NEUROCOGNITIVE EFFECTS OF GIST REASONING TRAINING IN STUDENT-ATHLETES WITH CONCUSSIONS, ADHD, AND LEARNING DISABILITIES

Thomas Nguyen, M.S.

Dissertation Prepared for the Degree of

DOCTOR OF PHILOSOPHY

UNIVERSITY OF NORTH TEXAS

August 2017

APPROVED:

Jennifer Callahan, Committee Co-Chair
Trent A. Petrie, Committee Co-Chair
Charles Guarnaccia, Committee Member
Vicki L. Campbell, Chair of the Department of Psychology
David Holdeman, Dean of the College of Arts and Sciences
Victor Prybutok, Dean of the Toulouse Graduate School

Concussions, attention-deficit disorder (ADHD), and learning disabilities can adversely impact learning and academic achievement, particularly with respect to attention, memory, and executive functioning; fortunately, cognitive training can be beneficial and remediating these weaknesses. One such program, strategic memory advanced reasoning training (SMART), utilizes a top-down approach to train individuals in executive, higher-ordered thinking strategies including strategic attention, integration, and innovation to facilitate information synthesis and enhance cognitive efficiency. Thus, the purpose of the study is to examine whether SMART improved performances on various neuropsychological measures tapping into attention, processing speed, memory, and executive functioning for college student-athletes with neurological conditions (e.g., concussions, ADHD, LD).
Copyright 2017

by

Thomas Nguyen
ACKNOWLEDGEMENTS

I would like to express my greatest of appreciation to my mother, father, and sister for consistently being by my side, through the good times and the bad. Without their love and support, I would not be where I am today and for that, I owe them my life. Special thanks goes out to my extended family members for keeping me sane and loving me unconditionally even though this long process of graduate school has kept me from seeing them on a regular basis. I love you all.

I am forever indebted to my mentor and advisor, Dr. Trent Petrie, who took me under his wing and accepted me into this PhD program. I will never forget all the time, effort, and energy you have put into me and to you I owe my professional career. To Dr. Jennifer Callahan, you adopted me into your research lab with open arms and have been the most influential person in the creation of this dissertation. Your knowledge in this process has been phenomenal, and your support and generosity is even greater. Thank you to the University of North Texas for my doctorate degree. Denton, you will always be in my heart.

Lastly, this dissertation is dedicated to the love of my life, Mai. You are everything I work for, and you make me strive to be the best man I can be. For all the support you’ve given me thus far, I will dedicate the rest of my life to repay you ten-fold.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>iii</td>
</tr>
<tr>
<td>CHAPTER 1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>Student-Athletes and Learning Difficulties</td>
<td></td>
</tr>
<tr>
<td>Cognitive Functions Important in Learning and Academic Performance</td>
<td></td>
</tr>
<tr>
<td>Concussions</td>
<td></td>
</tr>
<tr>
<td>Attention Deficit Hyperactivity Disorder</td>
<td></td>
</tr>
<tr>
<td>Learning Disabilities</td>
<td></td>
</tr>
<tr>
<td>Comorbidity of Concussions, ADHD, and Learning Disabilities</td>
<td></td>
</tr>
<tr>
<td>Cognitive Training</td>
<td></td>
</tr>
<tr>
<td>Purpose and Hypotheses</td>
<td></td>
</tr>
<tr>
<td>CHAPTER 2. METHOD</td>
<td>36</td>
</tr>
<tr>
<td>Participants</td>
<td></td>
</tr>
<tr>
<td>Instruments</td>
<td></td>
</tr>
<tr>
<td>Procedure</td>
<td></td>
</tr>
<tr>
<td>Data Analysis</td>
<td></td>
</tr>
<tr>
<td>CHAPTER 3. RESULTS</td>
<td>56</td>
</tr>
<tr>
<td>Participant Demographics</td>
<td></td>
</tr>
<tr>
<td>Analyses</td>
<td></td>
</tr>
<tr>
<td>CHAPTER 4. DISCUSSION</td>
<td>62</td>
</tr>
<tr>
<td>Review of Findings</td>
<td></td>
</tr>
<tr>
<td>Limitations</td>
<td></td>
</tr>
<tr>
<td>Future Directions</td>
<td></td>
</tr>
<tr>
<td>Conclusion</td>
<td></td>
</tr>
<tr>
<td>REFERENCES</td>
<td>76</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

The human brain – composed of neurons, glial cells, blood vessels, lobes, cortexes, white matter, grey matter, etc. – is uniquely different from all other living organisms. Human brains are responsible for planning out the day, fighting off an urge to do something instinctual, and shifting attention from cellphones to the TV while doing homework. This organ also houses human emotions, thoughts, and personality. It keeps memories of past birthdays, the names and faces of loved ones, and situations that should be avoided. In addition, the brain synthesizes reading material, simple or complex, creates innovative solutions to problems, and compares and contrasts different pieces of information. The utility of the brain is unquestionable; it is the core and the essence of what it means to be human. For an excellent review of brain structure and function, see Lezak, Howieson, Bigler, and Tranel (2012).

