COGNITIVE REHABILITATION WITH LEARNINGRX: PRELIMINARY IMPROVEMENTS IN MEMORY AFTER TRAUMATIC BRAIN INJURY

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ABSTRACT

Traumatic brain injuries (TBI) are the third contributing factor (30.5%) to all injury related deaths in the United States and consequences associated with a TBI vary in type of impairment and severity. This study assessed the effects of a time-limited intervention (LearningRx) aimed at improving memory function after a TBI. Individuals 18 and older were assessed for improvements in short-term memory (Numbers Reversed test), long-term storage and retrieval (Visual Auditory Learning test), and working memory using the Woodcock Johnson Tests of Cognitive Abilities and Tests of Achievement, 3rd Editions and archival data from LearningRx. Effects of gender and age on memory post-intervention were also assessed. Significant differences were found between pre and post test scores for each of the variables measured: Numbers Reversed, Visual Auditory Learning (13 standard score point gains) and Working Memory (16 standard score point gain). No significant differences between gender and each sub-test assessed were found. Also, no significant relationship was found for age and each sub-test measured. Limitations included: lack of a control group and the inability to assess for additional variables (severity, SES, ethnicity), thus limiting generalizability of the findings. Test-retest effects and limited sample pool may also have affected scores at post-test. Future directions include a larger sample; additional variables such as SES, severity of TBI, and ethnicity.

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CHAPTER I

INTRODUCTION

The field of professional psychology has evolved steadily into an integral healthcare profession; specifically cognitive rehabilitation associated with traumatic brain injury (TBI). Mild traumatic brain injury (mTBI) is one of the most frequently studied topics in clinical neuropsychology (Pertab, James, & Bigler, 2009). There are over one million new mTBI cases annually in the United States (Pertab et al., 2009) and at least 1.4 to 1.7 million people sustain a TBI annually (Faul, Xu, Wald, & Coronado, 2011; Kent, 2011). The consequences of sudden events such as a TBI can be devastating for the individual and their family, leading to problems with everyday activities and limited participation in society. Injuries such as TBIs encompass a variety of impairments in various combinations such that the content and extent of treatment will vary from person to person. Rehabilitation of impaired cognitive processes have become a standard component of medical care after TBI and provide one of many interventions designed to alleviate these consequences.

However, there is a need for research-based, time-limited intervention programs to help those with TBI improve their cognitive functioning. These interventions must also be readily available to clients and providers. Most interventions that are research-based typically involved one of two basic strategies. The first approach attempted to directly retrain those cognitive processes that had been impaired by injury based on the notion that damaged neural circuits could be retrained if they were partially or substantially spared after injury (Rohling, Faust, Beverly, & Demakis, 2009). The second approach attempted to develop new compensatory skills to enhance performance on everyday tasks, such as driving or baking a cake. It was based on the assumption that the individual would learn to compensate for deficits with newly learned strategies using retrained cognitive skills and functional reorganization of the brain (Rohling et al., 2009).

An area of research that, until recently, received less attention involved the first approach, directly retraining those cognitive processes that had been impaired by injury. This may have been due to uncertainty regarding the intensity of a cognitive skills intervention program, the qualification of the trainer, or age and initial ability level of participants. It was also unknown if a program solely focused on improving specific cognitive skills could improve the cognitive processes that had been impaired compared to broad rehabilitation (Rohling et al., 2009).

This chapter focused on laying the foundation and addressing the importance for conducting the current study. A brief history of cognitive rehabilitation will be provided, along with definitions and discussion of working memory, short-term memory, and long-term memory (or long-term storage and retrieval). Also intervention programs aimed at improving these skills will be briefly reviewed. Some literature on cognitive rehabilitation and TBI will be presented including interventions specific to this particular population. This is followed by a discussion of age and gender as it is related to TBI. Finally, the statement of the problem is presented, followed by specific questions and hypothesis relevant to this study.

A Brief History

In general, few historical accounts of neuropsychological rehabilitation are available, and those that are available are obscurely located. Boake (1991), comprehensively reviewed the history of cognitive rehabilitation after TBI and cited early works of Poppelreuter, Goldstein, Franz, Luria, Zangwill, Driller, and Ben-Yishay (Prigatano, 2005). He found that treatment of individuals with brain injury had existed since World War I; however, treatment was more focused on military servicemen compared to civilians. The term "cognitive rehabilitation," on the other hand, did not come about until the 1970s (Boake, 1991; Halligan & Wade, 2005). It was during World War I when changes in neurosurgical care were taking place (Prigatano, 2005) causing mortality rates among servicemen to fall from over 50% down to 35% (Boake, 1991). Most of the information gained during World War I came from Germany and the United States. At the time, Germany was the world's center on clinical neuroscience. They created a rehabilitation plan that called for patients to undergo extensive psychological evaluations to reveal their strengths and weaknesses, and then received therapies under medical and psychological care (Boake, 1991; Parenté & Herrmann, 1996).

Afterwards, a vocational workshop was added to assess the potential of the individual for different occupations (Boake, 1991). Therapeutic techniques followed a compensatory approach in which patients were trained to use different strategies to perform tasks (e.g., whole word reading) or to relearn lost functions (e.g., shaping speech sounds from mouth movements; Boake, 1991; Parenté & Herrmann, 1996).

At that time, head injury rehabilitation was far less advanced in the United States than in Germany due to the lack of rehabilitation models and a limited tradition in clinical neuroscience (Boake, 1991). Overall, occupational therapy and physical therapy were not recognized as therapeutic disciplines in the United States, and physical medicine and rehabilitation were not recognized as medical specialties (Boake, 1991). After the work of various advocacy groups, rehabilitation was implemented through special sections of general military hospitals, with 16 hospitals in 1918 increasing to 46 in 1919; after which many of the hospitals were closed (Boake, 1991). Within the United States the clinical approach was one of practicality as it emphasized the prevention of psychological complications and prepared patients to return to work. Patients were engaged in a routine activity schedule, with occupational therapy in the hospital wards, which then progressed to vocational training in workshops attached to the hospitals (Boake, 1991).

There was little information within the literature on what developed in the field of cognitive rehabilitation between World War I and World War II. It may be that there was little interest in brain injury during this time; however, at the start of World War II interest in cognitive rehabilitation was renewed in the United States, the Soviet Union, Great Britain, and other nations (Boake, 1991). During World War II, patients suffering from brain injury were segregated into special neurosurgical centers, and work/therapies were more carefully documented than the previous war (Boake, 1991) setting precedence, therefore, for modern day brain rehabilitation. Also during this time, Zangwill (1947) identified two approaches to the "re-education" process of patients with brain injury (as cited in Boake, 1991). The first was the substitution approach which he defined as "the building up of a new method of response to replace one damaged irreparably by a cerebral lesion" (Boake, 1991, p. 9), and compared this to the second approach, direct training, which stated that damaged abilities could be newly acquired by other brain regions (Boake, 1991). Due to skepticism underlying the direct training approach, the substitution approach was more favored.

With the end of World War II, there again was a sudden drop in interest surrounding head injury, and a lack of interest, therefore, in head injury rehabilitation. Interest was once again renewed, by military and civilian sectors, at international conferences held in 1969 and 1971 (Boake, 1991). At that time medical rehabilitation units dedicated to head injury were being established at Loewenstein Rehabilitation Hospital near Tel Aviv, Israel, Rancho Los Amigos Hospital near Los Angeles, California, and the Royal Air Force Medical Rehabilitation Unit in Chessington, Scotland (Boake, 1991).

Due to an increase in understanding the long term impact of TBI on individuals and their families during the 1980s, there was an increase in post-acute rehabilitation services to increase independence, community integration, and long-term social and emotional adjustment to brain injury (Prigatano, 2005; Sohlberg & Mateer, 2001). However, in the United States, due to increased financial cuts to rehabilitative services, Medicare restrictions, and the start of funding based on diagnosis-related groupings, many of these services were either shut down or cut back (Sohlberg & Mateer, 2001).

Traumatic Brain Injury

TBIs are the third contributing factor (30.5%) to all injury related deaths in the United States (Faul et al., 2011). There are approximately 1.4 to 1.7 million people who sustain a traumatic brain injury each year in the United States (Faul et al., 2011; Kent, 2011; National Center for Injury Prevention and Control, 2003), and about 75% of TBIs that occurred were due to concussions or other forms of mild TBI (Faul et al., 2011). Of this population, approximately 52,000 died, 275,000 were hospitalized and nearly 80% were treated and released from an emergency department (Faul et al., 2011). This estimate, however, was representative of the number of patients who sought treatment at the hospital emergency department or other form of medical facility, thus the number of individuals who did not seek any form of care was unknown.

Though a TBI could occur to anyone of any age, children aged 0-4 years were more likely to sustain a TBI due to falls, and older adolescents aged 15-19 were more likely to sustain a TBI due to motor vehicle accidents. Also, adults aged 65 years and older were more likely to sustain a TBI due to fall related injuries connected to the aging process and medications (Faul et al., 2011; Kent, 2011). Assault and firearm injuries were common causes of TBI in some urban areas and during wartime (Sohlberg & Mateer, 2001). Regardless of age group, men suffered from TBI twice as often as women (Faul et al., 2010; Kent, 2011; Sohlberg & Mateer, 2001) and were more likely to have an overall better outcome after treatment (Kent, 2011). In 2000, direct medical cost and indirect costs of lost productivity due to TBI in the United States was estimated to be $60 billion dollars (Faul et al., 2011).

Brain injury may occur in two ways: (a) immediate damage to brain tissue at the moment of impact due to mechanical forces or pathophysiological processes (i.e., brain swelling, intracranial hematoma, blood loss, arterial hypotension, and pulmonary complications; Jennett, 1990); and (b) secondary brain complications due to metabolic disturbances or the original neuronal damage (Sohlberg & Mateer, 2001). When assessing brain injury, there are three things that must be considered: distribution (focal, multifocal, or diffuse), severity, and the type of underlying pathology (Jennett, 1990; Rimel, Jane, & Bond, 1990). However, regardless of the location of the injury, there usually are contusions of the cortex in the frontal and temporal lobes (front and sides of the brain), as well as widespread disruption or stretching of nerve fibers in the white matter of the cerebral hemispheres and brainstem (Jennett, 1990). This is one reason why impairments vary from individual to individual.

Focal lesions are a common result of cerebrovascular events (hemorrhages or infarcts), neoplasms or tumors, brain abscesses, or penetrating injuries (i.e., gunshot wound; Sohlberg & Mateer, 2001). The effects of a focal lesion are directly related to its size, location and depth. Multifocal lesions can occur with multiple, distributed occurrences of the aforementioned pathologies. Multifocal lesions may also have common characteristics to various medical conditions such as severe cerebrovascular disease and TBI (Sohlberg & Mateer, 2001). Diffuse brain injury occurred when the injury had the potential to affect wide areas of the brain tissue. This type of injury was seen in cases of TBI involving significant acceleration-deceleration forces, hypoxic-ischemic injury, and a variety of metabolic, infectious, and inflammatory disorders (Sohlberg & Mateer, 2001).

In regards to TBI, there could be multiple sources of damage to the brain. Damage may result from mechanical forces such as being struck in the head by a rigid surface (i.e., baseball bat, windshield), resulting in a transfer of force from the point of contact to the head resulting in skull fractures and focal damage to the underlying brain tissue (Miller, Pentland, & Berrol, 1990; Sohlberg & Mateer, 2001). Acceleration-deceleration forces are another way in which damage may occur to the brain. This type of force occurred when the head suddenly stopped but the brain continued to move in the original direction of the motion and then rebounded in the opposite direction (Miller et al., 1990; Sohlberg & Mateer, 2001). This resulted in bruising or contusions to the areas of brain tissue which collided with the skull, and rebounding effects caused bruising or contusions to occur to the opposite side of the brain (known as coup and contre-coup injuries). Acceleration-deceleration forces could also tear small blood vessels of the meninges and brain surface causing blood to enter the space surrounding the brain, in turn exerting pressure on the brain itself (Miller et al., 1990; Sohlberg & Mateer, 2001). Acceleration-deceleration forces could also have stretching, deformation, and shearing effects on the neurons (known as diffuse axonal injury (DAI)). This type of injury may cause entire cell bodies, and those dependent on them, to die, causing axonal swelling or creating defective axonal transport (Sohlberg & Mateer, 2001). This may occur within 24 hours of injury, but may also continue for some time afterwards, and the extent of DAI was related to the severity of TBI and to functional outcome.

TBI severity occurred along a continuum from mild concussion to serious injury resulting in death or severe disability. The level of coma within the first 24 hours after injury and the duration of post-traumatic amnesia (PTA) are used to classify injuries as mild, moderate, or severe. Coma is defined as "a period of unconsciousness or unawareness following brain damage" (Sohlberg & Mateer, 2001, pp. 33). The level of coma within the first few hours after injury was a strong indicator of severity and was measured by using an observational measure called the Glasgow Coma Scale (GCS). It consisted of eye opening, best motor response, and best verbal response to determine the degree of coma and to monitor changes in the level of coma (Miller et al., 1990; Sohlberg & Mateer, 2001). The Glasgow Coma Scale ranged from 3 to 15, with a score of 8 or less indicating severe injury, 9-12 indicating moderate injury, and 13-15 indicating mild injury (Marion, Sharts, & Tyler-Kabara, 2004; Sohlberg & Mateer, 2001). Often times, mild and moderate TBI were referred to as concussions, and typically involved a brief period of loss of consciousness at the time of impact and some degree of retrograde or post-traumatic amnesia (Marion et al., 2004). However, at the time of evaluation those patients were able to follow commands. Mortality rates for those with mild injuries have been found to be zero and for those with moderate injuries to be approximately 4% (Marion et al., 2004). Of those, as many as 10% of mild injuries and 66% of those with moderate injuries had prolonged or permanent disabilities preventing the person from returning to work or school (Marion et al., 2004). The most rapid period of recovery after moderate to severe brain injury occurred during the first six months, with slow and ongoing recovery for up to two years after the injury (Gentleman, 2001; Pertab, James, & Bigler, 2009; Sohlberg & Mateer, 2001).

Age and Gender Differences

Research has shown that young individuals recovered more completely than older ones. One reason for this was that normal maturation of the central nervous system (CNS) involved the production of excess numbers of neuronal connections which were then lost as functional connections took precedence (Whyte, 1990). This allowed for alternate connections to be made in the event of brain damage in the young. Another explanation was that changes in neurotransmitter receptor density, in response to CNS injury, occurred at a greater extent in younger persons. An example of this would be individuals with hemispherectomies, which are extremely disabling in adulthood but are compatible with relatively normal cognitive function in children (Whyte, 1990). Also the possibility that as synapses of the young are more apt to change, the young are also more likely to explore other strategies for accomplishing their goals and at the same time more likely to alter those strategies in response to the severity of the injury (Whyte, 1990).

From the age of young adulthood (20 years of age) and increasing after the age of 50 years, the volume of gray and white matter in brain has been shown to decrease, with shrinking neuronal size, reduced synaptic density, and decreasing neurotransmitter levels (Senathi-Raja, Ponsford, & Schönberger, 2010). Based on animal research conducted by Kolb (1995; as cited in Senathi-Raja, Ponsford, & Schönberger, 2010), the brain may use the same mechanisms for recovery and adapting to aging and have a limited capacity, therefore, for plasticity. He believed that as the brain aged, decline would occur more rapidly in individuals with a history of head trauma due to the brain already utilizing its compensatory capacity to respond to the prior brain injury.

Limited research has been conducted on gender effects and recovery from TBI which has created some contradictory data. For example, research has shown that males suffer from TBI more often than females, but fatality rates are higher among females than males. In a study conducted by the UCLA Brain Injury Research Center, females had a mortality rate 1.28 times higher than males (Kraus, Peek-Asa, & McArthur, 2000). Some potential influences on recovery included the fact that some brain structures differed in shape and size between males and females, and these differences resulted in both inter- and intrahemispheric gender differences (Sohlberg & Mateer, 2001). It was also hypothesized that the amount of gender related hormones (i.e., higher progesterone and lower estrogen) circulating within the body may have had an effect on recovery mechanisms following brain injury (Sohlberg & Mateer, 2001).

Roof and Hall (2000) conducted animal research utilizing the contusion model experiments (thought to mimic human closed-head injury causing diffuse axonal damage) in rats which revealed that under high progesterone conditions, female rats showed no evidence of brain edema in the lesion area (as cited in Slewa-Younan, Green, Baguley, Gurka, & Marosszeky, 2004). The study concluded that high levels of progesterone protected the brain from secondary damage after TBI. Roof and Hall (2000) also gave a progesterone treatment to male rats before experimental injury and concluded that the treatment led to a reduction in incidence of cerebral edema and improved functional recovery (as cited in Slewa-Younan, et al., 2004).

Deficits in Memory

The range of impairment following TBI can vary greatly depending on the severity and location of injury. The most common cause of TBI, acceleration-deceleration injuries, resulted in the ventral and lateral (lower and side) surfaces of the frontal and temporal lobes to be at greatest risk for injury (Sohlberg & Mateer, 2001). Based on known functions of these regions of the brain, a wide variety of deficits may arise with attention, memory and new learning, planning and problem solving, language, perceptual-motor functioning, initiation, impulsivity, self-regulation of mood and emotional reactions, and self-awareness

(Adamovich, 1991; Brooks, 1990; Sohlberg & Mateer, 2001). Due to the breadth of deficits possible, this study focused on deficits in memory.

Though there has been debate among researchers, most agreed that memory included stages of attention, encoding, storage, and retrieval. Memory deficits occurred due to ineffective encoding of information, inadequate storage of information, difficulty retrieving information using recognition, cued recall or free recall, and/or a lack of strategy to deal with interferences (Adamovich, 1991). Thus, memory complaints ranged from simple forgetfulness to profound amnesia (temporary or permanent).

Attention has been important to memory as it allowed the system to access and utilize incoming information (Sohlberg & Mateer, 2001). At its most basic level, attention consisted of alertness and arousal. At higher levels, attention consisted of sustained attention, selective attention, and divided attention. Working memory was also part of attention as it allowed the individual to temporarily hold information for later use. Decreases in alertness, arousal, and sustained attention have been associated with damage to brainstem structures or diffuse, bilateral subcortical damage (Rios, Perianex, & Munoz-Cespedes, 2004). Problems with selective, alternating, and divided attention have been associated with damage to the thalamic structures or frontal lobe structures that control attention (Spikeman, Deelman, & van Zomeren, 2000; Sohlberg & Mateer, 2001).

Encoding has been considered an initial stage of memory. Phonological characteristics were known to be encoded when remembering verbal material and graphic representations were encoded when remembering visual information (Baddeley, 1981; Baddeley, 2000; Sohlberg & Mateer, 2001). The levels of processing hypothesis set forth by Craik and Lockhard (1972) suggested that information that was "deeply" processed would have a higher likelihood of being recalled than information that was "shallowly" processed. Thus encoding has been shown to be enhanced by strategies that resulted in deeper processing such as chunking or categorizing information. Memory problems with encoding have occurred when there was damage to a number of brain structures and networks, such as the dorsomedial thalamus and frontal lobe systems; problems have also resulted from lateralized damage to the hemisphere controlling the language systems or visual processing (Sohlberg & Mateer, 2001).

Storage of memory was referred to as the transfer of information to a location in the brain for permanent retention or access. Though the full extent of memory storage has not been understood, it has been known that storage of information can be disrupted when there was some interference in the learning process (Petersen & Weingartner, 1991; Sohlberg & Mateer, 2001). Damage to the hippocampal and bilateral medial temporal lobe structures were often associated with difficulty in storage of memory (Sohlberg & Mateer, 2001).

Though an individual may be able to encode the information, they would be unable to maintain it in storage over time.

The retrieval of memory required the ability to monitor the accuracy and appropriateness of memories being accessed. One way in which retrieval has been tested was to compare the ability to recognize something to the ability to recall something (Petersen & Weingartner, 1991; Sohlberg & Mateer, 2001). Usually, recognition of information was better than spontaneous recall of the information. Problems with retrieval have been linked with the frontal lobe as they are involved in strategy formation, memory for temporal order, self-monitoring, and initiating retrieval. Individuals with frontal lobe damage were also prone to having poor source memory and thus confuse where they may have learned the information (Sohlberg & Mateer, 2001).

Another important factor in memory consisted of long-term and short-term memory (the focus of this study). Short-term memory (also called primary memory) has been defined as information a person was able to hold prior to interruption. It has a limited capacity (usually 5-9 items) and could only be held for a short duration. Long-term memory (also called secondary memory) has been defined as the ability to hold information permanently and has unlimited storage capabilities.

Long-term memory can be further divided into the types of information being processed: declarative and nondeclarative memory. Declarative memory consisted of a person's knowledge base and was made up of semantic memory and episodic memory. Semantic memory referred to the broad area of cognition based on knowledge acquired about the world (i.e., word meanings, classes of information, facts, ideas; Sohlberg & Mateer, 2001). The individual possesses such information, but cannot recall when or where they learned it (i.e., names of fruits, colors). Episodic memories on the other hand were based on personal experiences and are associated with a particular time and place (i.e., first date, wedding day). After sustaining brain injury, individuals have intact semantic memory but were unable to expand on their semantic memory and create new knowledge due to an impaired episodic memory (Sohlberg & Mateer, 2001).

Nondeclarative memory allowed the individual to learn without having conscious awareness of learning. Nondeclarative memory was made up of priming and procedural learning. Priming referred to cues which prompted an accurate recall without the individual's awareness that the information was previously presented (Petersen & Weingartner, 1991). For example, reading a list of words that included the word 'table' and later being asked to complete a word beginning with 'tab', it was more likely that the individual would state the word 'table' than 'tablet'. Procedural learning referred to the acquisition of skills or action patterns and being able to perform those actions without having to recall the training (i.e., riding a bike; Petersen & Weingartner, 1991). Nondeclarative memory has generally been preserved in individuals with brain injuries (Sohlberg & Mateer, 2001).

Problems in any of the aforementioned areas have been managed by various techniques. These can be divided into two categories: (a) methods aimed to restore or improve memory ability across a variety of tasks and contexts; and (b2) methods which are domain-specific or aimed to teach a particular skill or body of information (Mateer, 2005; Sohlberg & Mateer, 2001). Examples of the former include memory practice drills, mnemonic strategies, prospective memory training, and metamemory training. Examples of the latter include mnemonic strategy training for specific information, expanded rehearsal time, use of preserved priming, and creating a personal history.

Research and Interventions

Since the end of World War II, there has been a surge of interest in understanding the mechanisms underlying brain injury and the effects they have on individuals (Prigatano, 2005). This interest has lead rehabilitation professionals to work with individuals with brain injury and their families in thoughtful and creative ways, as well as creating change in the health care delivery system (Prigatano, 2005). For years, the debate within cognitive rehabilitation had been on whether or not it was better to focus on training processes, skills, or functional abilities, and how best to accomplish this training (Mateer, 2005).

