement (see Tables 15 and 16). This outcome is similar to the outcome found in the MANCOVA analyses. The results are contrary to the findings of the MANCOVA using FSIQ as a covariate.

Another separate MANCOVA was run with PRI used as the covariate. The question posed by this analysis was "does the effect of group membership on the three academic achievement variables remain significant when PRI on the WISC-IV is controlled for?" Results were similar to the MANCOVA, using VCI as the covariate. The results of the MANCOVA analysis with PRI as the covariate indicated a significant omnibus effect, $F(3, 65) = 4.646$, $p = .005$, partial eta squared = .177. A step-down analysis looking at each dependent variable with the others controlled for showed that the results were significant for arithmetic achievement, $F(1, 67) = 6.209$, $p = .015$, partial eta squared = .085 (see Tables 17 and 18). Again, the results of this MANCOVA reveal similar outcomes found in the MANOVA analysis, but revealed a reversal in the pattern of outcomes seen in the MANCOVA using FSIQ as the covariate.

Supplementary Multiple Regressions

One planned outcome of the present study was to inform clinicians regarding the utility and practicality of using memory assessments. To further explore this topic, supplementary multiple regressions were used to analyze the unique independent ability of the Visual Memory Index, the Verbal Memory Index, and FSIQ to predict academic achievement in reading, spelling, and arithmetic. Regressions were run using the primary experimental groups, including individuals in the visual memory deficit group (n=32) and

Table 15

Supplementary Omnibus MANCOVA with VCI as Covariate

Effect	Value	*F*	Hypothesis *df*	Error *df*	Sig.	Partial η^2
Group						
Pillai's Trace	0.161	4.170	3	65	.009	0.161
Wilk's Lambda	0.839	4.170	3	65	.009	0.161
Hotelling's Trace	0.192	4.170	3	65	.009	0.161
Roy's Largest Root	0.192	4.170	3	65	.009	0.161

Table 16

Supplementary MANCOVA with VCI as Covariate: Stepdown Analysis

Effects	*d*	*F*	*p*	Partial η^2
Group				
Reading	1	1.582202	0.21281	0.02307
Spelling	1	2.749992	0.10193	0.039426
Arithmetic	1	4.336258	0.04113	0.060786

nondeficit comparison group (*n*=38), and supplementary experimental groups, which included individuals in the verbal memory deficit group (*n*=11), and the combined memory deficit group (*n*=8). Table 19 displays the intercorrelations between FSIQ on the WISC-IV and the Verbal Memory and Visual Memory Indices of the WRAML2. Table 20 displays the correlations among the Reading, Spelling, and Arithmetic subtests on the WRAT3. Although these correlations are fairly high, multicollinearity statistics show tolerance to be acceptable for this analysis. Table 21 displays the correlations between FSIQ, Verbal Memory Index, Visual Memory Index, and the outcome measures of Reading, Spelling, and Arithmetic on the WRAT3.

Reading Achievement

Model 1, using the independent variables of FSIQ, Verbal Memory Index, and Visual Memory Index to predict reading achievement scores was significant, $F(3, 85) = 15.515$, $p < .001$, accounting for 35.4% of the variance in reading achievement scores (see

Table 17

Supplementary Omnibus MANCOVA with PRI as Covariate

Effect	Value	*F*	Hypothesis *df*	Error *df*	Sig.	Partial η^2
Group						
Pillai's Trace	0.177	4.646	3	65	.005	0.177
Wilk's Lambda	0.823	4.646	3	65	.005	0.177
Hotelling's Trace	0.214	4.646	3	65	.005	0.177
Roy's Largest Root	0.214	4.646	3	65	.005	0.177

Table 18

Supplementary MANCOVA with PRI as Covariate: Stepdown Analysis

Effects	*d*	*F*	*p*	Partial η^2
Group				
Reading	1	0.367514	0.546411	0.005455
Spelling	1	1.160007	0.285327	0.017019
Arithmetic	1	6.209162	0.01519	0.084814

Table 19

Pearson Correlation Coefficients among Visual Memory Index, Verbal Memory Index, and FSIQ

	FSIQ	Verbal Memory Index	Visual Memory Index
FSIQ	1.000	.594**	.436**
Verbal Memory Index	.594**	1.000	.549**
Visual Memory Index	.436**	.549**	1.000

**$p < .01$, two-tailed

Table 20

Pearson Correlation Coefficients among Dependent Variables

	Reading	Spelling	Arithmetic
Reading	1.000	.809**	.579**
Spelling	.809**	1.000	.568**
Arithmetic	.579**	.568**	1.000**

**p < .01, two-tailed

Table 21

Pearson Correlation Coefficients among Independent and Dependent Variables

	FSIQ	Verbal Memory Index	Visual Memory Index
Reading	.562*	.238*	.076
Spelling	.528**	.270*	.010
Arithmetic	.694**	.485**	.337**

*p < .05, one-tailed. **p < .01, two-tailed

Table 22). However, only IQ accounted for significant unique variance in the dependent variable β =.682, p <.001, and neither Visual Memory Index or Verbal Memory Index contributed significantly after FSIQ was accounted for (see Table 23).