The literature on the human brain has grown exponentially. There is now more information regarding the brain in the last ten years than all the previous years studying it combined, dispelling major beliefs held for centuries (Chapman, 2013). One such belief was the concept of brain plasticity. Neuroplasticity is the term used to describe the constantly accruing changes in the structure of the brain as a result of environmental influences, both internal and external factors (Kolb & Whishaw, 2009). It was once believed that the brain was unalterable in brain functioning; that humans were born with a fixed number of neurons and if brain cells were destroyed, they could not be regenerated. Furthermore, the old model assumed that neural pathways were created during certain windows of time such as critical or sensitive time periods, but outside of those periods, these connections would be near impossible to form (Chapman, 2013). Contrary to previous findings, through the use of technology such as PET and MRI brain
scanning technology, neuroscientists now know that the brain continues to grow and evolve, and can repair itself throughout the lifespan (Raskin, 2011). Brains have the capacity to create new neurons in particular areas of the brain (i.e., neurogenesis), and neuronal connections or synapses can be developed, maintained, or repaired (Kolb & Whishaw, 2009). Most relevant to the current study, the brain can be repaired even when subjected to injury, illness, or disease, and there is no limit as to when this repair can occur.

To date, researchers have mainly focused on the etiologies of certain brain disorders and diseases, such as traumatic brain injury, stroke, developmental disorders (e.g., Attention deficit disorder (ADHD), learning disabilities) or even progressive conditions such as Alzheimer’s disease. Comparatively few studies are dedicated to examine interventions, therapies, and rehabilitations to improve brain functioning with these conditions (Chen, Abrams, & D’Esposito, 2006; Vas, Chapman, Cook, Elliott, & Keebler, 2011; Vas et al., 2015). Typically, cognitive training is geared towards compensating for a function that is lost (i.e., behavioral approaches) or remediating deficit areas (i.e., restorative approaches; Raskin, 2011). For example, if a diminished ability to express language and verbal content is flagged as a deficiency, speech therapy may be recommended to rehabilitate brain functioning localized to that specific part of the brain. Individuals who have been diagnosed with concussions, ADHD, and learning disabilities have been demonstrated to have difficulties with memory/learning and certain frontal lobe functions (Morgan & Ricker, 2008). Thus, the purpose of the current study is to document the effects of a particular type of neurocognitive training that appears promising in increasing cerebral blood flow and greater white matter connectivity to the frontal, executive functioning networks, thereby rehabilitating affected cognitive areas (Chapman et al., 2015). This training helps individuals construct generalized meanings from dense material that aid in learning called
Strategic Memory Advanced Reasoning Training (SMART). Recent preliminary studies report that the SMART program can enhance deeper understanding of information encountered in everyday life, referred to as gist-reasoning, with a variety of populations, including adolescents, ADHD individuals, older adults, military personnel, and traumatic brain injured patients (Anand, Chapman, Rackley, Keebler, Zientz, & Hart Jr., 2010; Cook, Chapman, Elliot, Evenson, & Vinton, 2014; Vas et al., 2011). To date, no studies exist regarding the SMART intervention’s effectiveness on (a) university student-athletes or (b) individuals with sport-related concussions, ADHD, and/or learning disabilities. Using a double-blind randomized controlled trial, student-athletes at a southern university were assessed using a battery of neuropsychological measures at baseline. Approximately half of the participants were assigned to the SMART program and the other half served as the wait-list control group. Then, the student-athletes were assessed immediately after the intervention (Post-Test 1) and then again four months after the intervention (Post-Test 2) to determine immediate and long-term effects of employing the strategies learned in the SMART program. The primary research questions investigated whether concussed, ADHD, or learning disabled student-athletes would improve their neurocognitive functioning after completing the SMART program on measures of attention, response inhibition, processing speed, working memory, narrative memory, verbal skills, visuospatial skills, and executive functioning. Moreover, the study examined whether these gains are maintained at four-month follow-up testing.

Student-Athletes and Learning Difficulties

According to the National Collegiate Athletic Association (NCAA; 2015), there are currently more than 460,000 NCAA student-athletes, the highest number ever recorded. Student-athletes have exceptional success in school and at work. Estimates show that eight out
of 10 student-athletes will earn a bachelor’s degree, a higher graduation rate than the normal college population (Riche, 2003). In addition, more than 35% of student-athletes will earn a postgraduate degree (NCAA, 2015), and may have high success rates after graduation. For example, many student-athletes achieve executive positions within their companies, and many other high-level executives have advocated for the hiring of student-athletes (Vozza, 2014; Ernst & Young, 2015). Fourteen out of the past 19 United States Presidents were involved in college athletics (Athlete Network, 2015). Ackerman (2010) suggests their off-the-field successes is correlated to transferrable skills that they learned on the field, court, track, etc. She describes student-athletes as understanding the value of teamwork, having a competitive nature, handling pressure well, being coachable and willing to learn, having a strong work ethic, understanding the importance of preparation, seeking challenges, being self-motivated, being mentally tough, and understanding the importance of time management. Hence, it is essential that the players themselves, educators, and administrators ensure and maintain the academic achievement that student-athletes can attain through participation in their respective sports.