Researchers now know that the brain is far more plastic than once thought. It has also been known that after an injury, it was possible for the brain to reorganize itself. Experiments have demonstrated that the brain can re-grow new dendrites in damaged regions resulting in increased connections among surviving neurons (Kolb & Gibb, 1999). While other studies have suggested that damaged neural circuits can be retrained if they have been partially or substantially spared after injury (Robertson & Murre, 1999; Rohling et al., 2009). A relationship between dendritic growth, structured environmental stimulation, and the recovery of lost function was also noted by Sohlberg & Mateer (2001). One way the brain has reorganized itself was through the effect of environmental enrichment (EE). The effect of EE, which exposed animals to complex, highly stimulatory, and social environments, has been studied in a number of TBI models. Using a midline fluid percussion (FP), characterized as percussion concussion, injury model that produced no noticeable histopathology, EE has been reported to improve cognitive function. In addition, Dietrich and Bramlett (2004) demonstrated that EE decreased overall contusion volume and improved performance in the Morris Water Maze task (the most widely used test to measure hippocampal-dependent spatial-based learning and memory). It was suggested that the effects of EE were reflected by changes in dendritic arborization, however further research must be conducted in this area (Dietrich & Bramlett, 2004).

Cognitive rehabilitation has been defined as a "systematic, functionally oriented service of therapeutic activities that is based on assessment and understanding of the patient's brain-behavior deficits" (Cicerone et al., 2000, p. 1596). Treatment was provided in a one-on-one therapeutic relationship, through group, home-based, and self-directed treatment formats (McDonald, Flashman, Saykin, 2002). These rehabilitation techniques aimed to improve cognitive deficits by restoring skills as much as possible to their previous levels, and/or by helping the person with TBI develop compensatory strategies for minimizing the effects of his or her deficits on daily life (McDonald, Flashman, & Saykin, 2002). Compensatory strategies were based on the assumption that individuals would learn to compensate for deficits with newly learned strategies using retrained cognitive skills and through the functional reorganization of the brain (Backman & Dixon, 1992; Rohling et al., 2009). Other treatments have targeted executive deficits primarily utilizing cognitive, behavioral, or combined cognitive-behavioral strategies, which have been designed to promote skill acquisition, internal initiation, and self-monitoring of performance (McDonald, Flashman, & Saykin, 2002).

After a moderate to severe TBI, repetitive drills have little impact on general recall or on memory outside of the training session (Dobkin, 2004). External aids such as calendars and appointment diaries and internal strategies such as rehearsal and visual imagery tend to help most patients (Dobkin, 2004).

The use of memory aids and both external and internal organizational strategies (e.g., key finders, organizers, alerts on a phone) have proven effective interventions for individuals (Sohlberg & Mateer, 2001). As can be expected, those with less severe damage have been able to implement such aids more successfully. However, it was important that the individual also have faith in their own memory capacity, the degree to which their memory had changed, and the degree to which their memory performance was under their personal control (Sohlberg & Mateer, 2001), as this would influence the level of effort the individual put forth on a task.

Advances in technology have also had major influences on rehabilitation. New technologies with computers and computer chips have allowed individuals to link with their therapists via cell phones, iPads, and other such devices. Computers have been used extensively in cognitive remediation and skill training (Dobkin, 2004) as new applications of already existing technologies have allowed therapists to support tracking, orienting, and signaling devices for people with severe memory impairments (Sohlberg & Mateer, 2001). Although there are many software programs targeting improved reaction time, various aspects of attention, language, problem solving, and other cognitive tasks, very little data has been collected to support the efficacy of these approaches (Dobkin, 2004).

Domain-specific training has also been shown to be effective. This training focused on matching the task demands in the therapy sessions to those the individual would face in the real world (Parenté & DiCesare, 1991). This was done by creating a virtual simulation of what the injured individual faced in their day to day life at home and/or at work. Another training method with empirical support was attention-concentration training (Parenté & DiCesare, 1991). The training worked on focused attention, selective attention, sustained attention, alternating attention, and divided attention. It functionally built upon therapy tasks at each of the five attention levels in a progressive manner (Parenté & DiCesare, 1991).

Statement of the Problem

Disabilities associated with TBI depend on the location and severity (mild, moderate, or severe) of the injury, as well as the age and health of the individual. For those who recover, common long-term disabilities have included: problems with cognition (memory, attention, reasoning), sensory processing (sight, smell, taste, touch, and hearing), communication (expressing and understanding speech), and/or behavioral or mental health issues (depression, anxiety, personality changes, aggression, social inappropriateness).

Initial treatment of TBI has focused on stabilizing the patient to prevent further injury. Long-term rehabilitation have included: physical therapy, occupational therapy, speech or language therapy, social therapy, vision therapy, psychiatric or psychological counseling, cognitive skills testing and training (Boake, 1991; Sohlberg & Mateer, 1998). Despite recent growth in medical rehabilitation, individual programs to improve cognitive functioning, group exercises to improve awareness and social behavior, family counseling, and treatment of severely injured individuals have not been addressed by time-limited treatment programs. In recent years, cognitive skills training programs have emerged claiming the ability to improve cognitive skills with any individual. One such program was LearningRx (LearningRx, 2005, 2010a).

The purpose of this study was to investigate LearningRx as a possible time-limited cognitive rehabilitation tool for patients with TBI. Specifically, this study compared pre- and post-LearningRx results on improvements in long-term storage and retrieval, short-term memory, and working memory, as well as exploring differences with gender and age in these area utilizing the Woodcock Johnson test, 3rd Edition (WJ-III; Woodcock, McGrew, & Mather, 2001). To date, no peer reviewed literature have been noted on the LearningRx program other than two studies conducted for dissertation or master's thesis, or research conducted by the company itself through an independent outside researcher (discussed in literature review). Information obtained about the program was provided by the LearningRx Company and through unpublished master's thesis and doctoral dissertations. Also, data obtained from the company was limited to age, gender, and pre- and post-intervention scores. Though TBIs can be differentiated as mild, moderate, and severe, and can be caused by various means, this study did not address these variables at this time as this information was not provided to this researcher.

The Intervention Program

The LearningRx program was developed as a means to train cognitive learning skills, in this case memory, through an individual and intensive time-limited intervention (LearningRx, 2005, 2010a). The program's structure allowed individuals the ability to develop appropriate strategies to complete tasks which were organized in a progressive and challenging manner (LearningRx, 2005, 2010a). The tasks were designed to address particular abilities and progressively increase the demands on those abilities (LearningRx, 2005, 2010a). Thus to help increase cognitive functioning, the targeted functions were worked on repeatedly. The LearningRx program facilitated learning through immediate reinforcement and feedback of correct and incorrect responses. As tasks moved from simple to complex, consistent feedback and reinforcement allowed the individual to master a task and continue building skills (LearningRx, 2005, 2010a).

The LearningRx program consisted of two intervention programs, "ReadRx" and "ThinkRx" which were similar in nature, but with one main difference. The "ThinkRx" program focused primarily on the improvement of cognitive skills, whereas the "ReadRx" program aimed to improve cognitive skills and increase reading achievements. Participants were engaged in either the Read or Think program, and this was determined through the use of the Woodcock-

Johnson Test, 3rd Edition (WJ-III; Woodcock, McGrew, and Mather, 2001). The WJ-III, was comprised of a standard battery with 10 tests, and an extended battery with 10 tests (Appendix B), measuring various areas of cognition. However, for purposes of the LearningRx program, only the standard battery was implemented, and this study focused on three specific sub-tests within the standard battery, Visual-Auditory Learning, Numbers Reversed, and Auditory Working Memory tests (explained below) as they addressed the cognitive areas for long-term retrieval, short-term memory, and working memory, respectively.

Within each program, participants received training in a center-based format from a certified trainer ("Pro"), or through a combination of center-based and home-based training ("Partner"). Training in the Partner program was provided by a certified trainer at the center and a parent or caregiver at home. The program was intended to provide 1:1 training, five days a week for 12 weeks (Think Pro and Partner Programs) or 20 weeks (Read Pro and Partner Programs). See Table 1 for specifics about the training program. Due to the limited number of participants in the study, this researcher was not able to assess differences in Partner versus Pro; however, this researcher was able to assess for differences between the ThinkRx and ReadRx programs, the differences between sub-tests within each of those programs, as well as overall differences amongst the sub-tests.

Visual-Auditory Learning was a test of long-term storage and retrieval (*Glr* of the Cattell-Horn-Carroll theory discussed in Chapter 3). It was a thinking ability test that required the participant to learn, store, and retrieve a series of visual-auditory associations. As a test of associative and meaningful memory, the participant was asked to learn and recall pictographic representations of words (rebuses). Preceding each story was an introduction page that presented four new rebuses, after which the participant was asked to translate sequences of rebuses that have been used to form sentences. There were seven test stories written with rebuses (Mather & Woodcock, 2001; Schrank & Flanagan, 2003). Though long-term memory was composed of multiple components, this study defined the term long-term memory according to the Cattell-Horn-Carroll Theory (Cattell, 1941; Horn, 1965) for *Glr*, as the ability to store information in and fluently retrieve new or previously acquired information (e.g., concepts, ideas, items, names) from long-term memory (McGrew, 2001). This has been further discussed in chapter 3.

Numbers Reversed was a test of short-term memory (*Gsm* of the Cattell-Horn-Carroll theory discussed in chapter 3). Though primarily used for measuring short-term memory span, this test has also been used to measure working memory or attentional capacity. The sub-test required the individual to hold a span of numbers in immediate memory while performing a mental operation on it such as reversing the sequence (Mather & Woodcock, 2001; Schrank & Flanagan, 2003).

Auditory Working Memory measured short-term auditory memory span, but could also be classified as a measure of working memory or divided attention. The test presented participants with audio recordings of a series of unrelated digits and words (e.g. dog, 1, shoe, 8, 2, apple). The participant was asked to reorder the information, repeating the words or objects first, and then the numbers in sequential order (e.g., apple, dog, shoe, 1, 2, 8). This sub-test required the individual to hold information in immediate awareness, divide the information into two groups, and shift attentional resources to the two new ordered sequences. (Mather & Woodcock, 2001; Schrank & Flanagan, 2003).

Research Questions to Be Addressed in This Study

The purpose of this study was to investigate a time-limited cognitive program, LearningRx, as a possible rehabilitation tool for patients with TBI. In response to this purpose, the following questions and hypothesis emerged:

Research Question 1: Does the LearningRx program provide improvement in cognitive rehabilitation for memory (long-term storage and retrieval, short-term memory, and working memory)?

Research Question 2: Does the gender of the participant affect improvement in memory rehabilitation?

Research Question 3: Does the age of the participant affect improvement in memory rehabilitation?

Hypothesis

1. The null hypothesis was that no significant differences in performance would be demonstrated on the measures evaluating changes in memory from the LearningRx program (ThinkRx and ReadRx) between pre-intervention and post-intervention scores. The research hypothesis stated that it expected a significant difference between pre-intervention and post-intervention scores as evident on the Woodcock-Johnson Tests of Cognitive Abilities, 3rd Edition (WJ-III COG), standard battery sub-tests for Visual-Auditory Learning, Numbers Reversed, and Auditory Working Memory, such that the program would demonstrate improvement in scores measuring long-term retrieval, short-term memory, and working memory, respectively, for individuals with TBI.
2. The null hypothesis was that no significant differences in performance would be demonstrated on Visual Auditory Learning (long-term storage and retrieval), Numbers Reversed (short-term memory), and Working Memory from the LearningRx program when assessing for gender differences. The research hypothesis stated that there would be no statistically significant differences between male and female

participant's post-intervention scores on the WJ-III COG, standard battery sub-tests for Visual-Auditory Learning, Numbers Reversed, and Auditory Working Memory, such that males and female participants would perform similarly.

3. The null hypothesis was that when assessing for age no significant differences in performance would be demonstrated on Visual Auditory Learning (long-term retrieval), Numbers Reversed (short-term memory), and Working Memory sub-tests. The research hypothesis stated an expected significant difference in post-intervention scores when assessing for age on the WJ-III COG, standard battery sub-tests for Visual-Auditory Learning, Numbers Reversed, and Auditory Working Memory, such that as the age of the participant increased, smaller post-intervention scores would be expected compared to younger participants.

The hypotheses were addressed through the use of limited archival data from LearningRx; age, gender, and pre-and-post scores were provided. There were 39 participants (29 males and 10 females), with a mean age of 30 years. Each participant was assessed both pre- and post-intervention on the Woodcock-Johnson III Tests of Cognitive Abilities (WJ-III COG); however, focus of this study was on three specific tests: Visual-Auditory Learning, Numbers Reversed, and Auditory Working Memory. Hypothesis 1 was addressed using a dependent t-test to evaluate if significant differences existed between pre-intervention and post-intervention scores on the aforementioned sub-tests of the WJ-III COG, as well as in each program of the LearningRx (ThinkRx and ReadRx), and with each sub-test within the ThinkRx and ReadRx programs. Hypothesis 2 was addressed with an analysis of covariance (ANCOVA) to understand if there were gender differences in post-intervention scores when the baseline sub-test measures (pre-intervention) was controlled for as a covariate. Finally, Hypothesis 3 was addressed using a partial correlation to test the relationship between age and post-intervention while controlling for pre-intervention for each of the sub-tests. Practice effects were addressed through the use of statistical tests (ANCOVA and partial correlation) as this researcher had eliminated the pre-intervention score as a covariate.

Limitations

There are many limitations to the present study; therefore, caution must be used when interpreting results. A major limitation was the lack of a control group in assessing the LearningRx intervention. Another major limitation of this study was that injury severity (mild, moderate, severe) was not known, making it impossible to make definitive statements of the study. Also affecting this study was the inclusion of a small sample size and the inability to assess for additional variables such as severity of TBI, socioeconomic status (SES), and ethnicity. This was due to the fact that limited archival data was provided to this researcher by the LearningRx Company. Additionally, by analyzing archival data, this researcher was unable to control for extraneous factors such as improperly diagnosed participants with TBI, number of males versus female participants to be included in the study, and possible human error when entering data. This researcher was also unable to verify the objectivity of the data since it had been produced and collected by LearningRx, a company which has a financial incentive in the results. Due to these limitations, generalizability of findings should be conducted cautiously. It would be advisable if future studies included a control group, larger sample size, utilize additional variables such as SES, severity of TBI, and ethnicity, including equal male and female participants, and independently collected data.

CHAPTER II

REVIEW OF THE LITERATURE

Traumatic brain injury (TBI) has been reported as the most common cause of brain damage with reported incidences ranging from 1.4 million to 3 million brain injuries per year in the United States (McCrea, 2008). TBI was the leading cause of disability in people under the age of 40, most commonly occurring in individuals aged 15 to 25 years (Draper & Ponsford, 2008), with more than twice as many males as females (Boswell, McErlean, & Verdile, 2002). Falls tend to be the most common cause of head injuries in infants and young children, as well as in the elderly population, whereas motor vehicle accidents were more prevalent for other age groups (Goldstein & Levin, 1990).

Blunt injury to the head, another cause of TBI, have resulted in diffuse injury predominantly affecting the frontal and temporal regions, producing a distinctive pattern of cognitive and behavioral deficits, with variations according to location and severity of the damage (Draper & Ponsford, 2008). Often times, TBIs resulted in multiple physical and neuropsychological deficits including a reduction in intellectual capacity, disorders of language and perception, impaired attention, and personality changes (Vanderploeg, Crowell, & Curtiss, 2001). Among moderate to severe TBI patients, a more enduring problem was memory impairment (Vanderploeg, Crowell, & Curtiss, 2001); however, the specific nature of the memory problems remain to be unclear. Some researchers have stated that it reflected an encoding problem, others have stated a consolidation deficit, and others a deficit in retrieval (Vanderploeg, Crowell, & Curtiss, 2001). Deficits have been recorded for recently performed actions, verbal paired-associate learning, word list recall, rote recall, memory for narratives, and recognition memory (Schefft, Dulay & Fargo, 2008). Many TBI patients often have a reduced capacity for functional independence, study, employment, leisure activities and personal and social relationships (Draper & Ponsford, 2008; Schefft, Dulay & Fargo, 2008). However, the factors contributing to these poor outcomes remained unclear. Different interventions have been available to TBI patients to help them cope and rehabilitate memory impairments.

Memory has been associated with the mental systems, representations, and processes that are involved in the acquisition and retention of information. Without this association our experiences would be random and isolated with no integrated relationship to one another. Without memory we would not be able to communicate with others as we would not know who the other person was or remember the substance of the material being communicated. Without memory, we would not be able to utilize any knowledge gained through experiences. From a psychological standpoint, personal identity was made possible from a person's accumulation and clarity of memories throughout the lifespan (Schacter, 1996).

Before providing a description of the processes and types of memory that are integral to prevailing conceptualizations of memory, a brief review of some perspectives and models of memory functioning has been presented. This is provided to allow the reader insight into research that has driven conceptualizations of memory and is not an exhaustive list of memory theories. These include a general historical perspective, the multi-store model, and the information processing model. The different types of memory are then discussed. Finally, the chapter ends with a discussion of memory rehabilitation, interventions that have been used to improve memory, and a discussion of the theory and development of the current intervention program.

An Ancient View of Memory

Since the beginning of time in Western civilization, memory has been viewed as a skill that can be trained using specific rules, techniques, and practices. Prior to the invention of the printing press, knowledge was passed through oral transmission to ensure the viability of the human race. Thus, memory is part of being human and is required to not only preserve knowledge, but to also contribute knowledge through the learning process.

Yates (1966) credited the Greek poet Simonides of Ceos (pre-Socrates) as the inventor of the “art of memory.” Simonides would associate places (loci) with the mental images (imagines) of the objects that were to be recalled and stored those images in the places where their memory would be preserved. For example, a building might be imagined and the elements of a speech would be “stored” in each room, thus aiding memorization. Simonides utilized visualization as the primary sensory modality to fix visual images into mental compartments. In today's age of computers, it is difficult to understand ancient philosophers and teachers who used mnemonic strategies to deliver speeches from memory. In a time "devoid of printing, without paper for note-taking or on which to type lectures, the trained memory was of vital importance" (Yates, 1966, p. 4). Due to its importance, this study briefly discussed historical perspectives, as well as the theoretical framework currently used for conceptualizing memory and treatment interventions for memory training and rehabilitation.

Historical Perspectives

The understanding and conceptualization of memory has been a focus within psychology throughout its existence as a scientific discipline. In 1885, Hermann Ebbinghaus published the results of his rigorous experiments in memory, and marked the beginning of programmatic experimental research (Wozniak, 1996). Ebbinghaus studied higher mental function by using nonsense syllables (comprised of a vowel sound being placed between two consonants) and discovered the fundamental principles of learning and memory which remain valid today. Ebbinghaus was the first to describe the shape of the learning curve (time required to memorize an average nonsense syllable increased sharply as the number of syllables increased), the distribution of learning trials over time was more effective in memorization than loading practice into a single session, and he noted that continued practice of material after the learning criterion had been reached enhanced retention. Ebbinghaus was also the first to describe primacy and recency effects which referred to the idea that early and late items in a list were more likely to be recalled than middle items (Wozniak, 1999).

Another influential thinker, William James (1890), conceptualized memory as being comprised of two systems: Primary memory, thought to support consciousness; and Secondary memory thought to contain permanent records of the past. Primary memory was viewed as our immediate awareness of space and time in which little effort was required to access its contents. Secondary memory, on the other hand, required more effort on behalf of the individual. During the second half of the twentieth century, when the cognitive movement in psychology emerged, Broadbent (1958) hypothesized there to be a separate short-term and long-term memory storage system (corresponding to James' primary and secondary memory) for the retention of memory. As a result, an organizational and scientific model of memory was formed.

Waugh and Norman (1965) investigated the primary and secondary memory concepts presented by James (1890) to determine if they could be supported by research. They found that primary memory had a capacity of about five items and concluded that beyond these items would be transferred to secondary memory. However, as research has continued in this area, it was noted that prior conceptualizations of memory as a dual component system had been oversimplified.

Multi-Store Model of Memory. The multi-store model, presented by Atkinson and Shiffrin (1968), was an extension of the primary (short-term) and secondary (long-term) memory conceptualized by James (1890), Broadbent (1958), and Waugh and Norman (1965). The multi-store memory model was viewed as a flow of information between three interrelated and temporarily based stores. Information imprinted on the sensory organs was initially processed by the sensory memory store. It was hypothesized that the sensory memory store was transient in nature (measured in milliseconds), providing awareness of information immediately following a stimulus. The sensory memory store was later referred to as iconic memory.

Information from the sensory memory store then passed into short-term memory store (STS). Atkinson and Shiffrin (1968) regarded STS as having a limited and temporary capacity capable of retaining information for seconds or minutes prior to recall or being discarded. Atkinson and Shiffrin discovered that short-term memory store could have a capacity of 7 ± 2 pieces of information. The information was encoded phonologically rather than semantically (i.e., following speech characteristics rather than the intrinsic meaning of the stimuli).

The other component of Atkinson and Shiffrin's (1968) multi-store model was long-term memory store (LTS). The LTS was a permanent storage system capable of holding information from minutes to decades. It was hypothesized that LTS had unlimited storage capacity, with information being encoded semantically rather than phonologically. Thus, retrieval of information from LTS required the ability to recall or access semantically encoded memories. Atkinson and Shiffrin emphasized that rehearsal or repetition of sensory information was the means to encode and transfer information to LTS.

Though the multi-store model was useful for memory theorists, it was not compatible with the information processing model emerging at the time. Sohlberg and Mateer (1989) argued that the multi-store model was too simplistic, especially regarding STS and LTS as unitary systems. Further research suggested that memory was multidimensional, with various overlapping levels of information processing, and not a storage-based system.

Information Processing Model of Memory. Though a universally accepted theory of memory has not been embraced, the information processing model has been the current representation in most research (e.g., Petersen & Weingartner, 1991). The popularity of computers in the 1960s influenced current theoretical models of memory. Information processing within a computer became a metaphor for the processes of memory within the human brain. The model proposed by Craik and Lockhart (1972) hypothesized a more complex approach to memory than the multi-store model. The new model was based on different levels of processing.

As research into memory evolved, researchers agreed that there were several processes to memory: attention, encoding, storage, consolidation, and retrieval. Attention was an important aspect in the conceptualization of memory. Without the ability to attend to stimuli, information could not be processed effectively. At its most basic, attention consisted of alertness and arousal, and at its most complicated it consisted of perception, maintaining concentration, distractibility, allocation of attentional resources, and motivation (Sohlberg & Mateer, 1989).