Spelling Achievement

Model 1, using the independent variables of FSIQ, Verbal Memory Index, and Visual Memory Index to predict spelling achievement scores was significant, $F(3, 85) = 14.615$, p <.001, accounting for 34.1% of the variance in spelling achievement scores (see Table 24). In this analysis, FSIQ accounted for significant unique variance in the dependent variable, β =.618, p <.001, as did the Visual Memory Index, β = -.295, p =.007 (see Table 25).

Verbal Memory Index did not uniquely account for a significant proportion of the variance. Because the simple correlation between the Visual Memory Index and spelling achievement subtest was not significant (r = .01, p=.926), the specific contribution it made to the model in this analysis was likely in the role of a suppressor variable, reducing the variance in FSIQ that was not related to spelling achievement, and thereby increased the predictive power of IQ. However, this significant result does not indicate that the Visual Memory Index and spelling achievement are directly related.

Arithmetic Achievement

Model 1, using the independent variables of FSIQ, Verbal Memory Index, and Visual Memory Index to predict arithmetic achievement scores, was significant, $F(3, 85) = 27.153$, p<.001, accounting for 48.9% of the variance in arithmetic achievement scores

Table 22

Model 1 Summary for Reading Achievement

Model	*R*	R^2	Adjusted R^2	*SE* of Estimate
1	.595	.354	.331	13.551

Note: Predictors: FSIQ, Visual Memory Index, and Verbal Memory Index

Table 23

Model 1 Coefficients of Reading Achievement

	Unstandardized Coefficients		Standardized Coefficients		
	β	Std. Error	β	*t*	Sig.
Model 1					
(Constant)	49.725	11.097		4.481	.000
FSIQ	.749	.121	.682	6.209	.000
Verbal Memory Index	-.076	.138	-.066	-.556	.580
Visual Memory Index	-.192	.110	-.185	-1.752	.083

Table 24

Model 1 Summary for Spelling Achievement

Model	*R*	R^2	Adjusted R^2	*SE* of Estimate
1	.584	.341	.318	12.666

Note: Predictors: FSIQ, Visual Memory Index, and Verbal Memory Index

Table 25

Model 1 Coefficients of Spelling Achievement

	Unstandardized Coefficients		Standardized Coefficients		
	β	Std. Error	β	*t*	Sig.
Model 1					
(Constant)	53.202	10.372		5.130	.000
FSIQ	.628	.113	.618	5.573	.000
Verbal Memory Index	.069	.129	.064	.537	.593
Visual Memory Index	-.283	.103	-.295	-2.760	.007

(see Table 26). In this analysis, only FSIQ was a significant predictor, β =.626, p<.001 (see Table 27).

Overall, the consideration of the multiple regressions using FSIQ, Verbal Memory Index, and Visual Memory Index indicated that FSIQ was related to all dependent variables of reading, spelling, and arithmetic achievement. The Verbal Memory Index did not appear to contribute significantly to any of the dependent variables. The only variable to which the Visual Memory index uniquely contributed was spelling achievement, but because of the nonsignificant simple correlation between Visual Memory Index and spelling achievement, it is likely that the contribution of Visual Memory Index was as a suppressor variable.

Additional Regression Analyses

In previous analyses, the indices of VCI and PRI, composites of the WISC-IV, were included as covariates in separate MANCOVA analyses. Additional regression analyses were run including these covariates to analyze the unique independent ability of the Visual Memory Index, Verbal Memory Index, VCI, and PRI to predict reading, spelling, and arithmetic achievement. Similar to the previous regressions, the participant data including the visual memory deficit group, verbal memory deficit group, combined memory deficit group, and nondeficit comparison group were used. Table 28 displays the correlations between Visual Memory Index, Verbal Memory Index, VCI, PRI, reading achievement, spelling achievement, and arithmetic achievement.

Table 26

Model 1 Summary for Arithmetic Achievement

Model	*R*	R^2	Adjusted R^2	*SE* of Estimate
1	.700	.489	.471	13.129

Note: Predictors: FSIQ, Visual Memory Index, and Verbal Memory Index

Table 27

Model 1 Coefficients of Arithmetic Achievement

	Unstandardized Coefficients		Standardized Coefficients		
	β	Std. Error	*β*	*t*	Sig.
Model 1					
(Constant)	7.360	10.751		.685	.495
FSIQ	.749	.117	.626	6.411	.000
Verbal Memory Index	.142	.133	.112	1.066	.289
Visual Memory Index	.003	.106	.002	.024	.981

Note: Dependent variable: Arithmetic Achievement on WRAT3

Table 28

Pearson Correlation Coefficients between Visual Memory Index, Verbal Memory Index, VCI, PRI, Reading, Spelling, and Arithmetic.