Unfortunately, participation in athletics is also associated with some risks that can adversely impact learning and achievement in school. Certain sports, particularly those which emphasize athletes maintaining a certain weight class (i.e., wrestling) or those that have an aesthetic component that favors athletes of a particular body size and shape (i.e., gymnastics, swimming) may be at-risk for eating disorders and pathogenic weight control behaviors (Anderson & Petrie, 2012; Petrie, Greenleaf, Reel, & Carter, 2008). Past research has shown that nutrition, or lack thereof, is linked to cognition and academic achievement (Bellisle, 2004; Choma, Sforzo, & Keller, 1998; Landers, Arent, & Lutz, 2001). In addition, a combination of excessive water restriction, heat, and physical exertion, commonly known factors related to the
sport environment, can also lead to decrements in neuropsychological performance (Grandjean & Grandjean, 2007). Conforming to the time demands of sports can also impact academic functioning. Many student-athletes spend upwards of 20 hours practicing, training, competing, and rehabilitating. In addition, they are part-time or full-time students and are expected to maintain a certain GPA while juggling their social life, jobs, families, romantic relationships, and other stressors. Even worse, these obligations may be particularly strenuous on individuals who have compounded other disadvantages such as having acquired injuries from their sport or suffering from academic learning difficulties. Injuries, in general, can make concentrating in the classroom very challenging, as individuals tend to be focused on the pain (Hart, Martelli, & Zasler, 2000). Specifically with concussions, pain arising from headaches or from anatomical structures that were impacted during a concussive blow can be an additional issue alongside other physical, cognitive, and emotional symptoms that may occur secondary to the head injury that prevent optimal learning (McRory et al., 2008; Seifert, 2014). Likewise, ADHD and learning disabilities can have significant negative effects on student-athletes’ learning, which may contribute to lower GPAs, failed classes, increased risk of dropout, and lower overall life satisfaction (Morgan & Ricker, 2008). Education-Impacting Disability (EID) is an academic waiver filed with the NCAA that identifies student-athletes who may have current impairments in learning that can have a substantial educational impact on academic performance (Ridpath, 2014). As such, these student-athletes may receive accommodations for their conditions such as learning disabilities, ADHD, and mental health disorders. Ridpath (2014) reported that in 2008, students with disabilities represented nearly 11% of all postsecondary students. If the proportion of individuals who have disabilities is similar to that of the normal population, there are an overwhelming of number of student-athletes who are struggling in the classroom on a day-to-day
Developing academic interventions that aid in learning complicated college-level material is of utmost importance.

Cognitive Functions Important in Learning and Academic Performance

*Consciousness, attention, and information processing.* The first requirement to appropriately learn information is to be conscious. Consciousness refers to the level in which an organism is receptive to stimulation or is awake (Lezak et al., 2012). Another working definition of consciousness is the awareness of the self and one’s surroundings that “requires consistent and reliable integration of attention, perception, and memory” (p. 393). The levels of consciousness range anywhere from full alertness to drowsiness, somnolence, stupor, and coma on a continuum (Trzepacz and Meagher, 2008). Any internal or external factor influencing an individual’s alertness can significantly diminish one’s ability to remain attentive, energized, or cognitively efficient to process information. Orientation deficits are one of the most common symptoms of brain disease. Impaired orientation for time and place may indicate widespread cortical involvement such as the case in Alzheimer’s disease, acute brain syndromes, lesions in the limbic system, or damage to the reticular activating system (Lezak et al., 2012), whereas impaired recall of different events or temporal contexts may suggest lesions in the brain involving the orbitofrontal cortex, basal forebrain, or limbic system (Schnider, 2000). It should be noted that while impaired orientation is highly indicative of a brain disorder, orientation can still be intact even with mild cognitive impairments.

Attention is the process which allows either a selective awareness of an aspect of the sensory environment or a selective responsiveness to one class of stimuli (Kolb & Whishaw, 2009). It refers to the capacity of how receptive an organism is to stimuli and engages the organism to begin processing the internal and external environment. A characteristic of the
attentional system is its limited capacity to grasp information at once. Attention requires the ability to process information but if there are competing modes of information, that process may be slowed or interfered. Note the attentional demands in this scenario: a parent is holding their baby while watching the other small children as they play in the yard, at the same time attending to the food that they are cooking on the stove. *Bottom-up processing* is a strategy in which information is processed due to an “attention-getting” stimuli where there is a bias in attention. For example, a person sees a red stop sign and attends to it when it appears in their visual field. The other strategy, *top-down processing*, is determined by the observer’s current goals. With this approach, the driver is actively scanning the environment for stoplights and stop signs. Studies have shown that bottom-up processing can be particularly effective when attending to conspicuous or threatening stimuli whereas others have demonstrated that top-down attentional biases can certainly override bottom-up processes (Theeuwes, 2010).

There are five aspects of attention: (1) simple attention refers to how much information can be taken in, (2) focused or selective attention is the capacity to maintain concentration on relevant stimuli while suppressing the awareness of competing distractions, (3) sustained attention or vigilance is the ability to attend to specific stimuli over a long period of time, (4) divided attention is the capacity to respond to multiple tasks at one time or attend to multiple elements within a single, often times complex task, and (5) alternating attention, which is the shifting of attention between tasks (Lezak et al., 2012). The latter four aspects are the most sensitive to types of brain disorders, and impaired attention and concentration among these types are associated with brain damage. Patients sometimes mistakenly characterize themselves as having a “memory problem” when one or more of these aspects of attention is compromised. For example, they failed to properly attend to the stimuli when presented and, as a result, they...
are unable to subsequently retrieve that information. Impaired attention is not always a global disability, thus it is important to distinguish simple attentional problems from the more complex, task-specific problems. The frontal lobes heavily mediate the attentional processes (Kolb & Whishaw, 2009).

The underpinning of attentional disorders may also be found in slow processing speed; the rate at which information is taken in and made sense of. Visuospatial skills largely depend on one’s ability to take in visual information and process it effectively and efficiently (Kravitz, Saleen, Baker, & Mishkin, 2011). Examples of visuospatial processing may include reading a bar graph or seeing a pattern to complete a jigsaw puzzle. Furthermore, difficulties may lie in one’s ability to interpret and apply the sounds that they hear. For instance, a student may have a problem with auditory attention if they have trouble blocking out the sound of the air conditioner during a class lecture. A deficit in the speed in which that information is processed can have broad-ranging effects on attentional activities and can also be perceived as a “memory problem.” For example, a child is struggling to keep pace with their parent while walking through the park. They are surrounded by the same stimuli and may see the same objects and events; however, because the child is focused on walking in sync with the parent, he or she may not have appropriately attended to the stimuli in order to remember what had occurred in the park. This example is analogous to an individual who has slowed information processing. Therefore, any issues stemming from attentional processes can disrupt input necessary for learning.