Encoding consisted of the individual's ability to assimilate material from working memory to long-term memory (Parenté & DiCesare, 1991) so it could be recalled or recognized at a later time. Attention, both effortful and automatic, was required to hold information in awareness to allow data to be encoded. The encoding of information allowed a stimulus to be recognized through associations with previous knowledge, permitting the encoding of information (Schacter, 1996). This area of encoding was where learning was thought to take place; involving the interaction of working memory and semantic/episodic memory (see discussion below explaining these terms), and storage/consolidation in long-term memory (Petersen & Weingartner, 1991). An encoding deficit presumed that persons with head injuries were unable to process information in working memory. Therefore, information may not effectively be transferred from working memory or short-term memory to long-term memory stores. This may have been due to rapid forgetting or not storing the information effectively (Parenté & DiCesare, 1991).

Craik and Lockhart (1972) proposed that information which was semantically (by meaning) encoded and retrieved, was more reliable than information which was encoded phonologically (by speech characteristics). Ebbinghaus (1885; as cited in Hothersall, 1995) was the first to discover that memory was facilitated by encoding on the basis of meaningful associations. Therefore, cueing to features associated with the temporal presentation of events/stimuli, organizing stimuli into categories (i.e., chunking), and active rehearsal were strategies for processing/encoding information at a deeper level and increasing the meaning of the content.

The storage of memory consisted of transferring information from short-term memory (where it was temporary) to long-term memory (where it was stored permanently) so it would be accessible in the future. Sohlberg and Mateer (1989) described consolidation as "a theoretical construct that provides for integration of new memories within the individual's existing cognitive/linguistic schema or framework" (pp. 139). A retrieval process was incorporated to utilize stored information.

Petersen and Weingartner (1991) described the retrieval process in memory as the accessibility to stored information. The retrieval processes involved searching for and activating memory traces and monitoring the reliability of their accuracy and appropriateness. The processes that facilitated retrieval were implicit/procedural and explicit/declarative memory (described below) as they relied on unconscious and conscious awareness, respectively, for 'decoding' memory traces.

Types of Memories

Learning, retention, and retrieval of information were various aspects of memory and those memories were not "mutually exclusive but rather refer to different theoretical formulations of memory function" (Petersen and Weingartner, 1991, p. 13). Short-term memory (STM) and long-term memory (LTM) were two fundamental components of the memory system. STM was considered to have limited capacity where incoming information lasted for a brief time before being transferred to LTM or being discarded. Information in STM lasted till new stimuli forced the existing information out, thus leaving only the most recent piece of information. LTM, on the other hand, consisted of a large or unlimited capacity where information was permanently stored in an organized manner.

Short-Term Memory. We are only briefly aware of our experiences before the brain and sensory system turned it into meaningful structures. Short-term memory, considered the focal point of learning and information processing, was also considered to be a mulitcomponent system. Baddeley (1981) stated that STM's role to temporarily store sensory information and cognition was best accounted for by working memory (WM). Working memory played an important role in processing tasks that ranged from speech comprehension to arithmetic and to learning complex reasoning. It was a tripartite system consisting of the central executive, phonological loop, and visuospatial sketchpad (Baddeley, 1981, 2000).

According to Baddeley (1981, 2000) the central executive was in charge of processing information. It was also thought to directly control the other two components of WM. The phonological loop maintained linguistic information by subvocal rehearsal and was responsible for the speech-like characteristics of many short-term memory tasks. The visuospatial sketchpad was used to create and manipulate spatial material using visualization. These three components of WM were often considered to be semiautonomous. Therefore, while one system was actively processing information, another would be available to perform other tasks (Baddeley, 1981; Baddeley, 2000; Bunge, Klingberg, Jacobsen, & Gabrieli, 2000).

Though widely researched, working memory has yet to be fully understood. It has been assumed that WM utilized a range of parallel subsidiary systems within the phonological loop and visuospatial sketchpad, suggesting that a deficit in one of these areas may not be catastrophic. However, if the central executive were to fail, a person would be severely limited in their ability to process information and participate in everyday living (Baddely & Hitch, 1974). As mentioned earlier, executive functioning impairment, in addition to attention and memory, are the three common sequelae to TBI. As attention, memory, and executive function were related and interdependent, their interdependence came from their functional association and shared neurocircuitry (Sohlberg & Mateer, 2001). Thus, TBI survivors often encountered problems with working memory, especially when attention deficits were also present.

One strategy implemented to help improve working memory, known as chunking, occurred when the individual linked pieces of information together. For example when one remembered a phone number, one can remember the area code (505) as one chunk of information in a ten digit number. Then, one would remember 544 as the second chunk to the number and finally the last four digits as the third chunk (2000). In this manner, the individual was only recalling three chunks of information rather than ten separate pieces of information.

Long-Term Memory. Long-term memory (LTM) has been conceptualized as having multiple subcompartments. Humans have the ability to remember both verbally based information (letters, names) and visually based information that cannot be described easily (a person's face). Memory was found to be better for an object that could be characterized by both verbal and visual information. If one modality was found to be relatively intact then it would compensate for deficits in the other (Sohlberg & Mateer, 2001).

Two subdivisions within LTM were semantic memory and episodic memory. Semantic memory referred to memory regarding knowledge based information about the world, including word meanings, classes of information, facts, and ideas that are not connected to a specific event or learning situation in the person's life (Sohlberg & Mateer, 2001). For example, a person may remember that a dog is an animal or that an apple is a fruit, but not remember when this information was acquired. On the other hand, episodic memory referred to knowledge about specific events in which personal experiences were tagged to a specific time and place (Sohlberg & Mateer, 2001). The episodic memory may be either as a participant or observer of an event and was often referred to as one's autobiographical memory. Following brain injury, individuals often presented with preserved semantic memory (having access to old knowledge; Parenté & DiCesare, 1991; Sohlberg & Mateer, 2001), but had difficulty creating new knowledge due to an impaired episodic memory (Sohlberg & Mateer, 2001).

The level at which information was remembered was related to the level of consciousness exercised during encoding and retrieval. Petersen and Weingartner (1991) defined four types of memories used to categorize differing levels of encoding and recollection awareness within long-term memory. These included implicit/explicit and procedural/declarative memory.

Implicit memory involved the ability to demonstrate previous learning despite the inability to recall the circumstances under which the learning took place (Petersen & Weingartner, 1991). It operated through unconscious mechanisms; therefore, it was implemented if recall was facilitated through priming or cueing of the target material, but memory for the learning experience was absent. Explicit memory referred to the conscious recall of recent events and was often called intentional memory. When a person was asked to remember specific details of a situation, explicit memory processes were implemented to recall the information. It was enacted through a deliberate and conscious act of remembering (Petersen & Weingartner, 1991).

The two types of memory associated with retrieval of memory were procedural and declarative memory. Procedural memory referred to the learning of perceptual, motor, and modifiable cognitive operations. Unconscious processes were involved in the retrieval of procedural memory (Petersen & Weingartner, 1991). Declarative memory referred to memory for information that was directly accessible by consciousness and was comprised of facts and data. Both procedural and declarative memories described how material was encoded in long-term memory (Petersen & Weingartner, 1991).

The information processing model of memory contained processes that operated simultaneously. The processes of memory were thought of being similar to the fundamental principles of computer technology (attention, encoding, storage, consolidation, retrieval). Memory, subdivided into short-term (including working memory) and long-term (visual/verbal and semantic/episodic) memory provided the framework for understanding the processes involved. Also differences between semantic/implicit/procedural and episodic/explicit/declarative memory were due primarily to the differences between information associated with each group (skills vs. specific events) and the level of consciousness involved during encoding and recall (unconscious vs. conscious).

An important aspect of LTM that was focused on in this study were aspects of storage and retrieval. Storage was assumed to consist of three mechanisms: transfer, placement, and image-production (Shiffrin & Atkinson, 1969). The transfer process included decisions involving what to store, when to store, and how to store the information, were all under the control of the individual. Selected information to be transferred was also based on the degree of familiarity for the incoming material. The location in which information would be stored was determined by the content of the information and if there was any pre-existing framework for the information. For example, the storage location of the word division was determined if it was preceded by the terms multiplication, addition, and subtraction, or if it was preceded by platoon, regiment, and battalion (Shiffrin & Atkinson, 1969). Image-production process determined what proportion of the information in short-term memory would be stored in long-term memory. So the longer the information stayed in, or was rehearsed in, short-term memory, the more information was transferred to long-term memory.

The retrieval process, like storage, was thought to consist of three mechanisms: search, recovery, and response generation (Shiffrin & Atkinson, 1969). The search process began with a mechanism that located various bits of information for examination. This was done either randomly, where all information in memory was searched (taking longer to locate the desired information) or it was done through direct methods in which the individual searched for information based on clues or other information gained in the search process (taking less time to locate the desired information). As each bit of information is examined, the recovery process determined how much information would be recovered, based on the amount of information stored initially. The response generation process examined the recovered information and decided whether to continue the search or terminate and provide a response. This study aimed to briefly describe these mechanisms as a means of providing a general framework within which this study could be placed.

Memory (Cognitive) Rehabilitation

In the 1980s, brain injury rehabilitation focused on interventions for specific cognitive deficits (Sohlberg & Mateer, 2001). However, due to financial pressures and length of stay limitations in rehabilitation facilities, enforced by health management companies, the focus shifted to one of "functional rehabilitation," with a decreased focus on direct neurocognitive interventions (Giacino, 1999). A study by Rassovsky et al. (2006) suggested that "such a shift in emphasis may not be entirely warranted given the apparent importance of neurocognitive mediators of outcome" (p. 575). In their study they found no direct effect of injury severity on functional outcome, suggesting that other intervening variables mediated the relationship between injury severity and functional outcome (Rassovsky et al., 2006).

There have been various strategies in which rehabilitation have taken place. The first strategy consisted of external rehabilitation. External rehabilitation involved changing the individual's environment to facilitate memory with the assumption that premorbid functioning of the memory would not occur. Therefore, behavioral expectations were adjusted to fit the individual and their level of functioning. Some examples of external memory aids included diaries, notebooks and lists. It may also be necessary to use a cueing device, such as a buzzer or alarm, to remind the patient to use their external memory aid (Leng & Copello, 1990; Mateer, Kerns, & Eso, 1996), or alter expectations for the individual's functioning (Mateer, Kerns, & Eso, 1996). In today's technological world, cell phones or PDA's may also be utilized to serve as aids in assisting individuals with their daily life. However, learning may be compromised due to difficulties with initiation, abstraction, and problem solving, all of which are present following a TBI (Mateer, Kerns, & Eso, 1996). Thus, it is necessary to adequately train the patient in these methods and how to use them in their specific real-world situations.

Ownsworth and McFarland (1999) investigated the remediation of "everyday memory impairment" using a diary combined with self-instructional training. Results indicated that there was better maintenance of strategy use and greater decline in memory problems, suggesting that some forms of compensatory strategy training were beneficial for patients years post-injury (as cited by Cicerone et al., 2005). Cicerone et al. (2005) also looked at the effectiveness of a portable pager to improve independence for people with memory and planning problems. During the intervention period, a pager was used to address specific problems in daily functioning. There were significant improvements in completing everyday tasks compared to no-treatment and baseline conditions. The use of a pager was beneficial for people who needed to complete particular tasks on a regular basis and due to its ease of use and relevance, helped address self-identified needs.

In a meta-analysis conducted by Cicerone et al. (2011), the authors identified a study done by Reese et al. (2007), reviewing 64 studies addressing cognitive rehabilitation for attention, learning or memory, executive functioning, and general cognitive rehabilitation approaches, and also included pharmacologic interventions. It was noted that Reese et al. (2007) found strong evidence supporting the use of external memory aides to compensate for functional memory problems, without necessarily improving upon the underlying memory abilities.

The second strategy involved internal strategies, which were based on restorative and compensatory approaches (Mateer, Kerns, & Eso, 1996). Restorative interventions attempted to change the individual's cognitive capabilities though "neuronal growth" associated with simple exercises of neuronal circuits (Kim et al., 2009; Mateer, Kerns, & Eso, 1996). This method involved exercises that enabled the person to practice tasks requiring specific cognitive abilities or processes to improve or restore those abilities (Mateer, Kerns, & Eso, 1996) utilizing memory functions that had been preserved by explicit and declarative memory systems. Internal strategies taught the person to use mental imagery, organize information in sequences, or to use acronyms and rhymes (Gentleman, 2001). Rote learning (repeated practice), encoding strategies (processing information at deeper levels), and visual mnemonics (visualizing room or route in their mind and then imagining each item to be remembered in a different part of it; Leng & Copello, 1990; Mateer, Kerns, & Eso, 1996) were some examples of restorative interventions. There has been evidence that restorative interventions may be helpful during the acute phase of recovery. However, such methods have not been found to be effective or generalizable to other tasks (Leng & Copello, 1990; Mateer, Kerns, & Eso, 1996).

Kaschel, Della Sala, Cantagallo, Fahlbock, Laaksonen, and Kazen (2002; as cited in Cicerone et al., 2005) evaluated the use of simple visual imagery techniques on individuals with mild memory impairments after TBI. In the study visual imagery was compared to "standard" approaches to memory treatment in seven rehabilitation centers (e.g., practical guidelines to improve memory, use of notebooks and calendars). Both the visual imagery and standard conditions were preceded by 3 months of no-treatment baseline, and then followed by memory training for 30 sessions over 10 weeks, with follow-up assessment 3 months later. Results indicated significant improvement for the imagery condition and was restricted to the therapeutic interval and recall of verbal material. Improvements were paralleled with positive changes in ratings of patients' memory functioning and were maintained at 3 month follow-up (as cited by Cicerone et al., 2005).

Another approach that has been shown to improve learning and behavior change in a rehabilitation setting was self-regulation (Schefft, Dulay & Fargo, 2008). Self-regulation was described as the process by which an individual generated and maintained goal-directed behaviors. It was hypothesized that active involvement by the individual lead to better information retention, and increased their perceived self-efficacy and positive effect (Schefft, Dulay & Fargo, 2008). This method of self-regulation or self-generated behavior was called the generation effect. The generation effect stated that memory and learning improved when an individual generated the information to be remembered rather than being the passive recipient of didactically presented information (Schefft, Dulay & Fargo, 2008). Self-generation procedures have been shown to improve performance in non-brain-injured students for memory of a narrative passages, paired-associated learning, memory for numbers, incidental learning, narrative texts in English as a Second Language courses, and learning multiplications (Schefft, Dulay & Fargo, 2008). Self-generation has also been shown to improve memory in non-demented elderly rehabilitation patients, individuals with Alzheimer's disease, multiple sclerosis, Parkinson's disease, and temporal or frontal lobectomy, as well as aphasia (Schefft, Dulay & Fargo, 2008). However its application in memory impaired patients has been relatively new.

One study reviewed by Cicerone et al. (2011) compared computer-assisted and therapist-assisted memory training with a no-treatment control condition for individuals with TBI. Both active treatment conditions utilized an errorless learning method and 20 sessions of memory skills training, management of daily tasks that incorporated memory skills, and consolidation and generalization of those skills. Results indicated that both treatments produced improvements on neuropsychological tests of memory functioning compared to the no-treatment group. Another study evaluated by Cicerone et al. (2011) evaluated an instructional sequence for individuals with severe memory and executive function impairments after chronic TBI. Participants were taught to use a simple email interface through a combination of errorless learning and metacognitive strategy training. Results showed a strong relationship between the instructional program and learning the e-mail procedures, and were maintained at 30 day follow-up. These studies supported the possible benefits of errorless learning for teaching new knowledge, including knowledge of compensatory strategies for individuals with severe TBI; effective for teaching specific information and procedures to individuals with mild executive functioning difficulties and memory impairments.

Schefft, Dulay & Fargo (2008) assessed the efficacy of self-generation encoding procedures in improving memory and learning for a verbal paired-associate task compared with the didactic presentation of information. They found that self-generation encoding procedures improved recognition memory test performance and cued recall, but not free recall. The findings indicated that a self-generation intervention provided a strong effect in improving recognition memory and cued recall test performance compared with the passive didactic presentation of information in individuals with TBI (Schefft, Dulay & Fargo, 2008). Self-generation was thought to be valuable because the efficacy of self-generation was shown not to be constrained to any specific modalities (Schefft, Dulay & Fargo, 2008). In other words self-generation has a broad utility. Recent literature on the efficacy of cognitive remediation strategies indicated that external and internal (e.g., mnemonics) compensatory strategies were recommended to be the best course of action (Schefft, Dulay & Fargo, 2008).

Compensatory approaches, on the other hand, allowed the individual opportunities to learn techniques or strategies providing them with the ability to compensate for the underlying cognitive impairment (Mateer, Kerns, & Eso, 1996). Compensatory training consisted of using mnemonic strategies to cope with impairments (Mateer, Kerns, & Eso, 1996). Just as with external rehabilitation, the assumption was that pre-morbid functioning for memory could not be recovered. Thus, the primary goal was to teach strategies to overcome the impaired memory. The interventions were behaviorally based on cognitive behavioral techniques and they included learning to refer to and follow a check list for a behavioral routine or learning to use external memory or organizational systems.

Visual imagery, one of the oldest recorded form of memory training (Yates, 1966), involved the formation of vivid mental pictures or images and connected these to the items to be remembered (Leng & Copello, 1990). One method included using the 'loci method' first introduced by Simonides (Yates, 1966). In this method the individual visualized a room or building in their mind and then imagined each item to be remembered in a different part of it. Another method involved the association of two items by visualizing them joined together in some way (e.g., in teaching the name Mr. Baker, the person was asked to look at a picture of Mr. Baker and imagine him wearing a tall white hat and carrying a loaf of bread). However, not all studies have been favorable in this method. This may have been due to fewer learning trials or patients forgetting to use the methods (Leng & Copello, 1990).

Another method called the "method of vanishing cues" was a computer-assisted approach to teaching domain-specific knowledge to adults with TBI (Leng & Copello, 1990; Mateer, Kerns, & Eso, 1996). It was based on empirical studies demonstrating that amnesic patients acquired a variety of motor, perceptual, and cognitive skills even though they did not remember the actual learning episode (Mateer, Kerns, & Eso, 1996). For example, a definition for a word was first presented, followed by as many characters of the target word as were needed for the individual to produce the correct word. If the response was correct, on the next trial the word fragment was reduced by one character. This procedure of reduction in cues was repeated until the individual was able to give the correct answer with no cues at all (Leng & Copello, 1990). Kerner and Acker (1985; as cited by Cicerone et al., 2000) evaluated the effectiveness of using memory retraining software and a computer for remediation of “mild to moderate” memory impairment at minimal of 3 months post-injury. Significant improvements were observed on psychometric memory performance after 12 training sessions, implying that memory skills were enhanced by use of computer-based memory retraining software. However, gains were not maintained when individuals were re-tested 15 days later. Therefore, little evidence was provided regarding the benefits of treatment through computer-based training beyond spontaneous memory improvements (as cited by Cicerone et al., 2000).

Patients experiencing traumatic brain injuries now have increased improvements in prognosis for recovery. This has been due to widely available CT scanning, early intracranial surgery, sophisticated neuro-intensive care, and better training of clinicians in early trauma care over the last 20-30 years (Gentleman, 2001). Rehabilitation of impaired cognitive processes has become a standard component of medical care after TBI (Rohling et al., 2009). It has been found that 95% of rehabilitation facilities serving TBI patients provided cognitive rehabilitation services (Mazmanian et al., as cited by McDonald, Flashman, Saykin, 2002).

In the first 1 to 2 years after TBI, studies have documented cognitive changes including slowed thinking, and difficulties with concentration and memory (Draper & Ponsford, 2008). Natural recovery from cognitive deficits tended to be maximal in the first six months after injury, but could continue for up to two years post injury (Gentleman, 2001). Different deficits recovered at different speeds, and there has been evidence that appropriate clinical interventions could influence this process and enhanced the recovery process (Gentleman, 2001). Neuropsychological tests have been implemented in numerous studies confirming the presence of impairments of attention, processing speed and memory in the first year after TBI (Boake et al., 2001; Draper & Ponsford, 2008; Novack, Bush, Meythaler, & Canupp, 2001). However, until recently, few studies have documented cognitive outcomes over longer periods of time post-injury (Draper & Ponsford, 2008). Studies conducted over periods of 10 years or more have focused on patients with extremely severe injuries. This painted a very bleak picture of long-term cognitive outcome, which may not necessarily apply across the spectrum of injury severity (Draper & Ponsford, 2008). Few studies have focused on objective testing to document impairments in attention, processing speed, memory, or IQ, instead of executive function (Draper & Ponsford, 2008).

In a study conducted by Draper and Ponsford (2008), cognitive impairments 10 years following TBI were examined. Results indicated that cognitive performances of TBI participants were significantly poorer than those of non-injured, demographically similar controls on tests in each of the domains of processing speed, memory, and executive functioning (Draper & Ponsford, 2008). Draper and Ponsford (2008) objective demonstration of cognitive impairments affecting processing speed, memory and executive function supported findings from long-term outcome studies that utilized subjective reports. Though the TBI patients included in the study represented a broader range of injury severity than that used in most other studies (Draper & Ponsford, 2008), it supported a significant relationship between injury severity and degree of cognitive impairment 10 years after injury.

On the other hand, Vanderploeg, Crowell, and Curtiss (2001) stated that an encoding deficit suggested that TBI-related memory problems represented impairments in the ability to attend to and register new information. Research regarding this hypothesis showed that TBI patients demonstrated impairments in semantic organization strategies, and/or slower rates of learning (Vanderploeg, Crowell, & Curtiss, 2001). Therefore, TBI patients demonstrated more rapid rates of forgetting and poorer performance on recognition tasks (Vanderploeg, Crowell, & Curtiss, 2001).

In the study by Vanderploeg, Crowell, and Curtiss (2001), findings indicated that impaired consolidation and not encoding or retrieval deficits were the most prominent verbal memory problem in TBI patients. They found that rates of learning did not differ among the three groups studied (TBI group, acquisition-matched control, and demographic-matched control). The authors concluded that since the rate of learning did not differ between TBI and controls, and other memory deficits were demonstrable, an underlying deficit in encoding was unlikely (Vanderploeg, Crowell, & Curtiss, 2001).

The study found that moderate to severe TBI patients had a significantly more rapid rate of forgetting new information than either acquisition-matched controls or demographic-matched controls. This was found to be consistent with consolidation problems in TBI (Vanderploeg, Crowell, & Curtiss, 2001). The TBI patients also showed less proactive interference, indicating that ongoing consolidation of new information would limit memory resources to process and consolidate/store additional new information, than demographic-matched controls (Vanderploeg, Crowell, & Curtiss, 2001), which pulled for consolidation problems.

An Intervention to Improve Memory

Cognitive rehabilitation may be directed toward many areas of cognition, including attention, concentration, perception, memory, comprehension, communication, reasoning, problem solving, self-monitoring and awareness. Cognitive rehabilitation has been distinguished from traditional rehabilitation and psychotherapy by its primary focus: the alleviation of acquired neurocognitive impairments and disability (Cicerone et al., 2000). Cognitive rehabilitation should be directed towards achieving changes that improve each person's function in areas that are relevant to their everyday lives (Cicerone et al., 2000).