	Visual Memory	Verbal Memory	VCI	PRI	Reading	Spelling	Arithmetic
Visual Memory		.549**	.269*	.274**	.076	.010	.337**
Verbal Memory			.498**	.459**	.238*	.270*	.485**
VCI				.600**	.519**	.486**	.645**
PRI					.417**	.365**	.503**
Reading						.809**	.579**
Spelling							.568**
Arithmetic							

* *p* < . 05, two-tailed

***p* < .01, two-tailed

Reading Achievement

The analysis using Model 2 which includes Visual Memory Index, Verbal Memory Index, VCI, and PRI to predict reading achievement scores was significant, $F(4, 85)$ 8.773, $p<.001$, accounting for 29.5% of the variance in reading achievement scores (see Table 29). However, only VCI accounted for significant unique variance in the dependent variable ($\beta=.441$, $p<.001$). PRI, Visual Memory Index, and Verbal Memory Index did not contribute significantly after VCI was accounted for (see Table 30).

Spelling Achievement

Model 2, using the independent variables of VCI, PRI, Verbal Memory Index, and Visual Memory Index to predict spelling achievement scores, was significant, $F(4, 85) = 7.851$, $p <.001$, accounting for 27.2% of the variance in spelling achievement scores (see Table 31). In this analysis, VCI again was the only variable that accounted for significant unique variance in the dependent variable $\beta =.407$, $p =.001$ (see Table 32).

Arithmetic Achievement

The model using the independent variables of VCI, PRI, Verbal Memory Index, and Visual Memory Index to predict arithmetic achievement scores was significant, $F(4, 85) = 18.580$, $p <.001$, accounting for 39.3% of the variance in arithmetic achievement scores (see Table 33). In this analysis, only VCI was a significant predictor, B = .455, $p <.001$ (see Table 34).

Overall, the results of these regressions indicate that VCI was related to all dependent variables of reading, spelling, and arithmetic achievement. The other factors of PRI, Verbal Memory Index, and Visual Memory Index did not appear to contribute significantly to any of the dependent variable.

Table 29

Model 2 Summary for Reading Achievement

Model	*R*	R^2	Adjusted R^2	*SE* of Estimate
2	.543	.295	.261	14.242

Note: Predictors: VCI, PRI, Verbal Memory Index, and Visual Memory Index

Table 30

Model 2 Coefficients of Reading Achievement

	Unstandardized Coefficients		Standardized Coefficients		
	β	Std. Error	*β*	*t*	Sig.
Model 2					
(Constant)	37.636	13.184		2.855	.005
VCI	.482	.132	.441	3.655	.000
PRI	.224	.142	.185	1.574	.119
Verbal Memory Index	-.026	.144	-.023	-.183	.856
Visual Memory Index	-.084	.114	-.081	-.741	.461

Note: Dependent variable: Reading Achievement on WRAT3

Table 31

Model 2 Summary for Spelling Achievement

Model	*R*	R^2	Adjusted R^2	*SE* of Estimate
2	.522	.272	.237	13.389

Note: Predictors: VCI, PRI, Verbal Memory Index, and Visual Memory Index

Table 32

Model 2 Coefficients of Spelling Achievement

	Unstandardized Coefficients		Standardized Coefficients		
	β	Std. Error	*β*	*t*	Sig.
Model 2					
(Constant)	45.675	12.394		3.685	.000
VCI	.411	.124	.407	3.318	.001
PRI	.135	.134	.121	1.008	.317
Verbal Memory Index	.130	.135	.121	.959	.340
Visual Memory Index	-.191	.107	-.199	-1.784	.078

Note: Dependent variable: Spelling Achievement on WRAT3

Table 33

Model 2 Summary for Arithmetic Achievement

Model	*R*	R^2	Adjusted R^2	*SE* of Estimate
2	.627	.393	.355	14.268

Note: Predictors: VCI, PRI, Verbal Memory Index, and Visual Memory Index

Table 34

Model 2 Coefficients of Arithmetic Achievement

	Unstandardized Coefficients		Standardized Coefficients		
	β	Std. Error	*β*	*t*	Sig.
Model 2					
(Constant)	-16.712	19.366		-.863	.391
VCI	.607	.149	.455	4.086	.000
PRI	.129	.156	.092	.823	.413
Verbal Memory Index	.278	.189	.176	1.468	.147
Visual Memory Index	.115	.126	.106	.906	.368

Note: Dependent variable: Arithmetic Achievement on WRAT3

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