**Memory.** The second layer of learning is memory, which is central to cognitive functions. Memory refers to the capacity to learn from experiencing the world, to remember past events, and to forecast the future. When healthy, memory processes in the brain encode the sensory environment, consolidate and store that information into units that are meaningful, and
facilitate retrieval of that information at a later time. Through specific case studies such as that of HM, a famous patient who received surgery to treat his epilepsy, scientists were able to better understand that memory was not just one construct but instead was multi-faceted in nature. Thus, memory functions were better conceptualized in terms of two long-term storage and retrieval systems: declarative system, otherwise known as explicit memory, and nondeclarative memory or implicit memory (Lezak et al., 2012).

Declarative memory is the ability to learn about and remember facts, events, objects, and other information. This type of memory involves a “conscious and intentional recollection” process. Declarative memory is associated with neural structures of the temporal lobe, composed of the hippocampus, perirhinal cortex, and connections with the ventral frontal cortex (Kolb & Whishaw, 2009). Housed in the medial temporal lobe is the hippocampus, whose function is important in memory, particularly for its role in translating short-term memory to long-term memory. Because declarative memory is so salient in everyday life, patients may report this type of memory as problematic. A three-stage model of declarative memory processing has been developed to better conceptualize dysfunctional memory. First, registration or sensory memory is the process which holds large amounts of sensory information momentarily. Research suggests that sensory memory is modality specific, with auditory or echoic memory lasting longer than visual or iconic memory (Koch and Crick, 2000). This process takes in the information from the environment and determines what information is stored as short-term memory or quickly filtered out. The second declarative memory processing and the first stage of short-term memory is coined immediate memory. Immediate memory is a temporary storage with limited capacity, momentarily holding the sensory information before transferring it to a more stable and permanent storage. This type of memory typically lasts
anywhere from 30 seconds up to several minutes and has the capability to hold seven plus or minus two units of information at a time. Immediate memory can transfer all information into a single storage place; however, another form of immediate memory, called working memory, is more intricate and operates using several processing subsystems. Working memory is the temporary storage that manages the information required to carry out complex cognitive operations (e.g., problem solving, learning, reasoning, and comprehension). It is comprised of a central executive system and two subsystems, one that processes language and the other processes visuospatial information. Some believe working memory to be the basis for general intelligence and reasoning; individuals who can hold large amounts of information in temporary storage at one time may be better equipped to problem solve complex problems from multiple perspectives (Dingfelder, 2005). The second stage of short-term memory is rehearsal. Rehearsal of the information present in immediate memory can lengthen the duration of a memory trace and can strengthen the likelihood that the information is passed into a longer-term storage. There is evidence of a more “intermediate step” (i.e., the third stage of short-term memory) in memory formation in which information can be stored from one hour to two days; however, that process is less understood.

The last stage of memory processing is long-term memory (i.e., secondary memory). Long-term memory is the maintenance and consolidation of the information from short-term memory into storage (Lezak et al., 2012). Learning is the acquisition of new information, thus is defined by the amount of consolidation that occurs. Though long-term memory and learning is related and intertwined, the processes are distinct. For instance, when a child begins to learn the multiplication table, he or she is gaining new knowledge and understanding of arithmetic. Eventually, when the information is consolidated and stored into long-term memory, the child
may be quick to retrieve the answers in order to perform basic computations. Learning can either take place through effortful and attentive mental activity or is learned incidentally. The neural structures that are involved in learning begin in the hippocampal and medial temporal regions and are gradually transferred to the neocortex into long-term memory (Kapur & Brooks, 1999). Declarative memory, in general, depends on top-down processing, in which the individual reorganizes the information in order to store it in a way that is meaningful.

Nondeclarative memory, an implicit, unintentional memory, encodes its information using bottom-up processing. Because the information is received and stored from the sensory information level, no higher-level cortical processes are needed. Nondeclarative memory is localized primarily in the basal ganglia, motor cortex, and cerebellum (Kolb & Whishaw, 2009). Two types of nondeclarative memory exist: procedural memory and priming (i.e., perceptual learning). Procedural memory is the most resistant form of memory to change, even in patients who have severely impaired recent and remote memories (Fuster, 1995). It is considered “how to” learning, which consists of motor and cognitive skill learning. Examples of procedural memory include getting dressed, brushing teeth, and riding a bike. Priming refers to the implicit memory that uses a cued recall, outside of the individual’s awareness, which initiates a specific response that was learned through previous exposure. The retrieval of learned information greatly depends on how the information was originally encoded, stored, and consolidated. Thus, memory processes serve as the bases for all learning.

Language. Language is a unique human ability. This cognitive function includes skills to express oneself, to understand speech and conversation, to categorize objects, to read texts, and to form thoughts and concepts. Language is generally thought of as communication through words (i.e., associations between a sound and a meaning), symbols, or gestures. This process is
highly multimodal in nature, utilizing auditory, visual, and motor systems to create, see, and hear speech. Language development is typically rapid; children by age six understand approximately 13,000 words and by the end of high school approximately 60,000 words (Wright, 2015); even more complex of a process is the formation of communication through the use of grammar. Thus, it is apparent that language is fundamental to learning, thinking, and academic achievement.