Research has suggested that the most effective cognitive rehabilitation programs were tailored to the personal profile of strengths and weaknesses of an individual with TBI, and set in a context of comprehensive rehabilitation services. These programs were more likely to be successful than a broad-based attempt to improve global cognitive functioning which did not focus on the specific deficits of a given individual, and did not first establish a foundation of basic skills on which to retrain higher cognitive processes such as executive functioning (McDonald, Flashman, & Saykin, 2002).

CompTrain, developed by Torkel Klingberg in 2001, was a program intended to increase student's working memory using computerized training, and was evaluated for a group of 53 students aged 7 to 12 who were diagnosed with Attention Deficit Hyperactivity Disorder (ADHD; Klingberg et al., 2005). The students had measured IQs above 80, were not on ADHD medication, and included 15 students with ADHD of the inattentive subtype. Students were randomly divided into control and experimental groups.

Subjects were also randomly assigned to either a home or school condition. Those in the experimental group completed 25 training sessions, approximately 40 minutes in duration, involving 96 working memory tasks over a period of five to six weeks. The control group received similar training but at a lower level of difficulty than the working memory level of the child. Effect sizes (Cohen's delta [Cohen, 1988]) on outcome measures including digit span (.59), the Stoop Test (.34), and the Ravens Matrices (.45) were significant. At follow-up, performance in the treatment group was as high, or higher than, post-intervention with effect sizes of 0.57 for digit-span, 0.25 for the Stroop Test, and 0.30 on the Raven's Matrices. This corresponded to 97%, 73%, and 67%, respectively, of the post-intervention effect. Additionally, parents' ratings of symptoms on the Conners' Rating forms reflected significant decreases from pre- to post-intervention in areas of inattention, hyperactivity, and overall ADHD index. Klingberg and colleagues (2005) concluded that the intervention was as effective as medication in improving working memory abilities in students with ADHD. However, it should be noted that the authors did not address the possibility of expectation bias on the part of the parents. Additionally, the only studies involving the CompTrain program were conducted by the developers of the program with a limited number of participants and limited follow-up measurements.

Development and Theory of LearningRx Intervention

In 1985, Dr. Ken Gibson, OD, specialist in pediatric optometry and visual processing, met with Keith Gibson, Ph.D. in clinical psychology and other specialists within the fields of special education, clinical and cognitive psychology, occupational therapy, central auditory processing, visual processing, learning disability, and memory research from various universities and professional clinics for an informal symposium in Appleton, Wisconsin (PACE, n.d.b). This symposium was led by Ken Gibson, OD, who himself suffered from dyslexia, to address how best to help individuals with learning disabilities. In 1995, after 10 years of informal research by educational, psychological and medical specialists from more than 350 schools, clinics, hospitals, and training locations, a program called Processing and Cognitive Enhancement (PACE) was created (PACE, n.d.a). The PACE program was overseen by a national board comprising of professionals from broad and diverse backgrounds including: social work, teachers, clinical and school psychologists, and optometrists (PACE, n.d.b). No peer reviewed articles or detailed history were identified or found for the PACE program; therefore, information gathered by this researcher regarding this program must be viewed cautiously.

According to a self-study conducted in 2001 from 113 locations, the program was deemed successful according to the Gibson Cognitive Test Battery (GCTB), Detroit Tests of Learning Aptitude (DTLA-3) and Woodcock-Johnson Test of Cognitive Ability (WJ-R; PACE, 2001). The GCTB showed an average 3.4-3.6 years gained in processing speed, working memory, visual processing, word attack, auditory analysis, and logic and reasoning. The GCTB, created by Ken Gibson, was a computerized test designed not as an IQ test, but as an easy and quick means of identifying strengths and weaknesses of cognitive areas ("Gibson Cognitive Test Battery", 2010). There were seven subsections within the test which were normed with a database of 6000 student records. However, no specific information regarding reliability and validity tests or test/re-test studies could be found except that the GCTB had undergone reliability and validity tests as well as a test/re-test study which was compared to a small sample of students who took the GCTB and a "well known battery that is similar in nature" and was found to have a "reasonably high correlation" ("Gibson Cognitive Test Battery", 2010). It was mentioned that the test would be re-normed when 20,000 student records had been collected.

The Detroit Tests of Learning Aptitude-3 (DTLA-3) had average of 3.1-3.3 years gained in long-term memory, short-term memory/attention, visual processing, logic and reasoning, comprehension, and visual motor abilities (PACE, 2001). The DTLA-3 was a measure of General Mental Ability

Composite (GMAC; representing best estimate of *g*) for children 6 years 11 months to 17 years 11 months on 11 subtests (Schmidt, 1994). The test was normed on 2,587 children, from 36 states. 1,532 children were tested on the DTLA-2, and their scores for the six subtests were retained and used on the norms for the DTLA-3. The remaining 1,055 children were tested entirely using the DTLA-3. It was purportedly matched to 1990 US census data for gender, ethnicity, race, residence, and geographic area. Internal reliability for the DTLA-3 global scores were .94 or higher and correlations for the subtests were found to be "satisfactory" (Schmidt, 1994). Test-retest reliability (with 2-week interval) for 34 children age 6-16 yielded estimates of .94 for the GMAC and .83 for the Optimal Level Composite (consisting of the four highest standard scores; Schmidt, 1994). However, test-retest data were collapsed across all age levels.

The Woodcock-Johnson Revised Test of Cognitive Abilities (WJ-R COG) showed an average of 4.2-4.8 years gained on long-term memory, short-term memory, processing speed, auditory processing, and visual processing (PACE, 2001). The WJ-R expanded the diagnostic capabilities of the original Woodcock-Johnson test, by incorporating the Cattell-Horn *Gf-Gc* theory and dividing the test into two main batteries: the Tests of Cognitive Abilities (WJ-R COG) and Tests of Achievement (WJ-R ACH). The WJ-R COG and WJ-R ACH were co-normed on 6,359 individuals, from the age of 2 years to 90+, and matched the 1980 U.S. Census (Kamphaus, 2005; McGrew, Woodcock, & Ford, 2009). Internal reliability was measured using the split-half method. It indicated that average reliabilities ranged from .87 to .93 for the standard battery and ranged from .76 to .93 for the supplemental battery (Kamphaus, 2005).

In 2002, Ken Gibson opened a LearningRx center in Colorado Springs, Colorado, as a means to implement the PACE program outside the educational system (LearningRx, n.d.). According to LearningRx (2010a), the program emphasized the following key areas: 1) one-on-one training, 2) sequencing, where new exercises and training are introduced in a logical order from simple to complex, 3) loading, where individual training tasks were layered and progressively increased in difficulty, and 4) intensity, where training was delivered at a rapid pace with techniques that created and maintained a high level of intensity.

The program also adhered to Bruner's (1964; as cited in Luckey, 2009) four rules of instruction for the most effective learning. The rules and the manner in which they are incorporated were as follows:

1) Experience must be described which explains why the student is willing and able to learn.

Program Implication. Every drill has a real world application to motivate the individual to persevere when challenged. For example, a student who has difficulty completing their work within an allotted time may be informed that a drill focused on improving processing speed would enable him/her to do their work more quickly. Additionally, students identified their own benefits to the drill after being coached by the instructor on possible benefits. In trainer training, individuality and specificity of the benefits were stressed.

2) The structure for teaching must be specified within the program. Additionally, teaching must relate new information to information already known, so it could be easily understood by the learner. Finally, when more than one concept was taught, these concepts must not be contradictory.

Program Implication. The structure for teaching within the program was specified in student and trainer handbooks, as well as in the training provided. Drills built on one another and strengthened cognitive skill areas. Some drills combined skills, such as memory and processing speed. For example, some of the memory training drills included using short-term, long-term, and working memory skills, as well as processing speed skills, such as repeating a list of words from memory within a certain time frame. Skills typically were not combined until basic proficiency in those skills had been achieved. Although the model of instruction was the same for all students, individualization occurred based upon the student's strengths and weaknesses. For example, a student with strong short-term memory, but difficulty with processing speed would spend more time on drills related to processing speed.

3) The most effective sequence of instruction should be clearly defined.

Program Implication. The instructional sequence required 90% mastery for all students on the same basic levels of drill training before moving to more complex drills.

4) A theory of instruction should specify the nature and pacing of rewards. In addition, there should be a point where rewards for learning shift away from extrinsic and immediate and towards rewards that were intrinsic and deferred.

Program Implication. Immediate corrective feedback was provided at each drill procedure throughout the training. Corrective feedback included correcting errors by immediately presenting the correct answer and then requiring the student to repeat the sequence or drill correctly. Consistent corrective feedback procedures were used, which enabled the student to be successful on repeated attempts; these procedures were present throughout the program with the goal that students would ultimately be able to self-correct. Students also received daily points which could be saved and used for extrinsic rewards available within the LearningRx center.

Research on the LearningRx Intervention

The LearningRx training program involved conceptually learning and understanding specific principles in order to demonstrate the learned concepts, and was designed to be generalizable to other aspects of life. The LearningRx procedures consisted of tasks that emphasized auditory or visual processes which required attention and reasoning. The individual was trained to develop appropriate strategies to complete tasks through structured experiences provided by the procedures (LearningRx, n.d.). The training used a synergistic “drill for skill” and meta-cognitive approach to developing cognitive skills (LearningRx, n.d.). The model was based on a hierarchical approach and designed to specifically target one or more specific cognitive skills. The tasks made repeated demands on a person’s abilities and progressively increased those demands (LearningRx, n.d.). LearningRx (n.d.) believed that in order to improve cognitive functioning, the targeted functions must be worked on repeatedly, and once an individual had “mastered” a task, higher level tasks targeting the same cognitive function must be available.

The LearningRx program, explained in greater detail in chapter three, included several different training programs. Each program incorporated either the Pro training, which included one-on-one training with a certified trainer five days a week, or Partner training which involved the parent or other person in some of the training at home. To date, there have been three independent researchers who have conducted research on the LearningRx Training Program: Marachi (2006), Luckey (2007), and Carpenter (2009). Two studies were conducted for the LearningRx Company and were published only on the company website, and one study was conducted as part of a doctoral dissertation, also found published on the company website. All the studies showed evidence of significant differences from pre- to post-test as a result of cognitive skills training with school aged children.

The first study conducted by Roxana Marachi, Ph.D., from California State University, Northridge, Department of Child and Adolescent Development, was based on an independent analysis of 2005 pre- and post-test results from 1265 LearningRx participants across 31 LearningRx centers throughout the U.S. (Marachi, 2006). Data was compiled at the LearningRx headquarters in Colorado Springs, Colorado, and consisted of students aged 4 to 22 with a mean age of 11.5 years and standard deviation of 3 years (Marachi, 2006). In t-test analysis of 30 cognitive skills measured pre-/post-intervention, each measure indicated increased test scores after LearningRx training. The author specifically analyzed 9 core cognitive skill areas (Visual-Auditory Learning Memory (LTM), Spatial Relations (visual processing), Concept Formation (logic and reasoning), Numbers Reversed (STM/WM), Pair Cancellation (processing speed), Sound Awareness (auditory processing), Segmenting Nonwords (auditory processing), Blending Nonwords (auditory processing), and Auditory Analysis (auditory processing)) which indicated an increase had been attained at post-test of 2.58 to 5.48 average years of improvement across the skills (Marachi, 2006). Each of the differences were significant at the .001 level of significance, with t-scores ranging between 13.81 and 40.62, indicating gains in cognitive skills after LearningRx (t-scores above 1.96 are considered to represent significant differences; Marachi, 2006).

Some limitations of this study were that no matched control group for comparison was utilized, data for the study was collected by the company itself, and the author did not control for demographic variables or specific age groups.

A second study was conducted by Alicia Luckey, M.A. (2007) as a doctoral dissertation project. The study focused on students whose scores fell in the lowest 25% of the sample, with analysis of change in age equivalents and percentile ranking using pre- and post-test scores from the Woodcock Johnson Tests of Cognitive Abilities, Third Edition (WJ-III COG) and the Woodcock Johnson Tests of Achievement, Third Edition (WJ-III ACH). The study included 2,080 students who completed the program in 2006. Students were enrolled in one of ten programs and ranged in age from 4 years to 19 years, 3 months, with a mean age of 11 years, and standard deviation of 3 years (Luckey, 2007). The Luckey (2007) study improved upon the Marachi (2006) study by accounting for elapsed time between pre- and post-test scores in the final analyses and used repeated measures analyses of variances (ANOVA) statistical analyses to account for the same students taking the same test at both pre- and post-test. Additionally, each program was analyzed in detail. Sixteen repeated measures ANOVAs were conducted to test for differences between pre- and post-test age equivalencies. A growth of 5 or more years was present in all areas of Auditory Processing as well as in Visual Processing, with sub-tests of Visual Auditory Learning and Concept Formation showing growth above 4 years; Pair Cancellation, Numbers Reversed, and Auditory Working Memory showing growth above 3 years; Spelling of Sounds, Word Attack, Decision Speed, and Retrieval Fluency showing growth above 2 years; and remaining sub-tests showed growth of 1 or more year (Luckey, 2007). All sub-tests analyzed were significant at the $p<.001$ level of significance. Analyzing percentile ranks, Luckey (2007) found that changes in percentile ranks ranged from 16.4 (Processing Speed) to 30.7 (Auditory Processing), and that all skills (with the exception of Processing Speed) were improved upon from below average range to average range. Though this study showed growth of at least 1 year as well as changes in percentile ranks, there were limitations to the study. Results must be evaluated cautiously and could not be generalized as results were based upon age equivalent scores and percentile ranks and no standard scores were analyzed for pre- and post-test scores. Also results could not be generalized to those performing in average or above average range as the study was focused on students in the lowest 25% of the sample. The study also utilized the same test when assessing pre- and post-test results, and though a repeated measure ANOVA was conducted, some effect of test-retest effect would be present.

A third study conducted by Dick Carpenter, Ph.D. (2009) from the University of Colorado, expanded the research on the LearningRx programs by including a control group. The study utilized a pre-post control group design and consisted of problem readers between 6 and 16 years of age living in the Colorado Springs, Colorado area. The treatment group included 31 students, and the control group included 30 students whose parents or guardians elected not to enroll in the LearningRx program after pre-testing (Carpenter, 2009). Mean age of students in the control group was 10.63 years (SD=2.78), and mean age of students in the treatment group was 11.58 years (SD=2.60). Though Carpenter (2009) did not account for the time elapsed between pre- and post-test, he did include covariates such as race, age, gender, and disability in the regression analyses results. Due to small group sizes, race/ethnicity were coded in two categories (white and minority), and disability was self-reported by parents/guardians (to include Attention Deficit Disorder, Autism/Asperger's/Pervasive Developmental Disorder, Dyslexia/Reading Problem, Learning Disability, Mental Retardation, Speech/Language Disability; Carpenter, 2009).

Results indicated that raw score points for the treatment group were different than the control group participants ranging from one and a half to six raw score points on Logic and Reasoning, Short-Term Memory, Word Attack, Phonemic Awareness, and Long-Term Memory. With Visual-Auditory Learning (Long-Term Memory) skills, the treatment group made significantly fewer mistakes compared to the control group (decrease in number of errors by little more than 6 points). Regarding Concept Formation (Logic and Reasoning), the treatment group had greater growth of almost 3 points. Also with this test, race/ethnicity proved to be a significant variable, with white students reported to have 5.5 points lower growth scores than minority students. For Numbers Reversed (Short-Term Memory), the treatment group showed significantly greater growth compared to the control group (3 points greater). For Word Attack and Sound Awareness tests (Decoding and Auditory Processing, respectively), the treatment group showed increase in scores that were 5 points greater than the control group (Carpenter, 2009). The coefficient of determination (R2) values averaged 20 percent, meaning 66 percent to 80 percent of the variance in scores were unexplained by the variables included in the analyses. This was to be expected as there were many variables which were not measured or included in this study that would have affected test scores. This included other types of instructions (school, tutoring) that students may or may not have received during the intervention, health and nutrition variables, or home/school environments. The study also utilized a small sample and was not randomized. Another limitation of the aforementioned studies were that all three researchers were assessing viability of the LearningRx program with school aged children who were experiencing difficulty with school work making it difficult, therefore, to generalize results to an adult population or non-academic population.

Based on positive intervention results in children with learning difficulties, and the time-limited implementation of the program, LearningRx appeared to be a possible intervention to help fill the gap for a time-limited rehabilitation tool for TBI. In 2010 LearningRx (2010b) conducted a pilot study to address cognitive functioning in 15 volunteer active duty service men and women suffering from TBI at the Washington State Department of Veterans Affairs and the Warrior Transition Battalion (WTB), Joint Base Lewis-McChord (JBLM) in Washington State. This project was the first to address the possibility of the LearningRx program's utilization as a rehabilitation tool for cognitive impairment in TBI patients. The program included 6 hours of intensive one-on-one (three hours) and online (three hours) cognitive skills training per week (LearningRx, 2010b). Results of this pilot program showed that WTB soldiers who remained in the program (11 of the original 15 volunteers) gained improvement in all seven areas of cognitive functioning (Processing Speed, Auditory Processing, Short-term Memory, Long-term Memory, Logic and Reasoning, and Visual Processing), including elimination of symptoms such as memory loss, poor concentration and difficulty organizing thoughts (LearningRx, 2010b). Average of 13 standard score points were gained across the 7 areas of cognitive functioning between pre-test and post-test, with greatest standard score gains in Processing Speed (23 points), Short-Term Memory (14 points), Auditory Processing (13 points), and Long-Term Memory (12 points; LearningRx, 2010b). Though the pilot study showed gains in skills, results must be cautiously interpreted as the sample utilized was small making generalizability difficult, as well as possible bias in analysis of the results as they were conducted by the LearningRx company, a company with personal stakes in the results, and not the Washington State

Veterans Affairs Department, a more objective party in the study. Also, the format of the program was altered (introduction of an online component) which may have altered results of the intervention program.

Based on results from the LearingRx pilot study at the Washington State Veterans Affairs Department, and results with children experiencing learning difficulties, this researcher wanted to focus the current study on non-military, adult participants. Also, this researcher aimed to specifically assess the LearningRx program as a means to change memory functioning within a time-limited manner for individuals with TBI that would be in order with the short-term treatment requirements of today’s healthcare and insurance industries.

CHAPTER III

METHODOLOGY

Participants

The archival samples employed for this study originated from the LearningRx Company database which collected data on participants from LearningRx training centers across the United States. The original data provided by LearningRx was de-identified prior to being sent to this researcher by Ms. Tanya Mitchell, Vice President of Research and Development. The data included 65 participants from 28 different centers across the United States. As this sample also included children below the age of 18 with TBI, the pool was narrowed down to 39 participants who met the following criteria: age 18 and over, enrolled in either ReadRx or ThinkRx intervention program, suffered a traumatic brain injury (either by self-report or medically diagnosed), and were evaluated using the Woodcock-Johnson Tests 3rd Edition (WJ-III) both prior to implementation of the intervention and at the conclusion of the intervention program so as to compare pre- and post-test scores to assess for changes in memory.

Due to limitations on the type of information provided by the LearningRx program (age, gender, and test scores), complete demographic information was not available for comparisons in this study (socioeconomic status, education, race). Demographics for the participants were as follows: 29 male and 10 female participants (n=39), mean age of 30 years (SD=9 years), with ages ranging from

19 to 52 years of age. Of the overall 39 participants, 15 were assessed for short-term memory (Numbers Reversed) and long-term storage and retrieval (Visual Auditory Learning; 12 males, 4 females) only, and 23 of the 39 were assessed for short-term, long-term storage and retrieval, and working memory (17 males, 6 females) on the WJ-III (see Table 2). It was unclear why differences in the assessment of Long-Term Storage and Retrieval, Short-Term Memory, and Working Memory among the participants were present. It was hypothesized this may be due to various reasons such as error in testing results, human error in forgetting to input the data, or tester decision not to test those specific subtests on the Woodcock Johnson-III. The small sample size may be due to limited number of adults who participated in the intervention as it was primarily provided for children who suffered from learning difficulties. In addition, of the 39 participants who tested in multiple sub-tests, the following participated in ReadRx (n=43) and ThinkRx (n=58).

Procedures

The CEO and founder of the company, Dr. Ken Gibson, O.D., was contacted regarding this study asking for permission to access their archival databank. Dr. Gibson referred this researcher to Tanya Mitchell, VP of Research and Development. After approval from LearningRx regarding the objective of the study, Ms. Mitchell sent this researcher pre-collected data points on participants already diagnosed with TBI who had participated in the LearningRx program.

Participants were recruited to the various LearningRx centers through general company marketing campaigns (television advertisements, magazine advertisements, radio advertisements, word of mouth) or through referrals. Each of the study participants completed general demographic information (Appendix A), pre- and post-testing of the Woodcock-Johnson-III, and completed either the ThinkRx or ReadRx program from LearningRx. Participants completed either the ThinkRx or ReadRx program based upon pre-intervention test results (did the participant need additional work on his or her reading skills), and both programs were included in this study. Informed consent forms were not signed at LearningRx as they were a private company providing services. It was also assumed that as LearningRx was a private company, individuals and/or their families utilizing its product were making an informed decision to go to the company to receive services, which they paid for with their own money. To protect the identity of participants within the program, each LearningRx center de-identified data at the time test results were put into the database (assigning arbitrary numbers to the participants). This data was further de-identified by Ken Gibson before being sent to this researcher. The twice de-identified data was sent to this researcher electronically via an excel spreadsheet, thus it will be stored on a password encrypted flash drive for a period of 7 years. At that time the file will be properly deleted from the flash drive.

This researcher also underwent Institutional Review Board (IRB) procedures at the Adler School of Professional Psychology on February 23, 2011 and was fully approved by the board on May 5, 2011 (Appendix C). The IRB process involved completing an application discussing a non-technical abstract, the research design (hypotheses, type of research design, data collection), step-by-step description of participants recruitment, detailed use of informed consent (if applicable), procedures used to protect confidentiality of participants and data, anticipated risks and benefits of the proposed study, and inclusion of contact information for agency and owner of the data set. As the study utilized archival data for human participants, the IRB board expressed concern regarding the lack of signed informed consent from the LearningRx Company for the use of data by an external researcher not affiliated with the LearningRx Company. To address this concern, the IRB committee was informed that the data was twice de-identified before being sent to this researcher. This researcher also created a data use agreement that was signed by this researcher, Dr. Robert Baker (dissertation chair), and Ms. Tanya Mitchelle (see Appendix D). Participants were not contacted post-hoc as it was determined in order to do so, specific contact information would have to be located and compiled into a central document in order to obtain post-hoc consent. In turn, this would purposely create potential harm and identification of specific participants by this researcher and the LearningRx Company. Current data obtained by this researcher ensured that neither this researcher nor the LearningRx Company or its centers would be able to readily identify participants in this study.