Researchers have developed frameworks to understand the localization of language processes through four lines of research: (a) anatomical studies of language, (b) studies of lesions in human patients, (c) studies of brain stimulation in patients before surgery, and (d) neuroimaging studies (Kolb & Whishaw, 2009). For the majority of individuals, language is lateralized to the left hemisphere. Many structures in the temporal, parietal, and frontal cortices such as the inferior frontal gyrus, occipitotemporal gyrus, medial superior temporal gyrus, and the insula are involved with language (i.e., structures encompassing Brodmann’s areas 44, 45, 22 and parts of 9, 4, 3-1-2, 40, 39, and 21; Kolb & Whishaw, 2009). Aphasias, or language disorders, have been instrumental in the understanding of neural structures that are associated with language. Three classification systems exist for categorizing aphasia: fluent, nonfluent, and pure aphasias (Kolb & Whishaw, 2009). Individuals with fluent aphasia have difficulties with auditory comprehension or in the repetition of words, phrases or sentences spoken by others despite having fluent speech themselves (e.g., Wernicke, conduction, transcortical, anomic). Nonfluent aphasias describe relatively good auditory verbal comprehension but have major difficulties in expressing language (e.g, Broca, transcortical motor, global). Individuals with pure aphasias may have selective impairments in reading, comprehension, writing, or the recognition of words. Pure aphasias, such as alexia (i.e., inability to read) and agraphia (i.e.,
inability to write), may involve both the left and right hemispheres as these disorders disrupt visual input which is a bilateral process in the occipital lobes (Benson, 1986). Dyslexia, a reading disorder, is associated with deficits in visual and language processes. In sum, language is a cognitive function that plays an essential role in learning. Any brain injuries, lesions, or diseases that affect any of the neuroanatomical structures can greatly hinder one’s ability to express, receive, or comprehend verbal information.

**Executive functions.** The executive functions consist of capacities that enable a person to engage in purposeful, independent, volitional, goal-directed behavior (Alvarez & Emory, 2006). These functions are also referred to as higher-level cognitive functions as they act as the “executive” in controlling and regulating lower-level cognitive processes. Willcutt and colleagues (2005) used factor analysis to suggest that executive functioning has at least four factors: response inhibition and execution, working memory, set shifting, and interference control. Additionally, executive functioning may play a crucial role in encoding and retrieval, the processes central to learning and memory (Pennington & Ozonoff, 1996). Furthermore, executive functions manage emotional and motivational processes as well. There is debate as to whether or not executive functioning, a neuropsychological construct, is associated with and subsumed by the frontal lobes of the brain. Although research has been inconsistent in proving the sensitivity and specificity of executive functioning measures to lesions in the frontal lobes, some studies have found that those who perform poorly on executive functioning measures had a “frontal lobe deficit” and those who had severe lesions in the frontal lobes performed poorly on these same measures (Stuss & Alexander, 2000). There are three principal frontal-subcortical circuits that are involved with executive functioning: orbitofrontal, ventromedial, and dorsolateral (Alvarez & Emory, 2006). Lesions in the orbitofrontal circuit (projects to the
ventromedial caudate nucleus) are involved with disinhibition, impulsivity, and antisocial behavior (Cummings, 1995); lesions in the ventromedial circuit (begins in the anterior cingulate and projects to the nucleus accumbens) are linked to apathy, decreased social interaction, and psychomotor retardation (Sbordone, 2000). For the relevance of this study, the dorsolateral frontal cortex (projects to the dorsolateral head of the caudate nucleus) has been linked to the higher-order executive functions such as verbal and design fluency, flexibility of thinking, planning, impulse control, working memory, creativity, concept formation, organizational skills, reasoning, problem-solving, and abstract thinking (Alvarez & Emory, 2006; Stuss & Alexander, 2000). Because these higher-level cognitive functions stem from simpler, “lower-level” forms of cognition and behavior, executive functions do not purely localize in the frontal lobes, but should also include diverse and diffuse structures of the central nervous system (i.e., frontal lobe connections to cortical, subcortical and brain stem sites).

Other important cognitive functions associated with learning. Visuospatial behavior is one’s ability to guide the body through space and understand spatial orientation. Examples include creating a cognitive map of where the car was parked at a busy mall lot, knowing which container will fit the leftover food, and navigating one’s way through football defenders to score a touchdown. Evidence from brain-injured studies suggest that visuospatial abilities are primarily subserved by the right hemisphere, particularly in the parietal cortex and cingulate cortex (Kolb & Whishaw, 2009). Right temporal regions including the hippocampus play a central role in nonverbal memory such as the ability to remember one’s route between work and home or remembering faces of people at a social gathering. Visuospatial behavior regulates learning through perceptual reasoning or the ability to visualize, understand, and work with nonverbal information.
Researchers understand the importance of emotion on overall brain functioning through studies of brain injuries. Neural correlates of emotion include structures in the prefrontal cortex, primarily in the cingulate cortex, the amygdala, paralimbic cortex (hippocampus, mammillary nucleus, anterior thalamus), and the hypothalamus (Kolb & Whishaw). It is evident that emotion and various aspects of cognition such as language and memory are heavily interrelated, as they are share similar neuroanatomical structures. Lesions in these particular areas of the brain can lead to deficiencies in inhibitory behavior, judgement and insight, and emotional processing (Lezak et al., 2012). Mood and anxiety disorders can also affect various neuropsychological processes such as processing speed, psychomotor functioning, attention, and subsequently memory processes (Gray & McNaughton, 2003; Shenal, Harrison, & Demaree, 2003). Thus, one’s emotional functioning can greatly influence their ability to learn material at home, school, or work.

Concussions

Between 1.6 and 3.8 million sports- and recreation-related concussions (i.e., mild traumatic brain injury; mTBI) occur in the United States annually (Langlois, Rutland-Brown, & Wald, 2006). Importantly, that range may be an underestimation of actual concussive events since as many as 50% of concussions are unreported or otherwise undetected (Iverson, 2005; McCrea, Hammeke, Olsen, Leo, & Guskiewicz, 2004). Fortunately, over the past ten years, there has been an influx of awareness and understanding of concussions due to more research being conducted, advances in neuroimaging and biomarkers, education, and media attention. Concussions are to be taken seriously as they can have immediate negative cognitive, neuropsychological, and emotional symptoms and, for some individuals, possible long-term consequences as well (McCrory et al., 2013).
In brief, concussions are a subset of traumatic brain injury (i.e., mild traumatic brain injury) and defined as a “complex pathophysiological process affecting the brain, induced by biomechanical forces” (McCrory et al., 2013, p. 1). Many of the world’s leading concussion experts developed a consensus statement at the 4th International Conference on Concussion in Sport, held in 2012 in Zurich, in order to further conceptual understanding of the brain injury and educate physicians and health care professionals who are involved in the care of injured recreational, elite, or professional athletes. From a clinical, pathologic, and biomechanical standpoint, there are several common features that may be utilized in defining the nature of a concussive event:

(1) Concussion may be caused either by a direct blow to the head, face, neck, or elsewhere on the body with an “impulsive” force transmitted to the head.” (2) Concussion typically results in the rapid onset of short-lived impairment of neurologic function that resolves spontaneously. However in some cases, symptoms and signs may evolve over a number of minutes to hours. (3) Concussion may result in neuropathological changes, but the acute clinical symptoms largely reflect a functional disturbance rather than a structural injury and, as such, no abnormality is seen on standard structural neuroimaging studies. (4) Concussion results in a graded set of clinical symptoms that may or may not involve loss of consciousness. Resolution of the clinical and cognitive symptoms typically follows a sequential course. However, it is important to note that in some cases symptoms may be prolonged. (McCrory et al., 2013, p. 2)

Concussions reflect neuropsychological functional injury, as opposed to a structural injury that might be seen through standard imaging techniques (e.g., CT, MRI, EEG), which can
make concussions difficult to diagnose. Furthermore, concussions can be widely variable as to how the injury was sustained. Sport-related concussions result from forces that are direct to the head or indirectly through the neck or body which typically induce a combination of rapid acceleration and deceleration. These biomechanical forces produce a linear and/or rotational (i.e., angular) acceleration/deceleration on the brain (Guskiewicz & Mihalik, 2011). Though research on the relationship between the strength of the force, the movement of the brain (e.g., linear, rotational), and clinical symptoms are mixed, it is agreed upon that the severity of the concussion is dependent on a variety of factors. Such factors may include individual differences in cerebrospinal fluid levels and function, vulnerability to brain tissue injury, relative musculoskeletal strengths and weaknesses, and the anticipation of an oncoming direct or indirect impact (Guskiewicz & Mihalik, 2011). On the whole, female collegiate athletes, particularly in soccer and basketball, had the highest number and injury rate of concussions suffered during competitions compared with male athletes from a variety of sports (Covassin, Swanik, & Sachs, 2003). Barnes and colleagues (1998) hypothesized that female athletes are at significantly greater risk of sustaining a concussion than their male counterparts because of their weaker neck muscles.

Concussions are also considered complex in regards to symptom presentation with no two concussions being the same. They may or may not involve the loss of consciousness and is often accompanied by mental status confusion or amnesia (Kelly & Rosenberg, 1997). Concussions may consist of a constellation of symptoms that may present immediately or have a delayed onset including various physical, emotional symptoms, and cognitive (Mainwaring et al., 2004). Physical symptoms can include vestibular issues (e.g., impaired balance, nausea, motion discomfort), post-traumatic migraines, vision changes (e.g., blurry vision, double vision,
photophobia, poor night vision, inconsistent/fluctuating vision, dizziness with motion, illusions of movement, dry eyes, decreased visual attention), and cervical conditions (i.e., injuries to the neck or spine) (McRory et al., 2013). Emotional symptoms consist of anxiety, irritability, depression, and other kinds of emotional or psychological disturbances (Mainwaring et al., 2004). Lastly, concussions can result in fleeting or prolonged cognitive symptoms such as fogginess, difficulty concentrating and focusing, memory impairment, cognitive fatigue, slow thinking and information processing, or feeling detached. To further cloud the diagnostic picture, some neurologic or psychiatric conditions can mimic the profile symptomology of a concussion. Mood disruption, loss of energy, changes in sleep, changes in appetite, and difficulty concentrating may appear similar to the somatic complaints often seen from individuals with depression (Didehbani, Cullum, Mansinghani, Conover, & Hart, 2013). Similarly, symptoms of posttraumatic stress disorder (PTSD) and post-concussive syndrome can overlap (e.g., attentional problems, depression; Warden, 2006; Mainwaring et al., 2004). Pre-existing mood and anxiety disorders (or psychological distress in general), or those that occur as a result of neurochemical changes that accompany concussions, such as depression, anxiety, and PTSD can exacerbate post-concussion symptoms and can prolong recovery times (Iverson, 2014; Klein, Caspi, & Gil, 2003; Mooney, Speed, & Sheppard, 2005). In addition, concussion diagnosis may be made more difficult as a result of the heavy reliance on self-reported symptoms. Some athletes may mask their injury or minimize their symptoms for a multitude of reasons (e.g., to remain on the field of play; fear of losing their position, playing time, or job; to “recover” more quickly). In addition, athletes may “sandbag” (i.e., malinger) their test results on baseline cognitive measures so that when tested again post-concussion, their performances after sustaining the head injury are less discrepant from their baseline (Erdal, 2012). Because of the
complexity of the concussion diagnosis and the psychosocial overlay of the pressures that come with playing sports, professionals who are charged with diagnosing, managing, and treating concussions as well as those who determine return to play (RTP) protocols must be adept at interpreting neuropsychological data and corroborating that information with athletes’ self-reported symptoms, historical background, and current situational context.