Instrument Used

Each trainee was assessed both pre- and post-intervention on up to 11 areas of cognitive processing according to scales on the Woodcock-Johnson III Tests of Cognitive Abilities (WJ-III COG), and Woodcock-Johnson III Tests of Achievement (WJ-III ACH). See detailed information on the WJ-III below. Average length of time between testing was five months (indicating possible practice effect issues), and testing was administered and scored by staffs (Center Directors and Assistant Directors) who were certified evaluators. LearningRx staff were trained and certified for evaluations by the LearningRx Company who invested in training through psychometricians at the time each Director and Assistant Director underwent training to operate a LearningRx center. Demographic information was collected through the LearningRx Pre-Assessment form (Appendix A) administered at the time participants were enrolling in the LearningRx program; however, age, sex, and cause of cognitive problem (TBI) were the only demographic information provided by the company for this study. Thus, neither injury severity nor additional demographic information/variables were available for assessment in this study.

Design Considerations

Repeated Testing. Repeated testing was implemented as a means to test for changes in short-term memory, long-term storage and retrieval, and working memory. A problem that was raised with this method was that of practice effects, defined as improvement in test performance due to repeated exposure to test materials. Repeated testing may not only be a source for potential error when looking at statistical results (Duff, et al., 2007), but may also indicate improvement from the intervention when there may not have been any. There were two studies mentioned in the *Woodcock Johnson-III Technical Manual* (McGrew & Woodcock, 2001) supporting test-retest reliability of the reported measures at extended retest intervals (see detailed discussion under the Woodcock Johnson-III section below). An attempt to identify specific literature pertaining to practice effects for the Woodcock Johnson-III on various search engines was unsuccessful by this researcher and the Adler School librarian. Therefore, the extent of practice effects for the specific tasks of the WJ-III could not be made, and general statement regarding practice effects was conducted.

Studies reviewed regarding practice effects in general involved minimal time between administration (less than three months; Falleti, Maruff, Collie, & Darby, 2006). Falleti et al. (2006) investigated the presence and magnitude of practice effects at very brief test-retest intervals (i.e., ten minutes and one-week) in a group of healthy young adults and practice effects at a longer test-retest interval (i.e., one month) in another group of healthy young adults using the CogState battery. They found that when tested ten minutes apart, performance generally improved from the first to the second assessment, but after the second assessment, the performance of the first group stabilized and did not improve further on any of the cognitive measures. They also found that test performance did not worsen over the first four assessments, which would have occurred had the participants become fatigued or lost motivation. When the time between tests was increased to one week, practice effects were evident on only two of the eight measures. When the test-retest interval was increased to one month, no significant practice effects were observed and the amount of change on all of the measures was small in magnitude. This study suggested that perhaps practice effects may be dependent on the number of times an individual performs any particular test battery. Also, the results were generally consistent with Benedict and Zgaljardic (1998) who stated that "the magnitude of practice effects usually decreases as the length of time between tests is increased" (as cited in Falleti et al., 2006, pp 1107). Though the use of an ANCOVA and partial correlation allowed this researcher to control for pre-intervention levels of functioning when looking at post-intervention levels, practice effects cannot be inferred in this study as no control group was utilized to help assess this effect.

Regression to the Mean. One must also consider regression to the mean when comparing test scores from two different points of time. This pointed to the likelihood that regardless of the score obtained at initial testing, the score obtained at time of second testing would be closer to the mean score of the test (Cohen, 2008). Thus, in this study regression to the mean implied that it was statistically unlikely that the exact same participants would again perform poorly or highly on the post-test as they had done on the pre-test. This means that collectively, those who scored “low” on the pre-test for each sub-test, would no longer score in the “low end” at post-test and would increase in performance, regressing towards the mean. The same can be said for those who performed in the “high end” at pre-test, as they would probably perform poorer in the post-test when considered as a group, again regressing towards the mean. Due to this phenomenon, it would be important to have a control group and compare results across groups so the real effect of an intervention program could be studied, as regression to the mean indicated that an improvement would happen irrespective of an intervention program. Though an ANCOVA was used with the change between baseline and follow-up as the outcome variable, no control group was utilized in this study so true effect of the intervention program could not be inferred.

Age. As stated above, individuals at both ends of the age spectrum (young and old) had a greater tendency to suffer a TBI than young adults (Faul et al., 2010; Kent, 2011). In the case of young children, damage occurred to the developing brain system may not present as severe at an early age, but may show effects as the child aged by showing lags in development and unexpected deficits. For older adults the concern was that acquired brain injury, along with an already aging and perhaps less flexible brain would make it more difficult to work with the acquired deficits (Senathi-Raja, Ponsford, & Schönberger, 2010). For purposes of this study, the focus was on young and older adults.

Overall, younger adults showed better improvements compared to older individuals for it was hypothesized that younger brains recovered more completely than older ones (Whyte, 1990). This was not only true when old and young individuals were compared, but also when comparing relatively closely spaced aged groups. Teuber (1975) examined the rates of recovery for a variety of different functions in soldiers who had suffered penetrating brain injuries. He found that 17- to 20-year olds made better recoveries than 21- to 25-year olds, who had better recoveries than individuals aged 26 and over. This was true for motor deficits, somatosensory deficits, visual field defects, and aphasia (as cited in Sohlberg & Mateer, 2001).

In older adults, falls were the most common cause of injury. Older adults were also, due to age, expected to have declines in cognitive abilities. Senathi-Raja, Ponsford, and Schönberger (2010), examined the association of age and time post injury with cognitive outcome 5-22 years post-TBI, in relation to matched uninjured controls. Results indicated that older age was associated with poorer performance across all cognitive domains, after accounting for normal age-related cognitive declines. Senathi-Raja, Ponsford, and Schönberger (2010) believed that poor outcome may be due to the older brain's decreased capacity to compensate during initial recovery or greater deterioration beyond the period of initial recovery due to reduced plasticity in the aging brain. Klein, Houx, and Jolles (1996) tested the hypothesis that TBI accentuated the effects of normal biological aging in a mild to moderately injured closed head injury population. On a perceptual interference task, the performances of injured middle-aged individuals were disproportionately worse than that of older injured individuals, and more comparable to that of the older control group. However, these findings were questionable as only a single test measure was used in the cognitive assessment, and there was no method for comparing educational background or estimating general intelligence. Overall, data from Klein, Houx, and Jolles (1996), Senathi-Raja, Ponsford, and Schönberger (2010), and other studies (Richards, 2000 as cited in Sohlberg & Mateer, 2001) suggested that older individuals were more vulnerable to the effects of brain injury. However, older adults had a more stable life style, better coping skills, better support, and fewer life demands than younger adults which would help older adults to achieve positive rehabilitation outcomes.

Gender. Despite the fact that males were twice as likely as females to sustain a TBI, fatality rates following TBI were reported to be greater for females compared to males (Tsushima, Lum, & Geling, 2009). In one study utilizing the Immediate Post-Concussion Assessment and Cognitive Testing battery with 79 college athletes two to eight days post-injury found concussed females performing significantly worse on visual memory compared to concussed males (Covassin, Swanik, & Sachs, 2007). However, in another study conducted by Groswasser, Cohen, and Keren (1998), female TBI patients had a better outcome than males in terms of work capacity following an inpatient rehabilitation program. Groswasser et al. (1998) concluded that this may have been related to progesterone functioning as a central nervous system (CNS) protector. A study conducted by Kraus, Peek-Asa, and McArthur (2000) of patients with moderate to severe TBI found that when mortality rates were examined according to the following age intervals: 16-29, 30-49, and 50+ years, women had lower mortality rates than men in the 16-29 year category. However, this was reversed in the other two age groups.

A meta-analysis conducted by Farace and Alves (2000) found that outcome after TBI was worse in women than in men, with a mean effect size of -.15 (negative sign indicating women having a worse outcome). They postulated that this was due to differences in premorbid factors, symptom reporting, injury factors, cognition and psychosocial factors, gender differences in the brain, sex hormones, and treatment effects.

One problem encountered in previous studies pertaining to gender was that of unequal sample sizes. This was problematic in that as group sizes became more discrepant, the assumptions of homogeneity of variance became more important (Farace & Alves, 2000). The homogeneity of variance was important because when group sizes were greatly discrepant; the larger group would be over-classified, thus causing misleading conclusions for a hypothesis test (Cohen, 2008). The other issue was that of age-matching between the genders (Slewa-Younan et al., 2004). Slewa-Younan et al. (2004), attempted to investigate sex differences in injury severity and outcome measures in an equally numbered, age-matched sample of patients with severe TBI who were admitted to a rehabilitation unit. They concluded that women with TBI were more likely than men to resume their pre-injury occupational and education levels, as predicted by Groswasser et al. (1998). Results found by Slewa-Younan, et al. (2004) differed from Kraus et al (2000) and Farace and Alves (2000), both of whom reported better outcome for men compared to women. This may have been due to the fact that the latter two studies did not match subjects by age. Due to the breadth of findings, further investigation in performance on assessment testing by males and females following a TBI is needed. Also, when attempting to search for specific studies involving memory and gender, this researcher was unable to do so.

Woodcock Johnson-III

The Woodcock-Johnson III (WJ-III; Woodcock, McGrew, & Mather, 2001) consisted of two distinct, co-normed batteries: the WJ-III Tests of Cognitive Abilities (WJ-III COG) and the WJ-III Tests of Achievement (WJ-III ACH). These test batteries were comprised of a wide age-range, comprehensive system for measuring general intellectual ability (*g*), specific cognitive abilities, oral language, and academic achievement (Schrank, McGrew, & Woodcock, 2001). However, for purposes of this project focus was on the WJ-III COG.

In administering a standard battery of the WJ-III COG (Woodcock, McGrew, & Mather, 2001), seven cluster scores as well as an overall General Intellectual Ability (GIA) score was provided (McGrew, Woodcock, & Ford, 2009). The seven cluster scores included: Comprehension-Knowledge (*Gc*), Long-Term Retrieval (*Glr*), Visual Spatial Thinking (*Gv*), Auditory Processing (*Ga*), Fluid Reasoning (*Gf*), Processing Speed (*Gs*), and Short Term Memory (*Gsm*). The GIA score is a differentially weighted overall *g* score rather than a summation of particular subtest scores, and was available for both the standard and extended batteries. The GIA-standard battery included the following subtests: (a) Verbal Comprehension (*Gc*), which tapped into the narrow abilities of lexical knowledge and language development; (b) Visual-Auditory Learning (*Glr*), which tapped into the narrow ability of associative memory such as learning novel symbols which were associated with words and the examinee was to remember the associations while simultaneously learning new associations; (c) Spatial Relations (*Gv*), which tapped into the abilities of visualization and spatial relations such as mentally manipulating objects to determine which ones fit to form a puzzle; (d) Sound Blending (*Ga*), tapped into the synthesis portion of phonetic coding such as listening to a series of sounds and blending them to form a whole word; (e) Concept Formation (*Gf*), tapped into induction such as learning rules and being able to apply them to novel problems; (f) Visual Matching (*Gs*), tapped into perceptual speed such that examinee must quickly and accurately locate two numbers from an array of numbers that were the same; (g) Numbers Reversed (*Gsm*), tapped into working memory, such that the tester was asked to repeat a series of numbers in reverse order from that originally given (McGrew, Woodcock, & Ford, 2009; Schrank, McGrew, & Woodcock, 2001; Schrank & Wendling, 2009).

Cattell Horn Carroll Theory of Intelligence. The WJ-III (Woodcock, McGrew, & Mather, 2001) was based on the Cattell Horn Carroll (CHC) Theory of Intelligence which integrated Raymond Cattell and John Horn's theory of fluid *(Gf)* and crystallized *(Gc)* intellectual abilities (Cattell, 1941; Horn 1965; Schrank, McGrew, & Woodcock, 2001). The CHC theory also integrated John Carroll's three-stratum theory (1993; Schrank, McGrew, & Woodcock, 2001). Carroll developed the idea that human cognitive abilities could be conceptualized hierarchically as followed: Stratum I included 69 specific, or narrow abilities, which were related to Stratum II; Stratum II included ten broad cognitive abilities which included Fluid Intelligence, Crystallized Intelligence, General Memory and Learning, Broad Visual Perception, Broad Auditory Perception, Broad Retrieval Ability, Broad Cognitive Speediness, and Processing Speed; and Stratum III which included one overarching, broad ability referred to as General Intelligence (g; Carroll, 1993; Schrank, McGrew, & Woodcock, 2001).

The ability to measure each factor provided greater generalizability (validity) of the CHC factor score to other situations. For the majority of factors, each broad CHC cluster was comprised of two qualitatively different narrow, or Stratum I, abilities. For example, in the WJ-III COG, the Long Term Retrieval *(Glr)* cluster included a measure of associative memory (Visual-Auditory Learning) and a measure of ideational fluency (Retrieval Fluency) and the Visual Spatial Thinking *(Gv)* cluster included a measure of visualization (Spatial Relations) and a measure of visual memory (Picture Recognition; Schrank, McGrew, & Woodcock, 2001).

Broad Cognitive Abilities. The WJ-III was derived from the seven most measured areas of the CHC Theory (McGrew, Woodcock, & Ford, 2006; Schrank, McGrew, & Woodcock, 2001), which included: Processing Speed (*Gs*), Short-Term Memory (*Gsm*), Long-Term Retrieval (*Glr*), Visual Processing (*Gv*), Fluid Reasoning (*Gf*), Auditory Processing (*Ga*), and Comprehension-Knowledge or Crystallized Knowledge *(Gc*). Thus, the WJ-III remained to be the only test tapping all seven abilities mentioned by measuring two separate, narrow abilities that load onto each broad ability (McGrew, Woodcock, & Ford, 2006). Each broad ability was defined and discussed separately below. The narrow ability Working Memory was discussed in the section addressing Short-Term Memory *(Gsm)*, the broad ability under which it was identified.

Comprehension-Knowledge (Gc). Comprehension-Knowledge *(Gc)*, also known as Crystallized Intelligence, was the ability to understand ideas and express one's thoughts with words. It represented the breadth and depth of knowledge of a culture and the ability to reason using previously learned knowledge or procedures. This factor was influenced by culture and formalized education (McGrew, Woodcock, & Ford, 2006; Schrank & Flanagan, 2003; Schrank & Wendling, 2009).

Fluid Reasoning (Gf). Fluid Reasoning *(Gf)*, also known as Fluid Intelligence, was the ability to reason, draw inferences, problem solve, and understand implications and concepts using unfamiliar information or novel procedures. This included basic reasoning processes and manipulating abstractions, rules, and logical relations. Fluid Reasoning tests used nonverbal stimuli, but also integrated verbal and nonverbal thinking (McGrew, Woodcock, & Ford, 2006; Schrank & Flanagan, 2003; Schrank & Wendling, 2009).

Visual Spatial Thinking (Gv). Visual Spatial Thinking *(Gv)* was the ability to process visual information ranging from simple perceptual tasks to higher level visual and cognitive processes. It was the ability to perceive, analyze, synthesize and think with visual patterns and the ability to store and recall visual representations. Visual Spatial Thinking incorporated fluidity of thought while utilizing visual stimuli, including memory, when visual stimuli were present (McGrew, Woodcock, & Ford, 2006; Schrank & Flanagan, 2003; Schrank & Wendling, 2009).

Auditory Processing (Ga). Auditory Processing *(Ga)*, was the ability to recognize differences and similarities between spoken sounds, including the ability to separate and combine spoken sounds. Auditory Processing and Working Memory interact with phonemic awareness tasks. For example, when asked to remove the middle sound of a word, the remainder of the sounds must be remembered. Tasks requiring an individual to reverse sounds or repeat sounds heard also incorporated working memory (McGrew, Woodcock, & Ford, 2006; Schrank & Flanagan, 2003; Schrank & Wendling, 2009).

Memory (Gsm and Glr). Short-term Memory *(Gsm)*, Long-Term Retrieval and Storage *(Glr)*, and Working Memory (WM, included within *Gsm*), all required an individual to recall information, with working memory being tasked to manipulate the information being recalled or temporarily stored. *Gsm* was the ability to store information temporarily in mind and mentally manipulate phonological stimuli to produce a response (Schrank & Flanagan, 2003). Once an individual used what was being held in immediate awareness to perform the new task, the information held was either stored or lost (Mather & Woodcock, 2001). This was considered to be an important automatic process necessary for general cognitive efficiency (Schrank & Flanagan, 2003). Though it was possible that *Gsm* may include other processes, it was mostly identified with memory span (Mather & Woodcock, 2001).

Glr was defined as the ability to think regarding the learning of new information and effectively storing and retrieving that information through association over a period of extended time (i.e., childhood; Schrank & Flanagan, 2003). Many narrow abilities were included in this broad category, such as associative memory, ideational fluency, meaningful memory, associative fluency, expressional fluency, naming facility, and word fluency (Mather & Woodcock, 2001). As stated earlier, *Glr* should not be confused with *Gc* (Crystallized Intelligence), *Gq* (Quantitative Reasoning), and *Grw* (Reading and Writing Ability) as they too are part of a person's store of acquired knowledge (Mather & Woodcock, 2001; McGrew, 2001). As such, *Gc*, *Gq*, and *Grw* represented what was actually stored in long term memory, whereas *Glr* represented the efficiency by which information was initially stored and later retrieved from long-term memory (Mather & Woodcock, 2001; McGrew, 2001). The long-term storage process began with the process of transferring information from immediate awareness to the stores of declarative and procedural knowledge (Mather & Woodcock, 2001). The amount of time that lapsed between the initial task performance and recall of that information was not particularly important in defining *Glr* (Mather & Woodcock, 2001; McGrew, 2001), as long as the information was not held in immediate awareness (Mather & Woodcock, 2001). McGrew (2001) referred to a fishing net analogy to help explain this difference: *Glr* was the process by which individuals efficiently added new nodes and links to their "fishing net" of stored knowledge to then later use these additional nodes and links when retrieving information. *Gc* was represented by the interconnected nodes of the fishing net. Each node represented an acquired piece of information, and the filaments between nodes (with many possible filaments leading to and from multiple nodes) represented links between different bits of stored information. Thus a person high in *Gc* ability would have a rich "fishing net" of information represented by many meaningfully organized and interconnected nodes. *Glr* would be the process of adding new nodes and then later conducting a "hard target" search to locate and extract/retrieve information in different nodes; *Glr* would not be made up of the content or the node. Thus, processing and attention played important roles in memory capacity (McGrew, Woodcock, & Ford, 2006; Schrank & Wendling, 2009).

Processing Speed (Gs). Processing Speed *(Gs)*, was the ability to find figures, make comparisons and carry out other simple tasks that involved visual perception, speed, and accuracy. It was the ability to work quickly and accurately to complete tasks and was typically measured using timed paper and pencil tasks

(McGrew, Woodcock, & Ford, 2006; Schrank & Flanagan, 2003; Schrank & Wendling, 2009).

Standardization

The Woodcock Johnson-III (Woodcock, McGrew, & Mather, 2001), was co-normed on 8,818 individuals representative of the United States as measured by the 2000 Census. All participants were administered both the WJ-COG and WJ-ACH so normative data for both sections would be based on a common sample. School aged children and adolescents (kindergarten through 12th grade) made up the majority of that sample (n = 4,784), with preschool age children (n = 1,143), undergraduate and graduate students (n = 1,165), and adults (n = 1,843). The sample was stratified based on 10 specific community and participant variables including age (24 months to age 90 years or older), community size, gender, race, type of school, education, and occupational status of adults (McGrew & Woodcock, 2001; Schrank, McGrew, & Woodcock, 2001).

Reliability. Reliability was defined as the consistency of a measure internally (within itself), over time (test-retest), with an alternative form of the measure (alternate form), and when used by others (inter-rater reliability; Cohen, 2008). A reliability score of .80 or higher was considered to be standard as a high reliability for tests used for individual assessment (McGrew & Woodcock, 2001; McGrew, Woodcock, & Ford, 2006; Schrank, McGrew, & Woodcock, 2001). The Standard Error of Measurement (SEM) was an estimate of the amount of error associated with an obtained score, and was directly related to the reliability of a score (Cohen, 2008).

The internal consistency reliability coefficient for the GIA Standard Battery (the seven subtests discussed above) in the WJ-III COG was .97 (SEM 2.60). Internal Consistency on the seven clusters associated with the CHC theory ranged from .81-.94 (SEM range of 3.64-6.51; Schrank, McGrew, & Woodcock, 2001). Though these were strong reliabilities for individual tests, it was recommended that WJ-III cluster scores be used for interpretation as they were based on two or more tests and possessed consistently, therefore, higher reliabilities (Median r= .90-.97, Median SEM (SS)= 2.60-4.86; McGrew, Woodcock, & Ford, 2006; Schrank, McGrew, & Woodcock, 2001). The Visual-Auditory Learning test had a median reliability of .86 in the 5-19 age range and .91 in the adult range (Mather & Woodcock, 2001). The Numbers Reversed test had a median reliability of .86 in the 5-19 age range and .90 in the adult range (Mather & Woodcock, 2001). The Auditory Working Memory test had a median reliability of .88 in the 5-19 age range and .84 in the adult range (Mather & Woodcock, 2001).

Validity. When discussing validity, one referred to the degree to which an assessment measured what it was supposed to measure. There are several different types of validity: content, construct, and concurrent validity. Content validity was constructed from a theoretically based test design. It was addressed through specification of a master test- and cluster-content revision based on the CHC theory (Schrank, McGrew, & Woodcock, 2001). In the WJ-III COG each test was designed to be a primary measure of a narrow ability (or Stratum I ability in CHC theory), and to ensure that each item in test measured the same narrow ability or trait, fit criteria based on the Rasch model (which stated that the comparison of two individuals who were tested should be independent of which items were included in the tests; Choppin, 1983) were used during item selection (Schrank, McGrew, & Woodcock, 2001).

The construct validity was based on confirmatory factor-analytic (CFA) models as the design of the WJ-III was an extension of the previously validated broad CHC ability structure of the Woodcock Johnson-Revised in 1989 (McGrew, Woodcock, & Ford, 2009; Schrank, McGrew, & Woodcock, 2001). Almost all tests from the WJ-III COG load onto one factor, indicating that what was being measured was relevant to the overall construct of the cognitive ability. The correlations between related clusters were higher than correlations between clusters that were not related (r= .20-.60), indicating that each cluster was measuring distinct but related abilities (Schrank, McGrew, & Woodcock, 2001).

Concurrent validity had shown that the General Intellectual Ability (GIA-Std) scores had correlations ranging from .67 to .76 across several samples, and with full scale or composite scores from the Wechsler Preschool and Primary Scale of Intelligence-Revised (WPPSI-R; Wechsler, 1989), the Wechsler

Intelligence Scale for Children-Third Edition (WISC-III; Wechsler, 1991), the Differential Ability Scales (DAS; Elliott, 1990), the Kaufman Adolescent and Adult Intelligence Test (KAIT; Kaufman & Kaufman, 1993), and the Stanford-Binet Intelligence Scale-Fourth Edition (SB-IV; Thorndike, Hagen, & Sattler, 1986). These correlations indicated that the g scores were valid measures of general intellectual ability (McGrew, Woodcock, & Ford, 2006; Schrank, McGrew, & Woodcock, 2001).

Test-Retest Reliability. Per McGrew and Woodcock (2001), the WJ-III underwent two test-retest studies (though particular authors for the tests were not identified). The first study reported test-retest correlations for 15 cognitive and achievement tests with retest intervals of less than one year to 10 years. The second study reported test-retest correlations for 17 achievement tests and 12 achievement clusters, all with a retest interval of one year.

The median reliabilities for the Acquired Knowledge tests (Synonyms/Antonyms, Academic Knowledge, Letter-Word Identification, Passage Comprehension, Applied Problems, and Spelling/Punctuation and Capitalization) ranged from .78 to .96, with a median of .88. For traits that were less stable over time, the reliabilities were slightly lower for the Thinking Ability tests (Memory for Names, Visual Closure, Incomplete Words, Concept Formation, and Analysis-Synthesis) with a range from .61 to .83, with a median of .73, and the Cognitive Efficiency tests (Visual Matching, Cross Out, Memory for Words, and Memory for Sentences) with a range from .60 to .86 and a median of .78. For detailed tables and distributions the reader is referred to McGrew and Woodcock (2001), Woodcock Johnson-III Technical Manual, pp. 38. For the 29 reliabilities reported for all ages within the WJ-III ACH tests and clusters, the median retest reliability was .94 (McGrew & Woodcock, 2001). Thus, these test-retest correlations supported the reliability for the reported measures across administrations at extended retest intervals.

Cognitive Rehabilitation Intervention

The LearningRx program consisted of two training programs, ThinkRx and ReadRx. Participants were placed in one of the two programs based on their pre-intervention test results and what the participants identified as their primary focus areas (LearningRx, 2005). Skills for both programs overlapped with one another; however, based on the program the participant was placed in, different areas were emphasized.

The LearningRx program consisted of tasks emphasizing both auditory and visual processes and required attention, reasoning skills, mental imagery, processing skills, and organizational skills (LearningRx, 2005). The participants learned to develop and implement appropriate strategies to complete a task during the structured training experience. This included a gradual increase in the level of challenging tasks to allow trainees early success. Cognitive skills were developed through the use of immediate feedback and highlighting the relevance of each procedure to the participant's individual life (LearningRx, 2005). Additionally, the use of a metronome during procedures helped trainees to gradually increase the fluency and speed of their response. This in turn helped to make cognitive functioning more automatic (LearningRx, 2005).

ThinkRx. The Think program focused exclusively on cognitive training drills. The program consisted of 60 minutes of one-on-one training with a certified trainer, 5 days per week for 12 weeks. The session was divided into 10 minutes of training spent on sound awareness and word attack skills (similar lessons to ReadRx but fewer in number) and rest of the session was spent on cognitive training drills. This format was followed until the participant completed the few ReadRx lessons, after which full 60 minutes was spent on cognitive training drills (LearningRx, 2005).

The ThinkRx training consisted of 24 procedures and over 1000 levels which were graded according to difficulty, and tasks became more complex (Carpenter, 2009; LearningRx, 2005; Luckey, 2007; Marachi, 2006). The pace was regulated by mastery of the task; therefore, the number of tasks completed during training sessions differed from student to student. However, administration of the procedures was standardized across trainers (Carpenter, 2009; LearningRx, 2005; Luckey, 2007; Marachi, 2006). While all cognitive skills were addressed, the program was individualized t primarily to address and strengthen deficient areas and enhance strengths (Carpenter, 2009; LearningRx, 2005; Luckey, 2007; Marachi, 2006). See Appendix E for example of ThinkRx procedure. The procedures required focused attention and progression through the levels, which required the attainment of increased speed and complexity of processing. Also, as the levels of the task were met, the sequenced demands were increased, making the task increasingly intense and challenging (Carpenter, 2009; Luckey, 2007; Marachi, 2006).

ReadRx. The Read program focused on both reading and cognitive abilities. The program consisted of 60 minutes of one-on-one training with a certified trainer, 5 days per week, for 20 weeks. The session was divided into 30 minutes of training focused exclusively on phonological processing drills and basic word attack skills and 30 minutes of training focused exclusively on cognitive training drills (LearningRx, 2005).

The ReadRx program included the 24 procedures of the ThinkRx program, as well as an additional 24 lessons of approximately 8 procedures each focusing on areas referred to as auditory processing, basic code, and complex code skills involved in reading rate, accuracy, fluency, comprehension, spelling, and writing (Carpenter, 2009; LearningRx, 2005; Luckey, 2007; Marachi, 2006). The training method was similar to ThinkRx. See Appendix F for example of ReadRx procedure.

Partner and Pro Formats. Participants also elected if they would like to utilize a Pro format or Partner format. Within the Pro format, all training was provided at the LearningRx center and was conducted by a certified trainer 5 days per week (LearningRx, 2005). The Partner format consisted of 3 days per week training at the center by a certified trainer as well as home based training on the remaining two days of the week provided by parents, caregivers or significant others. As part of the Partner program, a homework log was assigned to the home-based trainer with specific training exercises to be completed (LearningRx, 2005). The home-based trainers were asked to log hours spent training with the student. The start of each center-based session, the certified trainer reviewed the home training log and the student received points or fun dollars based on completion of home training to place toward their goal amount (LearningRx, 2005). Points or dollars were redeemed at regular intervals and exchanged for a prize. The differences between Pro versus Partner formats were not studied as possible separate variables by this researcher as the sample size for this study was small. The differences between Pro versus Partner formats were variables to be addressed in future studies.

Trainers

Certified. Certified trainers held a minimum of a four-year college degree and underwent 20 hours of direct training (LearningRx, 2005). This training included instruction on the intervention program, its contents and procedures, trainer policies, participating in 10 observations of a master level certified trainer, 10 guided sessions in which the trainee gradually increased the number of procedures in which they lead, information on research pertaining to the intervention program, and finally passing a trainer certification test (LearningRx, 2005).

Home-Based. Home-based trainers were used when the student was enrolled in the Partner program. Home-based trainers varied from mothers, fathers, grandparents, siblings, husbands, wives. The person identified as the primary home trainer would observe the first six sessions being conducted by the certified trainer (LearningRx, 2005). Home-based trainers also participated in the last 15 minutes of each session over the 12 or 20 weeks, in which the certified trainer observed the home trainer and student working on a drill, provided immediate feedback, and demonstrated procedures. Home-based sessions were recorded on a log and the student received incentives (points or fun dollars toward prize goals) for each hour of training completed at home (LearningRx, 2005).

Outcome Measures

The basic subtests administered from the WJ-III COG by LearningRx were as follows: Test 2: Visual Auditory Learning; Test 3: Spatial Relations; Test 5: Concept Formation; Test 7: Numbers Reversed; and Test 20: Pair Cancellation. Supplemental tests for the WJ-III COG included: Test 1: Verbal Comprehension; Test 4: Sound Blending; and Test 6: Visual Matching. Test 9: Auditory Working Memory could also be added to the WJ-III COG, which along with test 7 would provide a working memory clinical cluster score. Basic subtests administered from the WJ-III ACH consisted of: Test 13: Word Attack; and Test 21: Sound Awareness. Supplemental tests for the WJ-III ACH consist of: Test 6: Math Fluency; and Test 20: Spelling of Sounds.

For the purpose of answering the hypothesis questions in this study regarding changes in short-term memory, long-term storage and retrieval, and working memory, this study focused on the following three sub-tests: Test 7: Numbers Reversed (short-term memory); Test 2: Visual Auditory Learning (long-term storage and retrieval); and Test 9: Auditory Working Memory (working memory). These sub-tests assessed the following CHC clusters, *Gsm* and *Glr,* respectively (working memory was included under the broad category of *Gsm*). The Numbers Reversed test primarily measured short-term memory span, but it was also classified as a measure of working memory or attentional capacity (Mather & Woodcock, 2001; McGrew, Woodcock, & Ford, 2009). The test required the individual to hold a span of numbers in immediate awareness (memory) while performing a mental operation on it (reversing the sequence; Mather & Woodcock, 2001; McGrew, Woodcock, & Ford, 2009). *Gsm,* or short-term memory and working memory, was specifically assessed as this study was interested in possible memory improvements across all "stages" of memory as well as the idea that short-term memory and working memory were considered to be the first "stage" in the memory process and thus wanted to see if memory problems in TBI were due to processes occurring during short-term and working memory. The Visual-Auditory Learning test was a test of long-term storage and retrieval. The thinking ability test required the individual to learn, store, and retrieve a series of visual-auditory associations. The participant was asked to learn and recall pictographic representations of words that had been used to form sentences. Seven test stories were written with pictographic representations of words and preceding each story was an introduction page that presented four new pictographs (Mathers & Woodcock, 2001; McGrew, Woodcock, & Ford, 2009). This domain was also specifically studied as the study wanted to assess possible improvements in storage and retrieval process and if the intervention would imply larger changes in memory function with the Visual-Auditory Learning sub-test or the Numbers Reversed or the Working Memory sub-tests. The Auditory Working Memory test measured short-term auditory memory span, but could also be classified as a measure of working memory or divided attention (Mathers & Woodcock, 2001). The measure asked the participant to listen to a series that contained digits and words (i.e., dog, 1, she, 8, 2, apple). The participant then attempted to reorder the information, repeating the objects first in sequential order and then the digits in sequential order. This task required the ability to hold information in immediate awareness, divide the information into two groups, and shift attentional resources to the two new ordered sequences (Mathers & Woodcock, 2001; McGrew, Woodcock, & Ford, 2009).

Scoring was completed during testing to determine basal and ceiling levels. Raw scores were totaled and converted into age and grade equivalents, percentile ranks, and discrepancy scores with the use of Scoring Tables. Compuscore and Profiles Programs (computerized scoring and interpretation program used to derive scores for tests and clusters; Riverside Publishing, n.d.) were used for all other scoring. Two indices of general cognitive functioning (i.e., intelligence) were provided by means of the General Intellectual Ability (GIA) score and the Brief Intellectual Ability (BIA) score. Also provided was a breakdown of each individual subtest area. As mentioned previously, for purposes of this study only Visual Auditory Learning, Numbers Reversed, and Working Memory subtests were assessed. In this study, the independent variable was identified as participation in the LearningRx intervention program (even though no control group was included in the study), and changes in short-term memory, long-term storage and retrieval, and working memory, as measured by the WJ-III sub-tests, were identified as the dependent variables.

Data Analysis

Hypothesis 1 – Overall Improvements in Memory Score with LearningRx. The LearningRx program was predicted to provide significant positive change in cognitive ability post-intervention. The program was hypothesized to improve memory function in individuals with TBI, as evident by their test results pre-intervention to post-intervention based on the Woodcock

Johnson-III. This hypothesis was addressed with dependent t-tests to evaluate whether a significant difference existed between pre-intervention and post-intervention scores for each of the WJ-III sub-tests for Visual Auditory Learning, Numbers Reversed, and Working Memory, as well differences in pre-intervention and post-intervention scores for each of the ThinkRx and ReadRx programs (both overall and by sub-test). A major limitation of the study was the inability to assess severity of TBI, or the lack of a control group; therefore, results must be interpreted cautiously.

Hypothesis 2 – Effects of Gender on Memory Scores Using LearningRx. LearningRx Visual Auditory Learning, Numbers Reversed, and Working Memory scores post-intervention were predicted to not show statistically significant differences between male and female participants. This hypothesis was addressed with an analysis of covariance (ANCOVA) to understand if there were gender differences in post-intervention scores when the baseline measure (pre-intervention scores) were controlled for as a covariate. By using an ANCOVA and controlling pre-interventions scores as a covariate allowed this researcher to adjust for any pre-intervention effects on performance that may have occurred.

Hypothesis 3 – Effects of Age on Memory Scores Using LearningRx. LearningRx Visual Auditory Learning, Numbers Reversed, and Working Memory scores were predicted to show significant differences in post-intervention scores when accounting for age. That is scores were predicted to be inversely related to the age of the participant. This hypothesis was addressed using a partial correlation to determine if there were significant differences between age at the time the intervention was implemented by utilizing change in scores with age. In other words, the pre-intervention score was used as a covariate (pre-score minus post-score) to assess the relationship between age and post-intervention scores. This in turn allowed for adjustability of any pre-intervention effects on performance that may have occurred.

CHAPTER IV

RESULTS

Descriptive Statistics

Descriptive statistics were calculated for age, gender, pre-intervention scores and post-intervention scores for each LearningRx sub-test (Visual Auditory Learning, Numbers Reversed, and Working Memory). For Numbers Reversed test there were 29 males and 10 females, aged 19 to 52 years, with a mean age of 30 years (SD=9 years). For the Visual Auditory Learning test there were 29 males and 10 females, aged 19 to 52 years, with a mean age of 30 years (SD=9 years). For the Working Memory test there were 17 males and 6 females, aged 19 to 45, with a mean age of 30 years (SD=8 years). See Table 2.

Hypothesis 1 - Overall Improvements in Memory Score with LearningRx

It was hypothesized that the LearningRx program would provide improvements in memory functioning for participants with TBI based on data gathered pre- and post-intervention. This hypothesis was based on a combination of assumptions. First, was the assumption that exercises enabling the person to practice tasks requiring specific cognitive abilities or processes would improve or restore those abilities utilizing memory functions that had been preserved (Mateer, Kerns, & Eso, 1996). It was also based on the assumption that self-regulation would lead to better information retention (Schefft, Dulay, & Fargo, 2008). Third, the hypothesis was based on the assumption that the most effective cognitive rehabilitation program tailored to the strengths and weaknesses of the individual with TBI (McDonald, Flashman, & Saykin, 2002). Dependent t-tests were used to evaluate whether a significant difference existed between pre-intervention and post-intervention scores for each of the WJ-III sub-tests, the ThinkRx and ReadRx programs, and each sub-test within the ThinkRx and ReadRx programs.

When each LearningRx sub-test was analyzed separately, results found a significant increase in post-intervention scores compared to pre-intervention scores. When the WJ-III Numbers Reversed sub-test was administered assessing short-term memory, an increase from pre-intervention scores of 91.13 (SD=18.31) to post-intervention scores 104.18 (SD=17.43) was noted and this increase was statistically significant ($t=5.16$, $p<.001$, $r^2=.418$). An effect size represented the percentage of the variability in the dependent variable that could be explained by or accounted for by the independent variable. R^2 values lay between 0.0 and 1.0, with values near .01, .09, and over .25 indicating small, medium, and large effects (Cohen, 1988), respectively. Therefore, a value of $r^2=.418$ indicated a large effect. For the Visual Auditory Learning test assessing long-term storage and retrieval, pre-intervention scores were 84.18 (SD=21.66) and the post-intervention scores were 97.95 (SD=18.59). This difference was also statistically significant ($t=6.98$, $p<.001$) and shown to be large as demonstrated by the effect size of

r^2=.568. Finally, for the Working Memory test pre-intervention scores were 89.35 (SD=15.04) and the post-intervention scores were 105.43 (SD=15.32). The difference was statistically significant (t=5.68, p<.001, r^2=.606) with a large effect size.

When assessing the ThinkRx program in general, an increase from pre-intervention score of 88.36 (SD=21.69) to post-intervention score of 99.21 (SD=18.45) was noted and this increase was found to be statistically significant with a large effect (t=6.95, p<.001, r^2=.736). When assessing the ReadRx program, an increase from pre-intervention score of 87.60 (SD=15.22) to post-intervention score of 105.77 (SD=15.83) was noted and this increase was also statistically significant (t=-7.71, p<.001) with a large effect size of r^2=.258. On average, participants in the ThinkRx program indicated greater improvement across all three sub-tests compared to the ReadRx program. This is hypothesized to be due to the ThinkRx program spending more time on cognitive skills than the ReadRx program. When each individual sub-test was assessed by either the ThinkRx or ReadRx program, the ThinkRx program was shown to have made the most difference under the Visual Auditory Learning sub-tests, having the largest effect (r^2=.787). See Table 3 for details.

Hypothesis 2 - Effects of Gender on Memory Score Using LearningRx

Review of the current literature indicated that the memory impairments sustained after a TBI are diverse in severity and outcome based on gender.

However, researchers have reported inconsistent findings when evaluating groups of males and females who sustained a TBI based on predictor variables (e.g., differences in hormones, age, cognitive and psychosocial factors) and outcome (e.g., fatality rates, cognitive complaints; Farace & Alves, 2000; Groswasser et al, 1998; Kraus et al., 2000; Tsushima, Lum, & Geling, 2009).

Numbers Reversed (Short-Term Memory). Based on the literature, it was hypothesized that differences in scores between males and females would not be significantly different in the Numbers Reversed sub-test post-intervention score. An analysis of covariance (ANCOVA) was conducted to understand if there were gender differences in post-intervention scores when the baseline measure (pre-intervention score) was controlled for as a covariate.

The first step in the assumption screening process was to check the assumption of homogeneity of regression slopes. There must be a linear relationship between the covariate and dependent variable (Brace, Kemp, & Snelgar, 2009). This assumption was tested by ensuring there were no significant differences between testing groups on the pre-intervention score and by inspecting scatterplots for linear relationships. There were no significant differences between testing groups (gender) and the baseline WJ-III measure for Numbers Reversed (pre-intervention), $F(1, 38)=.394$, $p=.534$. In addition, the scatterplots comparing pre-intervention and post-intervention scores showed a linear relationship (See Figure 1). This result meant that the data met the assumption of homogeneity of regression slopes. The second step was to conduct Levene's test for equality of error variances. Levene's test ensured the error variance of the dependent variable was equal across groups (Brace, Kemp, & Snelgar, 2009). Results found Levene's test to not be significant ($F(1,37)=.114$, $p=.738$).

As the above mentioned assumptions for homogeneity and equal variance were tested and met, an ANCOVA was conducted to assess for gender differences in post-intervention scores when the baseline WJ-III Numbers Reversed measure (pre-intervention) was controlled for as a covariate. The pre-intervention scores averaged 91.13 (SD=18.31) and the post-intervention scores averaged 104.18 (SD=17.43). The results from the ANCOVA found no differences between Gender and Numbers Reversed post-intervention scores ($F(1,36)=.037$, $p=.849$, $\eta^2=.001$) when controlling for Numbers Reversed pre-intervention scores. Again, an effect size represented the percentage of the variability in the dependent variable that could be explained by or accounted for by the independent variable. Eta Squared (η^2), described the proportion of the total variability in the data that was accounted for by the effect under consideration (Fritz, Morris, & Richler, 2012). Eta squared values lay between 0.0 and 1.0, with values near .0099, .0588, and .1379 indicating small, medium, and large effects (Cohen, 1988), respectively. Therefore, a value of $\eta^2=.001$, or .1% of variance, indicated essentially no effect.

Visual Auditory Learning (Long-Term Storage and Retrieval). It was hypothesized that post-intervention Visual Auditory Learning sub-test scores for participants having completed the LearningRx program would not be significantly different between male and female participants. In order to conduct an ANCOVA to understand if gender differences were present in post-intervention scores when controlling pre-intervention scores as a covariate, this researcher tested for particular assumptions. First an assumption of homogeneity of regression slopes was conducted. Results indicated no significant differences between male and female participants and the baseline WJ-III measure for Visual Auditory Learning (pre-intervention), $F(1,35)=.053$, $p=N.S.$ The scatterplots comparing pre-intervention and post-intervention scores for males and females showed a linear relationship (see Figure 2). Thus, the data met the assumption of homogeneity of regression slopes. Lastly, an assumption assessing Levene's test for equality of error variances was conducted and found not to be significant ($F(1,37)=1.339$, $p=.255$), indicating the error variance of the dependent variable was equal across groups.

As the above mentioned assumptions for homogeneity and equal variance were tested and met, an ANCOVA was then conducted to assess for gender differences in post-intervention scores when the baseline WJ-III Visual Auditory Learning measure (pre-intervention) was controlled for as a covariate. The pre-intervention score for Visual Auditory Learning averaged 84.18 (SD=21.66) and post-intervention score averaged 97.94 (SD=18.59). The results from the ANCOVA found no differences between male and female participants for post-intervention scores ($F(1,36)=2.422$, $p=.128$, $\eta^2=.063$) when controlling for pre-intervention scores. Performance was shown to have medium effect as demonstrated by the effect size of $\eta^2=.063$.

Working Memory. It was hypothesized that there would be no significant gender differences for Working Memory post-intervention scores. In order to conduct an ANCOVA to understand if there were gender differences in post-intervention scores when the baseline scores (pre-intervention) were controlled for as a covariate, this researcher first tested for particular assumptions. First an assumption of homogeneity of regression slopes was conducted. There were no significant differences between testing groups (gender) and the baseline WJ-III measure for Working Memory (pre-intervention), $F(1,19)=.063$, p=N.S. The scatterplots comparing pre-intervention scores and post-intervention scores for males and females were inspected and found to have a linear relationship (see Figure 3). This result meant that the data met the assumption of homogeneity of regression slopes. An assumption assessing Levene's test for equality of error variances was conducted and found not to be significant ($F(1,21)=.009$, p=N.S.) meaning the error variance of the dependent variable was equal across groups.

As the above mentioned assumptions for homogeneity and equal variance were tested and met, an ANCOVA was then conducted to understand if there were gender differences in post-intervention scores when the baseline WJ-III Working Memory measure (pre-intervention) was controlled for as a covariate. The pre-intervention score for Working Memory averaged 89.35 (SD=15.04) and post-intervention score averaged 105.43 (SD=15.32). The results from the ANCOVA found no differences between the Gender and Working Memory post-intervention scores ($F(1,20)=1.258$, $p=.275$, $\eta^2=.059$) when controlling for (Working Memory) pre-intervention scores. Performance was also shown to be medium as demonstrated by the effect size value of $\eta^2=.059$.

Hypothesis 3 - Effects of Age on Memory Scores Using LearningRx

It was hypothesized that there would be a significant positive difference between age and post-intervention scores in each of the sub-tests (Numbers Reversed, Visual Auditory Learning, and Working Memory) such that it was believed younger participants would perform better than older participants. This was based on the assumption that older individuals were more vulnerable to the effects of brain injury and that younger adults showed more improvements compared to older individuals (Klein, Houx, & Jolles, 1996; Senathi-Raja, Ponsford, and Schönberger, 2010; Sohlberg & Mateer, 2001; Whyte, 1990). Partial correlations were completed to test the relationship between age and post-intervention scores while controlling for the pre-intervention score for each of the sub-tests. Results indicated no significant relationship between post-intervention scores and age (r=.24, p=N.S., r^2=.058) for the Numbers Reversed sub-test.