One of the first studies to examine the neuropsychological effects of sport head injuries was conducted by Barth and colleagues (1983). Seventy-one concussed athletes were found to have impairments in memory and visuospatial skills. Since then, other brain functions have been found to be associated with the cognitive effects of concussions; and as such, assessments to diagnose concussions should include neuropsychological measures that tap into the frontal lobe functions that are most susceptible to change post-concussion: attention and concentration, cognitive processing (speed and efficiency), learning and memory, working memory, executive functioning, and verbal fluency (Guskiewicz et al., 2004). Acutely concussed individuals are most likely to experience lapses in attention/concentration (Echemendia, Putukian, Mackin, Julian, & Shoss, 2001) and memory (Lovell et al., 2003). Studies have shown that acutely concussed individuals can experience cognitive deficits, but may experience significant improvements within 24 hours to ten days; the vast majority of individuals resolve their cognitive symptoms within one month (Macciocchi, Barth, Alves, Rimel, & Jane, 1996). Bruce & Echemendia (2009) used traditional and computerized assessments to test long-term cognitive functioning of collegiate male athletes who have experienced multiple concussions. They found little to no relationship between history of self-reported concussions and lasting neuropsychological impact. However, there is contrary evidence to suggest that certain populations may be at-risk to experience long-term negative effects of concussions: younger
athletes (Majerske, Mihalik, Ren, Collins, Reddy, Lovell, & Wagner, 2008) and multiple concussions (Collins, Lovell, Iverson, Cantu, Maroon, Field, 2002; Iverson, Gaetz, Lovell, & Collins, 2004). Collins et al. (1999) found that college football players who had two more concussions were more likely to endorse symptoms and perform more poorly on measures of processing speed than athletes who have not been concussed. This evidence also suggested that people tend to make full, rapid recoveries from the cognitive effects of one concussion whereas there may be more permanent sequelae following multiple concussions. For instance, within trauma patients, those with multiple concussions exhibit greater deficits in auditory processing than those with only one concussion (Gronwall, 1977). Additionally, athletes who sustain multiple concussions were more likely to perform worse on memory tests at 2 days post-injury compared with athletes who have only sustained one concussion (Iverson et al., 2004). However, there is new evidence that shows tiny neuroanatomical structural changes as a result of repetitive, nonconcussive blows to the head; though its effects on cognition is not yet known (Bailes, Petraglia, Omalu, Nauman, & Talavage, 2013). Because research on concussions are still in its infancy, more empirically-based studies to determine the longitudinal neuropsychological sequelae are needed. In light of the potential deleterious effects of concussion, it is important that we also consider developmental factors, such as childhood disabilities, that may hinder one’s ability to learn, concentrate, and be successful in school.