Results found a positive, but not significant, relationship between post-intervention scores and age (r=.23, p=.17, r^2=.053) for Visual Auditory Learning sub-test. No relationship was found between post-intervention scores and age for Working Memory sub-test (r=-.04, p=.86, r^2=.002). See Table 4 for details. R^2 values for the Numbers Reversed and Visual Auditory Learning sub-tests indicated a small to medium effect, and a negligible effect was indicated for the Working Memory sub-test.

CHAPTER V

DISCUSSION

The main objective of this study was to assess the effects of a time-limited intervention program aimed at improving cognitive skills after sustaining a traumatic brain injury (TBI); specifically focusing on improvements in short-term memory (and working memory) and long-term storage and retrieval, as measured by the Woodcock Johnson-III Tests of Cognitive Abilities Numbers Reversed, Visual Auditory Learning, and Working Memory sub-tests. As there has been a lack of research investigating short-term, direct retraining of cognitive processes, this study aimed to contribute additional information to this body of research.

Recently, managed care has focused on acute psychological treatments with early return of patients to outpatient status. Early, effective interventions and awareness of the availability of effective treatments may reduce the impact of TBI on patients (and their families) long term. Cognitive skills treatment would not necessarily be considered a “short” treatment in the conventional sense (as training would last from 12-24 weeks), but if established as evidence based, it would provide a means to treating memory functioning after TBI that would be shorter in time frame than other rehabilitation methods. It would also be in accordance with managed care/insurance timelines for shorter inpatient stays, reduced outpatient coverage, fewer day treatment programs, and a mandate to reduce cost.

Summary

The findings of this study appear to show significant positive differences for LearningRx, a time-limited, measurable, cognitive training intervention, for short-term memory (*Gsm*), working memory (Gsm), and long-term storage and retrieval (*Glr*) for individuals with varying severities of TBI. It was also found that there were no differences in improvement based on gender or age. Overall, individuals participating in the LearningRx program appeared to improve pre- to post-intervention; however, these apparent findings are only preliminary and could be due to many other factors, only one of which may be the effectiveness of the program. There were other factors that were not controlled for due to a lack of information (see limitation section). Results from this study can only be considered preliminary at best, and additional steps would be needed to investigate and control for the influence of other factors before anything definitive could be said about the effectiveness of the LearningRx program.

Hypothesis 1: Overall Improvements in Memory Score with LearningRx. The initial hypothesis evaluated the effect of a time-limited cognitive program, LearningRx, on memory function. A pre- and post-test evaluation, as assessed by the WJ-III, it was predicted that individuals would demonstrate improvements in short-term memory, long-term storage and retrieval, and working memory. Results appear to indicate a significant increase in post-intervention scores for all three areas of memory as evidenced by pre-intervention scores of 91.13 and post-intervention scores of 104.18 for Numbers Reversed (short-term memory), pre-intervention scores of 84.18 and post-intervention scores of 97.95 for Visual Auditory Learning (long-term storage and retrieval), and pre-intervention scores of 89.35 and post-intervention scores of 105.43 for Working Memory, and large effect sizes of r^2=.418, .568, and .606, respectively. However, results cannot infer actual improvement in memory functioning as no control group was used for comparison, nor was the severity of TBI known as this would affect the anticipated recovery trajectory for individuals. The improvement in post-scores may have been due to other factors such as practice effects, actual improvements in memory functioning due to the intervention, naturally occurring cognitive improvements following a TBI, or some combination thereof. Statistical differences were also found when assessing the ReadRx and ThinkRx programs as well as when assessing each WJ-III sub-test under the ReadRx and ThinkRx programs. Though results suggest that the ThinkRx program provided greater improvements than the ReadRx program, perhaps due to the increased amount of time spent on cognitive skills training in the ThinkRx program, this study cannot truly infer that the intervention program itself was responsible for this change. Changes found in the program data may have been due to the assessment of different variables than what was actually being trained for by the program or the cognitive domains measured may have been affected in a different way than what was anticipated following a head injury. To obtain more statistically significant results, a randomized control trial would be needed.

Based on the cognitive rehabilitation literature, this study hypothesized that the improvements noted in this study might be due to the LearningRx intervention utilizing exercises targeting specific cognitive abilities or processes (in this case short-term memory, working memory, and long-term storage and retrieval) which had been preserved by the explicit and declarative memory systems. The intervention also implemented the use of mental imagery, organizing information sequentially, repeated practice, processing information at deeper levels, and visual mnemonics (Kim et al., 2009; Leng & Copello, 1990; Mateer, Kerns, & Eso, 1996) to help improve skills. Though it was not assessed in this study, it might be possible that those using the LearningRx intervention implemented internal strategies based on compensatory and restorative interventions and self-regulation methods during the various tasks performed during training. This includes repetitive practice using visual mnemonics, setting own goals for sessions, and active participation during skills exercise. The use of self-regulation in memory impaired patients, along with specific compensatory and restorative interventions were not tested for in this study and future research within these areas would be beneficial.

Hypothesis 2: Effects of Gender on Memory Score Using LearningRx. Memory disruptions of specific memory abilities with certain severity of TBI within a given timeframe have commonly been reported following a TBI (Adamovich, 1991; Brooks, 1990; Gentleman, 2001; Marion et al., 2004; Pertab, James, & Bigler, 2009; Petersen & Weingartner, 1991; Rios, Perianex, & Munoz-Cespedes, 2004; Sohlberg & Mateer, 2001; Spikeman, Deelman, & van Zomeren, 2000). Previous studies have reported inconsistent results between gender and improvements in memory functioning of individuals who sustained a traumatic brain injury; therefore, the purpose of this study was to determine if gender differences were present for individuals sustaining a TBI regarding memory functioning. It was hypothesized that there would be no difference in post-intervention scores between males and females. When each sub-test for memory was investigated it was found that there were no differences between gender when measuring improvements in short-term memory, long-term storage and retrieval, and working memory. The results of this study supported the findings of other investigators such as Tsushima, Lum and Geling (2009) that males were twice as likely to suffer TBI as females, as there were more males than females in this study. However, these findings could be due to differences in symptom reporting or cognitive and psychosocial factors such as pre-morbid functioning, gender perceptions regarding illness/deficits, and socioeconomic status. The results of this study did not support the findings of other investigators such as Covassin, Swanik, and Sachs (2007) that females had higher fatality rates than males or that females had better outcome than males (Groswasser, Cohen, & Keren, 1998) as no differences were noted between gender and memory functioning post-intervention in this study. An important factor that may account for finding no difference between gender on memory functioning may be due to the lack of a control group. Other factors affecting gender have been postulated to be due to differences in premorbid functioning, injury factors (severity, location, length of time), structural differences in the brain between males and females, sex hormones (progesterone), treatment effects, and/or age of the individual. Future research is needed in this area in order to assess cognitive changes between genders taking into account these extraneous factors as well as ensuring that the sample of males and females are large enough to address the hypothesis properly.

Hypothesis 3: Effects of Age on Memory Score Using LearningRx. The third hypothesis stated that there would be an inverse relationship between age and each of the sub-tests (Numbers Reversed, Visual Auditory Learning, and Working Memory) post-intervention scores such that it was believed younger participants would perform better than older participants. Results indicated no significant relationship between post-intervention scores and age for short-term memory (Numbers Reversed) and long-term storage and retrieval (Visual Auditory Learning) and no relationship was found between post-intervention score and age for Working Memory. This preliminary evidence suggested that though post-intervention scores increased as the age of the participants increased, there were no differences noted in scores when looking at age and change scores between pre- and post-intervention.

It is impossible to say if these differences were true differences due to the intervention or other extraneous factors as, again, no control group was utilized for comparison. However, preliminary findings were not consistent with previous research findings that younger adults showed better improvements compared to older adults. As an older adult, the brain was believed to be less flexible due to the natural aging process. Sustaining a TBI at this point was thought to make it more difficult for individuals to work with the acquired deficits from the TBI due to reduced plasticity of the brain (Senathi-Raja, Ponsford, & Schönberger, 2010). Senathi-Raja, Ponsford, and Schönberger (2010) found that older age was associated with poorer performance across all cognitive domains, after accounting for normal age-related cognitive decline. This was also consistent with Himanen et al. (2006) finding that higher age at injury (especially over 60 years) was a significant risk factor for cognitive decline, whereas younger age at injury was predictive of improvement in cognition. However, findings from closed head injury research regarding the impact of age on outcome have been mixed (Himanen et al., 2006; Klein, Houx, & Jolles, 1996; Senathi-Raja, Ponsford, & Schönberger, 2010).

Results from this study speculated that though older participants entered the study with somewhat higher pre-intervention scores than younger individuals, which could have played a factor in higher post-intervention scores, when pre-intervention scores were taken into account as a covariate, no significant relationships were noted. It would be expected that younger adults would perform better than older individuals based on the research; however, as this was not the case in this study other theories must be explored. It is possible that differences seen in this study may have been due more to statistical differences from other causes such as premorbid functioning or history of trauma and not a direct result of the LearningRx program. It would also be possible that the initial impact of the TBI (depending on severity) may have mitigated as the older participants in this study had functioned with their memory deficits for a longer period of time allowing them the opportunity to better compensate for their deficits. Additional protective factors for older adults such as a more stable life style, better coping skills, better support, and fewer life demands than younger participants might have helped older participants achieve what seemed to be positive memory rehabilitation. Future studies should establish if these and other factors were protective or aiding in changes in memory functioning. It would also be important to determine a clear set of expectations regarding performance for someone who sustained a TBI and if this affected effort, as well as determining if the older brain's poorer capacity to compensate during the initial recovery process or greater deterioration beyond the period of initial recovery due to the reduced plasticity in the aging brain affected current results (Senathi-Raja, Ponsford, & Schönberger, 2010).

Limitations of the Study

Given that data provided for this study was limited, and supplied entirely by the company marketing the program, the effectiveness of LearningRx remains uncertain. It is important to keep in mind various assumptions and limitations regarding the study and to cautiously interpret its results. First, and perhaps most important, there was no control group utilized in this study. The lack of a control group makes it impossible to determine if the results were truly due to the LearningRx intervention or to other factors such as practice effects or naturally occurring recovery as research has indicated that individuals will undergo improvements 6 months to two years post-injury depending on the severity of the injury. Therefore, all results in this study are considered preliminary at best, and additional research is needed regarding LearningRx and changes in memory functioning.

Another important limitation of the study was the unknown severity of the TBI as recovery trajectory would be different based upon mild, moderate, or severe brain injury. Though participants in the current study represented a wide variety of TBI severity and functional disability regarding levels of memory impairments, the precise level of injury severity was not known as other measurements were not conducted pre- and post-intervention (i.e., Glasgow Coma Scale or Activities of Daily Living); therefore, formal statement of improvement is impossible to identify at this time. Other important factors to consider, which were also unknown due to limited data, were the dropout rate for the study and the length of time prior to treatment with LearningRx. As stated earlier, length of time between injury and treatment may have a role in allowing an individual to learn compensation skills for their deficits or allow for natural recovery to occur, which would affect results of the study.

Assuming improvements in TBI memory impairments in general or by age or gender should be applied cautiously. However, it was assumed that the current sample represented a lower level of severity and functional disability than a typical inpatient sample. It was also important to understand that individuals in an inpatient setting receive treatment for additional external/internal injuries (i.e., broken bones, organ damages, etc.) which compete for attention with cognitive rehabilitation during the recovery process. Sufferers of TBI are often released quickly once medically stable with their other injuries and cognitive rehabilitation may not have fully been addressed. Thus, findings from this study would not be generalizable to inpatients with TBI. Also, demographic variables such as socioeconomic status, level of education, occupation at time of injury, if currently working, and ethnicity were not provided for this study, thus adding to concerns about the generalizability to the larger population. Other potential limitations of this study include lack of information regarding co-morbid health problems, history of drug use, history of alcohol use, IQ, history of head trauma, pre-morbid functioning, and kind of injury sustained. Reliability of self-reported measures of participants regarding their diagnosis of TBI is also questionable as no formal instruments were utilized to assess TBI, severity of TBI, limitation in daily activities, or other rehabilitation methods were attempted.

Though the sample represented a wide age range (19-52 years-old) and included both males and females, the majority of the participants were males between the ages of 27-37. This was important to consider since existing research suggested that males and females may have differing patterns of recovery due to gender differences such as hormones and brain structure. A small sample size as well as statistical differences due to extraneous variables would make it difficult to properly infer the interaction of age and gender on TBI using LearningRx.

Additional limitations to consider were that data gathered and assessed on cognitive deficient areas were limited to the areas tested for by the LearningRx Company. The lack of additional instruments intended to measure cognitive deficits limited the depth and breadth of the study. Secondly, the data provided for this study came from a proprietary company and this researcher did not have control of the data collection process or who was included in the original data sent by the company. Therefore, since other individuals have placed the original data in a computer system, there may be the possibility of human error during data input. Thirdly, it would be not be feasible to compare the same injury and severity within a test group as all participants were volunteers for the program.

Confounding variables such as history of the client, maturation of the client, testing effects, selection process, and change in tester, would have affected outcome scores. Thus, even though results show some statistical differences, causality cannot be inferred with this study alone. Finally, it was assumed that those partaking in the LearningRx program were more willing to “try something new” and may not have held, therefore, the same expectations in improvement as those participating in other empirically validated treatments. It may also be assumed that motivation of each individual would vary, thus affecting pre- and post-data, as well as the assumption that different LearningRx centers may have provided different levels of training, despite continuity of the protocol, thus affecting pre-and-post data.

Future Directions for Research and Clinical Practice

Currently, 95% of the rehabilitation facilities serving the needs of persons with a brain injury provided some form of cognitive rehabilitation, which included individual, group, and community-based therapies, or some combination thereof (Cicerone et al., 2000; McDonald, Flashman, & Saykin, 2002). Acute care over the last 20-30 years have included CT scanning, early intracranial surgery, neuro-intensive care, and better training of clinicians in early trauma care (Gentleman, 2001). Long-term treatments have included physical therapy, occupational therapy, speech/language therapy, social therapy, psychiatric or psychological counseling, and cognitive skills testing and training (Boake, 1991; Sohlberg & Mateer, 2001).

Once again, although this study appears to indicate positive differences for individuals post-intervention when utilizing the LearningRx program, these results cannot be declared definitive as there were too many unknown variables (lack of control group, natural recovery, kind/severity of injury, dropout rate, time between injury and intervention, SES, pre-morbid functioning, drug/alcohol use, history of trauma) which would affect results of the study. Future studies should investigate the LearningRx intervention program with the inclusion of a control group amongst inpatient TBI patients and outpatient TBI patients. Archival data provided by the LearningRx Company was limited in nature; therefore, additional variables that may have affected results could not be assessed. It would be beneficial for future studies to include and assess the following variables: socioeconomic status, race/ethnicity, specific age categories, occupation/education level, level of support from family and friends, co-morbid health issues, and history of drug and alcohol use. It would also be important to have the study data collected and reviewed by someone other than the LearningRx staff and administrators.

Additional research is necessary to formulate an understanding of the sequelae present during the acute phase as well as possibility of spontaneous recovery for injury and cognitive improvement or stabilization over time with various injury severities. Research has indicated that time since injury, location and severity (mild, moderate, or severe) of a traumatic brain injury determined the extent of disability and recovery associated with the injury. Overall, specific interventions directed at facilitating the learning of specific skills and domain-specific knowledge was found to be effective for those with moderate to severe impairments (Cicerone et al., 2000). Therefore, the trajectory of recovery for survivors of TBI needs to be better understood, necessitating research to investigate benefits of the LearningRx intervention on memory when assessing each type of TBI severity (mTBI, moderate, severe) through the use of a Glasgow Coma Scale, as well as specific types of TBI injuries, time between injury and intervention, history of head trauma, impact of mood on daily functioning, and perception the patient has of themselves (i.e., sick role). It would also be beneficial to attempt to match severity and type of injury in order to assess for potential improvements in memory. This would allow for a specific cognitive profile to be created for treatment of this population and potentially allow the intervention to be implemented in a focused manner.

In addition, Cicerone et al. (2000) found that memory remediation was most effective when subjects were fairly independent in daily function, were actively allowed to identify the memory problem to be treated, and were capable and motivated to continue active, independent strategy use. This included the use of self-regulation methods (Schefft, Dulay, & Fargo, 2008) and compensatory and restorative interventions (Kim et al., 2009; Mateer, Kerns, & Eso, 1996). Therefore, future studies should implement a standard self-report measure to assess for quality of life and level of functioning pre-and-post intervention, conduct interviews with the participants to gain a more complete picture of their functioning pre- and post-intervention, assess effort implemented throughout the intervention, and compare the LearningRx program to other compensatory and restorative interventions identified in the literature.

Previous findings, along with this study, have documented inconsistent results when addressing gender and memory functioning. To address the lack of continuity in outcome between genders, future studies may want to include samples with equal number of males and females to better assess improvements in memory. Additional questions about gender differences for memory rehabilitation that warrant further investigation include premorbid factors, symptom reporting, and adequate sample size. Inclusion of possible gender differences in memory functioning after LearningRx would also aid in expanding on the current, but limited, literature regarding gender differences in memory functioning.

Within this study, an attempt was made to compare young adults to older adults regarding memory functioning post-intervention. However, preliminary results from this study appeared to contradict documented literature, warranting further investigation. For example, one question that arose was whether the sample was large enough and if the results indicated were due to the intervention or other factors such as practice effects, as no control group was present. Another question that arose was whether older individuals had protective factors which appeared to increase their post-intervention scores to be similar to that of younger participants. A final question that arose when assessing age was if the differences seen in this study were possibly due to statistical differences from other causes such as pre-morbid functioning or time since injury and not as a result of the LearningRx program.

In general, future investigations are needed in order to determine if preliminary results found in this study are accurate: that is, would LearningRx improve memory functioning for individuals with TBI if the intervention was compared to a control group and assessed for other possible confounding variables? Research addressing these questions would facilitate in adding potential cognitive rehabilitation method for TBI. With the current direction in health care, LearningRx showed potential to providing a time-limited intervention for improving memory functioning in individuals with TBI. As McDonald, Flashman, and Saykin (2002) have suggested, the most effective rehabilitation programs were tailored to the specific strengths and weaknesses of the individual with TBI. Such an individualized program was more likely to be successful than a broad-based attempt to improve global cognitive functioning which did not focus on the specific deficits of the individual. LearningRx attempted to establish a foundation of basic skills upon which higher memory processes could be retrained, thus allowing the program to focus on the specific deficits and monitor any changes in skill levels. In all, preliminary results from this study show significant statistical differences when looking at the program data between pre- and post-intervention scores. However, further comprehensive research on LearningRx needs to be conducted before meaningful statements can be made about the program

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Appendix A

LearningRx Pre-Assessment Questionnaire

LearningRx Pre-Assessment Questionnaire

Assessment is for Last ________ First ________ MI ____ Date of Birth ________

Gender: ☐Male ☐Female Race: ☐White ☐Black ☐Hispanic ☐Asian ☐Native American ☐Other ________

Address ________ City ________ State ____ Zip ________

E-mail ________ Primary contact phone ________ Cell ________

How did you hear about us? (Please detail below) ☐Direct Mail ☐Magazine ☐Newspaper ☐Radio ☐Referral ☐Television ☐Yellow Pages ☐Web ☐Other ________ Details: ________

List occupation or employer of parent(s) or of adult client. ________

Check the education level obtained by the parent or guardian with the highest education level:
☐Did Not Complete High School ☐Completed High School ☐2-Year College Degree ☐4-Year College Degree ☐ Post-Graduate Degree

General Information

Give a brief statement of the primary reason for today's assessment. ________

What are your expectations of LearningRx? ________

Indicate any diagnosis/labels/disorders that have been used to describe this person: ☐ADD ☐ADHD ☐ Autistic/Asperger's/PDD ☐Dyslexia/Reading Problem ☐Emotional Disability ☐Gifted ☐Learning Disability ☐ Mental Retardation ☐Physical Disability ☐Speech/Language Disability ☐Traumatic Brain Injury ☐ Other ________

Learning Performance History

Indicate any problems in the following areas:

☐Reading	☐Comprehension	☐Reversals of letters or words	☐Motivation/behavior
☐Writing	☐Avoidance of school or work	☐Loses place/skips lines	☐Low self-esteem
☐Math	☐Works too hard	☐Poor memory	☐Overly active
☐Spelling	☐Slow work	☐Attention/concentration	☐Other ________

[Information for school-aged students]

Mother's (Last, First, MI) ________ Phone (H) ________ (W) ________ (C) ________

Father's (Last, First, MI) ________ Phone (H) ________ (W) ________ (C) ________

Guardian's (Last, First, MI) ________ Phone (H) ________ (W) ________ (C) ________

Guardian's Relationship to Student ________

List grade, school, and teacher ________

Birth was ☐premature ☐late ☐normal. Birth weight ________ Any complications during pregnancy or delivery? ☐Yes ☐No

List all major health problems to date: ________

Is your child on any medication for ADD/ADHD? ☐Yes ☐No

Indicate problem areas: ☐headaches ☐vision ☐speech or hearing List current medications ________

Is the student achieving at expected levels in school? ☐Yes ☐No (Comments) ________

Has the student ever repeated a grade? ☐Yes ☐No Please explain ________

Type of classroom: ☐Mainstream for all subjects ☐Special classroom for all subjects ☐Special classroom for some subjects

List any past or current help, training, or tutoring utilized for the above problems ________

Would you like to have a copy of the assessment results sent to the student's teacher? ☐Yes ☐No Physician? ☐Yes ☐No

Teacher's name, phone, and address ________

Physician's name, phone, and address ________

Learning Skills Rating Scale

Read each of the following statements and rate the individual according to the following scale. Place your rating number in the box provided to the right of each statement. Please be sure to rate every item.

COMPARED TO OTHERS OF THE SAME AGE AND GENDER, THIS BEHAVIOR:

0 - Occurs less often OR the question doesn't apply to the age of this individual
1 - Occurs at about the same frequency
2 - Occurs slightly more
3 - Occurs considerably more
4 - Occurs significantly more

1. Distracted from the task at hand
2. Reading is slow
3. Poor reading comprehension
4. Often asks to have things repeated
5. Has difficulty maintaining attention
6. Slow, deliberate speech
7. Makes spelling errors in written assignments
8. Has difficulty remembering telephone numbers
9. Has difficulty organizing activities
10. Completes math assignments slowly
11. Has difficulty sounding out unknown words
12. Needs to look multiple times when copying
13. Has difficulty doing two things at once
14. Takes a long time to complete tasks
15. Oral reading is slow or choppy
16. Has difficulty following verbal directions
17. Avoids prolonged mental effort
18. Generally does things slowly
19. Needs words repeated when taking spelling tests
20. Has difficulty recalling stories and jokes
21. Has difficulty remembering things just heard
22. Is often one of the last to complete tasks
23. Avoids reading
24. Gets poor test results when being tested for facts
25. Is impulsive
26. Avoids or has difficulty with video games
27. Has difficulty finding words for verbal expression
28. Needs to restudy or reread materials
29. Has poor study or work habits
30. Writing assignments take too long
31. Has difficulty reading or spelling phonetically
32. Has problems remembering names
33. Poor sense of direction/map reading skills
34. Poor math grades or test scores
35. Has poor handwriting
36. Swears or uses obscene language
37. Jigsaw puzzles are difficult or avoided
38. Has difficulty understanding stories or jokes
39. Squints, blinks, or rubs eyes when reading
40. Loses temper
41. Misreads similar words
42. Thoughts and materials are poorly organized
43. Has difficulty hearing
44. Argues with authority figures
45. Poor at or dislikes drawing
46. Poor at or avoids games like chess and checkers
47. Has poor coordination
48. Refuses requests or disobeys rules
49. Has difficulty with word math problems
50. Has problems seeing the "big picture"
51. Has speech difficulties
52. Deliberately does things that annoy others
53. Has difficulty creating pictures in the mind
54. Takes a while to catch on to new things
55. Complains about eye strain or fatigue
56. Blames others for mistakes
57. Lacks creativity or imagination in writing
58. Doesn't like card games
59. Is bothered by loud sounds
60. Is angry and resentful
61. Poor at problem solving
62. Has difficulty planning steps to solve problems
63. Skips words or lines when reading
64. Holds grudges or seeks revenge

LearningRx

Appendix B

WJ-III Selective Testing Table - Clusters

Selective Testing Table - Clusters

WJ III Tests of Cognitive Abilities

Battery	Test	Gen. Intell. Ability - Std	Gen. Intell. Ability - Ext	Brief Intellectual Ability	Verbal Ability - Std	Verbal Ability - Ext	Thinking Ability - Std	Thinking Ability - Ext	Cog. Efficiency - Std	Cog. Efficiency - Ext	Compreh.-Knowl. (Gc)	Long-Term Retriev. (Glr)	Visual-Spatial Think (Gv)	Auditory Processing (Ga)	Fluid Reasoning (Gf)	Processing Speed (Gs)	Short-Term Mem. (Gsm)	Phonemic Awareness	Working Memory	Broad Attention	Cognitive Fluency	Executive Processes	Delayed Recall (note 1)	Knowledge (note 2)
		Intellectual Ability			Cognitive Categories						CHC Factors							Clinical Clusters						
Standard Battery	1. Verbal Comprehension	◆	◆	◆	◆	◆					◆													
Standard Battery	2. Visual-Auditory Learning	◆	◆				◆	◆				◆												
Standard Battery	3. Spatial Relations	◆	◆				◆	◆					◆											
Standard Battery	4. Sound Blending	◆	◆				◆	◆						◆				◆						
Standard Battery	5. Concept Formation	◆	◆	◆			◆	◆							◆							◆		
Standard Battery	6. Visual Matching	◆	◆	◆					◆	◆						◆								
Standard Battery	7. Numbers Reversed	◆	◆						◆	◆							◆		◆	◆				
Standard Battery	8. Incomplete Words																	◆						
Standard Battery	9. Auditory Working Mem.																		◆	◆				
Standard Battery	10. Vis-Aud. Learn. - Delayed																						◆	
Extended Battery	11. General Information		◆			◆					◆													◆
Extended Battery	12. Retrieval Fluency		◆					◆				◆									◆			
Extended Battery	13. Picture Recognition		◆					◆					◆											
Extended Battery	14. Auditory Attention		◆					◆						◆						◆				
Extended Battery	15. Analysis-Synthesis		◆					◆							◆									
Extended Battery	16. Decision Speed		◆							◆						◆					◆			
Extended Battery	17. Memory for Words		◆							◆							◆							
Extended Battery	18. Rapid Picture Naming																				◆			
Extended Battery	19. Planning																					◆		
Extended Battery	20. Pair Cancellation																			◆		◆		

Notes: (1) Also includes Test 12: Story Recall--Delayed from the WJ III Tests of Achievement; (2) Also includes Test 19: Academic Knowledge from the WJ III Tests of Achievement

 -- Source: WJ III Tests of Cognitive Abilities Examiner's Manual by N. Mather and R.W. Woodcock, code 9-23631, pg. 12

Appendix C

IRB Approval Form from Adler

ADLER SCHOOL of Professional Psychology

May 5, 2011

Poonam Ishanpara
Adler School of Professional Psychology
17 N Dearborn
Chicago, IL 60602

Dear Ms. Ishanpara,

The Institutional Review Board evaluated the changes to your application, proposal **#11-010**, *Cognitive Rehabilitation with LearningRx*. Your application has now received **Full Approval**. This means that you may proceed with your plan of research as it is proposed in your application.

Please note that if you wish to make changes to your procedures or materials, you must provide written notification to the IRB in advance of the changes, co-signed by your Dissertation Chair, Dr. Robert Baker. Such changes must be approved by the IRB prior to implementation. Good luck as you proceed with your research, and please feel free to contact myself or other IRB committee members should you have any questions.

Sincerely,

Catherine McNeilly, Psy.D., CADC
Core Faculty, Psy.D. Program in Clinical Psychology
Chair, Institutional Review Board
Adler School of Professional Psychology

Appendix D

Data Use Agreement with LearningRx

ADLER SCHOOL of Professional Psychology

DATA USE AGREEMENT BETWEEN
LearningRx
And
Poonam Ishanpara
Adler School of Professional Psychology

This Data Use Agreement is made and entered into on **7/30/2012**, between **LearningRx**, hereafter "Holder" and **Poonam Ishanpara**, hereafter "Recipient."

1. This agreement sets forth the terms and conditions pursuant to which Holder will allow Recipient access to the requested data.

   1.1 The requested data set is a subset of an existing database housed at **LearningRx.** The data for this project is part of a **generally compiled information regarding testing data.** The use of the database for outcomes related research was approved by **Tanya Mitchell, VP of LearningRx & Ken Gibson, CEO.** The primary investigator and current Receiver of the data is **Poonam Ishanpara.** The dataset includes the following information: an **arbitrarily assigned client ID number, sex of participant, age of participant, specific learning program completed, and pre-and-post test scores (i.e., overall and for each subtest).** All patient identifiers have been removed from the dataset prior to the Receiver accessing the described data.

   1.2 Recipient of the data set does not incur any financial gain on behalf of LearningRx, Adler School of Professional Psychology or Recipient herself. No other actual or perceived conflicts of interest have been identified or disclosed that would impact this agreement.

2. Permitted Uses and Disclosures

   2.1 Except as otherwise specified herein, Recipient may make all uses and disclosures of the data set necessary to conduct the research described herein:

   The purpose of this research project is to **study the possible contribution LearningRx program may have on cognitive rehabiliation for individuals suffereing from Traumatic Brain Injury, specifically long-term, short-term, and working memory.**

   The data set will not be disseminated for publication or oral/poster presentation without consulting with the Holder. **As such, information gathered from the data set will be used as part of the requirements for completion of doctoral dissertation, including oral presentation and publication of the dissertation defense through Adler School of Professional Psychology.**

ADLER SCHOOL of Professional Psychology

3. The de-identified data set containing no remaining private health information as defined by HIPPA guidelines is allowed to be taken off the original Holder's site (i.e., LearningRX facilities) by the Recipient to facilitate completion of the above described research.

   3.1 In addition to the Recipient, the individuals, or classes or individuals, who are permitted to use or receive the aggregate outputs from statistical analysis and related reports for purposes of the dissertation include: **Dr. Robert Baker, Committee Chair, Dr. Douglas Whiteside, Dr. Christine Bard, Committee members, and Dr. Kim Chivers, statistican.** The IRB at the Adler School of Professional Psychology is also permitted to review the data as necessary to ensure privacy and protection of human subjects.

4. Recipient Responsibilities

   4.1 Recipient will not use or disclose the data set for any purpose other than permitted by this Agreement pertaining to the dissertation project or as required by law;

   4.2 Recipient will use appropriate administrative, physical and technical safeguards including password protected files to prevent use or disclosure of the data set other than as provided for by this Agreement including keeping with guidelines consistent with policies of **LearningRx** and with the ethical practice and research guidelines described by the American Psychological Association (APA) guidelines for data retention of seven (7) years (notwithstanding any already existing data use agreements);

   4.3 Recipient will report to the Holder any use or disclosure of the data set not provided for by this Agreement of which the Recipient becomes aware within 15 days of becoming aware of such use or disclosure;

   4.4 A summary report of the data analysis findings will be provided to the Holder.

5. Term and Termination

   5.1 The terms of this Agreement shall be effective as of **7/30/2012**, and shall remain in effect until the data set is destroyed or returned to the Holder.

   5.2 Upon the Holder's knowledge of a material breach of this Agreement by the Recipient, the Holder shall notify the Recipient of the Holder's knowledge of such material breach in writing within 45 days and provide an opportunity for Recipient to resolve the breach or end the violation. If efforts to resolve the breach or end the violation are not successful within 60 days of the Recipient's receipt of the Holder's notice of breach, the Holder shall report the problem to the dissertation chair, **Robert Baker**, and the Adler School of Professional Psychology's Institutional Review Board (IRB) representative **Catherine McNeilly, Psy.D.**

ADLER SCHOOL of Professional Psychology

5.3 Holder agrees to submit a continuing approval notice to the Adler School of Professional Psychology 1 year after the project approval date and every year thereafter until the project is closed or as required by the overseeing Institutional Review Board.

6. General Provisions

6.1 Each party agrees that it will be responsible for its own acts and the results thereof to the extent authorized by law and shall not be responsible for the acts of the other party or the results thereof;

6.2 This Agreement (a) is the complete agreement of the Parties concerning the subject matter hereof and supersedes any prior agreements, understanding or discussions with respect to the subject matter hereof; and (b) may not be amended or in any manner modified except by a non-electronic written instrument signed by authorized representatives of both Parties.

6.3 If any provision of this Agreement is found unenforceable, the remainder shall be enforced as fully as possible and the unenforceable provision shall be deemed modified to the limited extent required to permit its enforcement in a manner most closely representing the intention of the Parties as expressed herein.

6.4 A signed copy of this agreement will be given to both the Holder and Recipient

7. Contact Information of Recipient: **Poonam Ishanpara, M.A., pishanpara@gmail.com, 319-594-6536 (cell).**

8. Adler IRB Contact Information (institution overseeing research of the Recipient):

Catherine McNeilly, PsyD., Adler School IRB, cmcneilly@adler.edu, 312-662-4347

IN WITNESS WHEREOF, the parties hereto execute this agreement as follows:

Signature: ________________

Date: 8/09/2012

By: Tanya Mitchell VP Research & Development LearningRx

Signature: ________________

Date: 8/10/12

By: Poonam Ishanpara

Primary Investigator, Student, Adler School of Professional psychology

ADLER SCHOOL of Professional Psychology

Signature: Robert T. Baker III, PsyD

Date: 8/10/12

By: Dr. Robert T. Baker III, PsyD
Dissertation Chair, Core Faculty, Adler School of Professional Psychology

17 North Dearborn, Chicago, Illinois 60602 • 312-662-4000 • Fax 312-662-4099
www.adler.edu

APPENDIX E

Example of ThinkRx Procedure

Attention Arrows

Develop divided, sustained and selective attention, processing speed, visual sequencing, saccadic fixation, and self-regulation.

Using a metronome and a board with several rows of different colored arrows randomly pointing in the four primary directions, the student would proceed through the following levels:

Level 1**:** Student calls out the color of the arrows without error in 3 rows within a set time (for between 10 and 30 seconds).

Level 2: Student calls out the direction of the arrows without error for three rows within a set time.

Level 3**:** Student calls out the color of the arrows in four rows on every other beat, in sync with the metronome set to between 85 beat per minute (bpm) and 160 bpm.

Level 4**:** Student calls out the direction of the arrows as if they were turned a quarter-turn clockwise on every other beat (in sync with the metronome set to between 85 bpm and 160 bpm).

Level 5**:** Student calls out the color of the "up" and "down" arrows and calls out the direction of the "right" and "left" arrows in 4 rows on every other beat (in sync with the metronome set to between 85 bpm and 160 bpm).

Level 6+**:** The levels continue to increase in difficulty. Throughout the procedures, the trainer includes a variety of distractions ranging from low level (walking around the student, coughing, etc.) to high-level (singing, holding a conversation, etc.).

APPENDIX F

Example of ReadRx Procedure

Using a metronome, the trainer said a word consisting of three to five sounds and the student recited the word, but without one of the sounds, as directed.

Level 4: Drop either the first or the last sound.

Level 8: Drop out a sound as directed, varying which consonant sound to drop (Trainer: “cat,” beat, “last,” beat; Student: “ca,” beat, beat; Trainer: “lut,” beat, “first,” beat; Student: “ut,”…)

Table 1

Program Description Matrix

Program	Total Hrs of Training	Total Hrs w/certified Trainer	Hrs in "Read" Program	Hrs "Read" w/certified Trainer	Hrs. "Think" Program	Hrs. "Think" w/certified Trainer
Think						
Pro	60	60	0	0	60	60
Partner	60	36	0	0	60	36
Read						
Pro	100	100	50	50	50	50
Partner	100	60	50	30	50	30

Table 2

Descriptive Statistics for Each of the LearningRx Sub-Tests

	Numbers Reversed			
	N	M	SD	Range
Age (years)		29.83	8.99	19-52
Pre-Intervention		91.13	18.31	41-134
Post-Intervention		104.18	17.43	65-137
Gender				
Male	29			
Female	10			
	Visual Auditory Learning			
	N	M	SD	Range
Age (years)		29.83	8.99	19-52
Pre-Intervention		84.18	21.66	29-130
Post-Intervention		97.94	18.59	60-134
Gender				
Male	29			
Female	10			
	Working Memory			
	N	M	SD	Range
Age (years)		29.66	7.94	19-45
Pre-Intervention		89.35	15.04	53-109
Post-Intervention		105.43	15.32	72-135
Gender				
Male	17			
Female	6			

Table 3

Paired Samples (Dependent) T-Tests for Programs and Sub-Tests

Program/Test Type	Pre-Intervention M (SD)	Post-Intervention M (SD)	N	t	p	r^2
ReadRx Overall	87.60 (15.22)	105.77 (15.83)	43	-7.71	<.001	.258
ThinkRx Overall	88.36 (21.69)	99.21 (18.45)	58	-6.95	<.001	.736
ReadRx – NR	88.69 (17.99)	106.75 (16.68)	16	-3.81	.002	.163
ReadRx – VAL	86.56 (12.98)	103.81 (15.43)	16	-6.07	<.001	.479
ReadRx – WM	87.55 (15.19)	107.18 (16.38)	11	-4.04	.002	.230
ThinkRx – NR	92.82 (18.74)	102.39 (18.09)	23	-3.68	.001	.594
ThinkRx – VAL	82.52 (26.25)	93.87 (19.81)	23	-4.32	<.001	.787
ThinkRx – WM	91.00 (15.37)	103.83 (14.83)	12	-4.27	.001	.582
Numbers Reversed Overall	91.13 (18.31)	104.18 (17.43)	39	5.16	<.001	.418
VA Learning Overall	84.18 (21.66)	97.95 (18.59)	39	6.98	<.001	.568
Working Memory Overall	89.35 (15.04)	105.43 (15.32)	23	5.68	<.001	.606

Note: NR=Numbers Reversed; VAL=Visual Auditory Learning; WM= Working Memory

Table 4

Partial Correlation Results for Post-Intervention and Age

	Post-Intervention x Age (control for Pre-Intervention)			
LearningRx Sub-Test	N	r	p	r^2
Numbers Reversed	36	.24	.15	0.058
Visual Auditory Learning	36	.23	.17	0.053
Working Memory	20	-.04	.86	0.002

Note: Partial correlation controlling for Pre-Intervention, 2-tailed test.

Figure 1

Scatterplot Comparing Pre-Intervention and Post-Intervention Scores for Gender Groups in Short-Term Memory

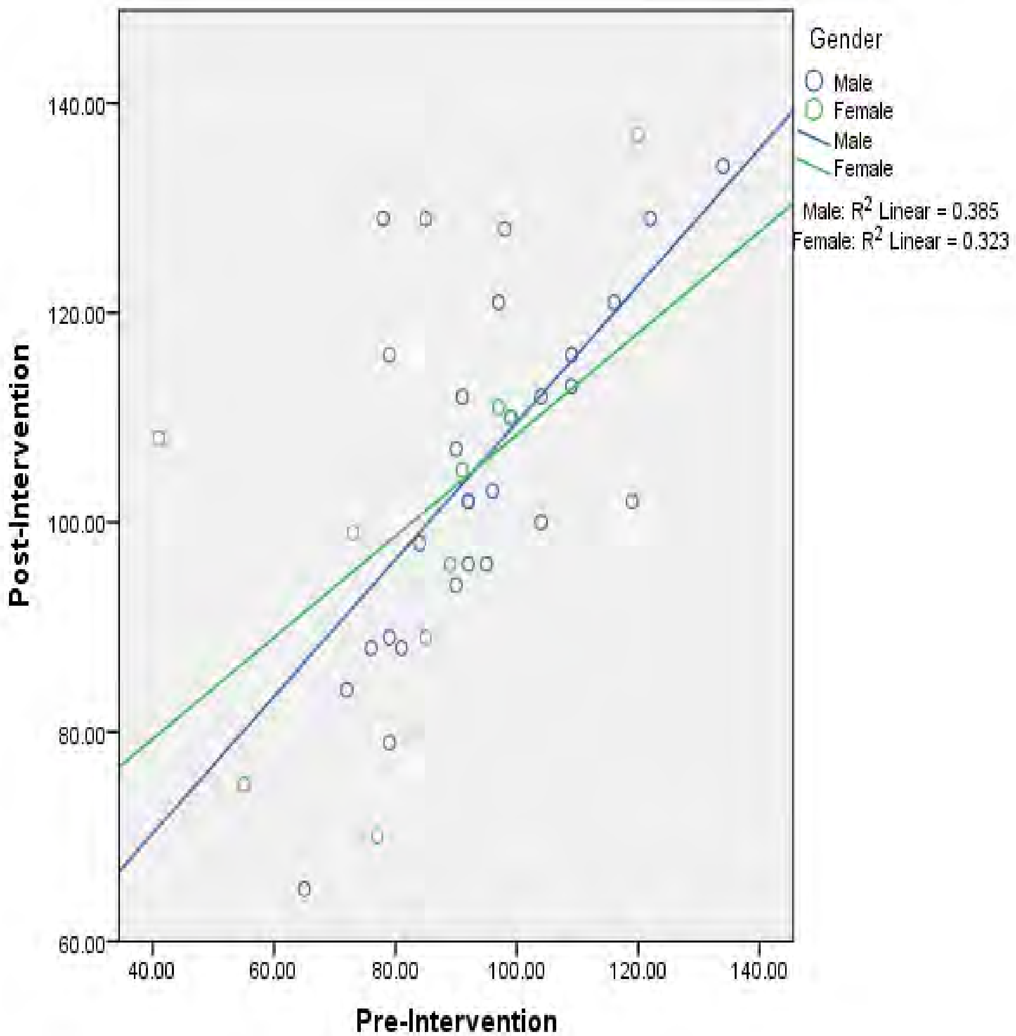

Figure 2

Scatterplot Comparing Pre-Intervention and Post-Intervention Scores for Gender Groups in Long-Term Storage and Retrieval

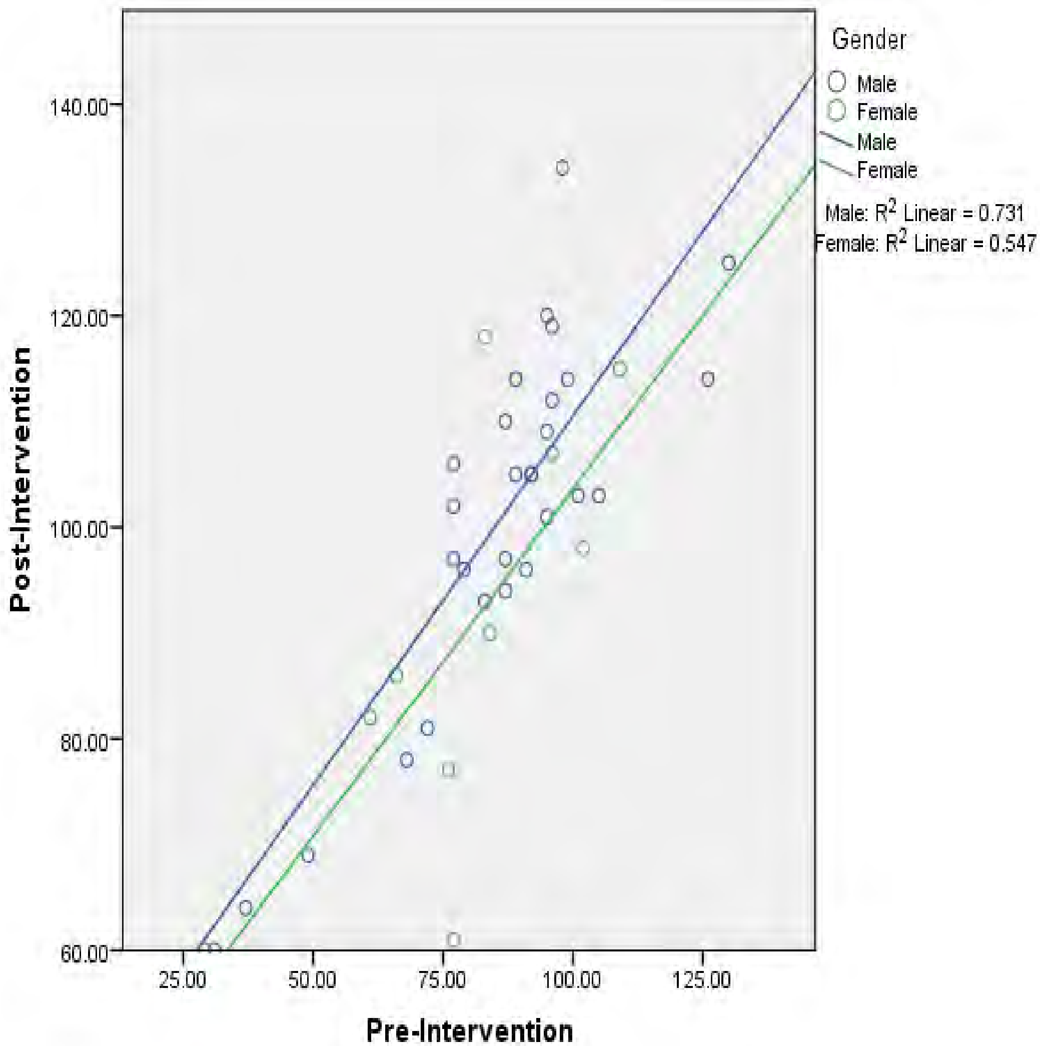

Figure 3

Scatterplot Comparing Pre-Intervention and Post-Intervention Scores for Gender Groups in Working Memory