Attention Deficit Hyperactivity Disorder

Attention deficit hyperactivity disorder (ADHD) is among the most prevalent of all childhood psychiatric disorders. Prevalence rates estimate that 3-7% of school-aged children are affected with this condition (Halperin, Marks, & Schulz, 2008) though the Centers for Disease Control have estimated that 11% of children ages 4-17 have ADHD as of 2011 (2015). Boys are
more likely to be diagnosed with ADHD than girls, but this finding may be attributed to boys having more co-morbid conditions. According to the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed., text rev.; *DSM-5*; American Psychiatric Association, 2013), twin studies have shown that ADHD is highly heritable, yielding a correlation of .76. ADHD is a disorder that originates in childhood, and its essential features are signs of developmentally inappropriate inattention, impulsivity, and hyperactivity. It should be noted that most individuals have symptoms of both inattention and hyperactivity, though in some cases one is more dominant than the other. Thus, the *DSM-5* created a distinction between presentation subtypes (e.g., combined type, predominantly inattentive type, predominantly hyperactive type). A diagnosis of ADHD requires six or more symptoms of inattention (e.g., failure to pay close attention to details, difficulty organizing tasks and activities) and/or six or more symptoms of hyperactivity (e.g., excessing talking, fidgeting, or inability to remain seated in appropriate situations. Symptoms of ADHD must involve impairment in behavior across multiple settings (e.g., school, work, home) that can lead to deficits in performance in general. According to the *DSM-5*, ADHD tends to look differently across the lifespan as well. Longitudinal studies exhibit a decrease in the number of symptoms as the child with ADHD ages; 50% of preschool aged children no longer display developmentally inappropriate externalizing behaviors by the school-age years. Signifying a decrease in rates, only 4-5% of adults continue to meet the diagnostic threshold of ADHD. Excessive gross motor activity in ADHD children evolves into internal feelings of restlessness by adolescence and adulthood; excessive distractibility evolves into avoidance/procrastination behaviors (e.g., difficulty with task completion, time management, organization and planning) and problems with sustained effort and concentration.
It appears that there are significant deficits in learning and delayed memory (Anderson, Egeland, & Oie, 2013), working memory (Martinussen, Hayden, Hogg-Johnson, & Tannock, 2005), and executive functioning (Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005) for ADHD individuals, though the etiology of this disorder is not well-understood. There exist a number of theories for the development of this condition. Some studies show similarities between children with ADHD and patients with lesions to the prefrontal cortex. Therefore, it is conjecture that ADHD appears to affect processes mediated by this area, namely executive functioning. A meta-analysis conducted by Willcutt et al. (2005) found that ADHD is associated with deficits across a number of executive functioning domains, but the strongest and most consistent effects were obtained on top-down processing measures of response inhibition, vigilance, spatial working memory, and some measures of planning. Children with ADHD tend to exhibit deficits in multiple components of working memory (Martinussen et al., 2005). The model proposed by Barkley (1997) predicts that deficits are strongest in behavioral inhibition, working memory, regulation of motivation, and motor control with ADHD individuals. Both types of ADHD, inattentive and hyperactive, share similarities in deficits on measures of executive functioning, the inattentive type may have additional problems between perceptual-motor speed and processing (Barkley, Grodzinsky, & DuPaul, 1991). Despite the link between ADHD and executive functioning weaknesses, inconsistent findings suggest that these deficits are not the cause of all ADHD cases (Nigg et al., 2005; Tsal, Shalev, & Mevorach, 2005); rather, weaknesses in executive functioning appears to be one facet of several that paint the etiologic picture of ADHD. Tsal, Shalev, and Mevorach (2005) contend the executive functioning theory, which minimized the contribution of attention deficits, by demonstrating that ADHD children suffer from deficits in different types of attention: selective attention, executive attention,
orienting of attention, and most profoundly, sustained attention. Another alternative theory states that ADHD is related to deficiencies with inhibitory control mechanisms that preclude the efficient use of higher-order functions, thereby leading to behavioral difficulties (Aron, Robbins, & Poldrack, 2004). It has also been found that some individuals with ADHD may have deficits in brain reward systems associated with an ability to tolerate delay, which are relatively independent of executive function impairments (Seidman, 2006). Given that the prefrontal cortex does not fully develop until early adulthood and that lesions in this area have not been shown to be correlated with behavioral difficulties until the adolescent years (when individuals with ADHD are generally growing calmer), Halperin, Marks, & Schulz (2008) argue that ADHD is caused by deficits in unspecified subcortical regions that remain static throughout the life and cause heterogeneous deficits in a bottom-up manner. Additionally, they believe that the reduction in symptomatology of ADHD over time is caused by neural plasticity and the developing prefrontal cortex’s ability to compensate for the presented deficits in a top-down manner. Taken together, ADHD research has not always been consistent with respect to localization and the processes by which the brain regions mediate, hence there may be more heterogeneity within and possible multiple pathways to the disorder. Although ADHD may thwart a person’s ability to learn as these individuals may be inattentive, impulsive, or hyperactive, the condition does not usually indicate an inability to encode and process information; thus, learning disabilities (i.e., a difficulty in some type of processing despite an average level of intelligence) need to be considered.

Learning Disabilities

Learning disabilities are an umbrella term used for a variety of academic and school-related difficulties (Kolb & Whishaw, 2009). Diagnoses of learning disabilities are classified as
developmental disorders because there is some abnormality in the way that the brain develops and thus possibly representative of central nervous system dysfunction (Nicholson, Fawcett, Berry, Jenkins, Dean, & Brooks, 1999). Individuals with learning disabilities have intelligence within normal limits and have sufficient opportunities to learn either at school or in the home environment, yet fail to achieve a level of scholastic success that is expected of them. DSM-5 estimates that the prevalence rates of learning disabilities range from 2-10% and approximately 5% of students in U.S. public schools are diagnosed. Some of these children are unable to meet the demands of their curricula and drop out; others have to repeat one or more grades and have difficulty learning. Some children fail to master specific content areas, and some fail to master any core content areas. As learning-disabled children mature and advance in school, they may carry with them these emotional scars from a difficult educational experience that may hinder their abilities to succeed in further school, working, or social relationships if there is no academic intervention to combat their learning challenges. To further solidify this point, Spreen (1988) followed a group of 203 learning-disabled people longitudinally. Through various data points such as assessments and interviews, he found that learning-disabled people who suffered through their short school career often experienced a miserable social life full of disappointments and failures. They also had a relatively poor chance of obtaining training necessary for skilled types of jobs. Corroborating with parental interviews, the researchers found that the children with learning disabilities often had serious negative effects on well-being, happiness, and social interactions. The group of learning disabled children were found to have less detailed memory of their childhood than the children without learning disabilities. As the subjects aged, even though they made better personal and occupational adjustments, their dislike for school and dissatisfaction with it persisted. Although somewhat pessimistic, this study highlights the
importance of careful assessment and diagnosis of learning disabilities, and to develop cognitive rehabilitation programs targeted towards the acquisition of skills in which the individual is deficient.

The DSM-5 has broadened its approach to identifying individuals with learning disabilities. A single diagnosis, specific learning disorder, was formed to encompass those who suffered deficits in general academic achievement. More importantly, this diagnosis includes specifiers for the areas of reading, mathematics, and written expression to effectively target interventions. It is believed that these specifiers are an indication for a subset of symptoms, such as difficulty in reading. Specific learning disorder in itself describes a difficulty in a person’s ability to function across many domains of functioning including school, work, and relationships because many so activities revolve around one’s capacity to master number facts, written words, and written expression. In fact, students with learning disabilities tend to also experience poor memory, poor reasoning, and poor problem solving across home and academic settings (Silver et al., 2008).

Although reading disorder (RD) and mathematics disorder (MD) are distinct, high comorbidity rates exist between the specific learning disorder specifiers (American Psychiatric Association, 2013). This finding suggests that there may be general cognitive abilities that are common among RD and MD. One study by Moll, Göbel, Gooch, Landerl, and Snowling (2014) examined three cognitive factors that are frequently found in children with attentional problems: processing speed, temporal processing, and working memory. Ninety-nine school children were randomized into four groups: children with only RD, children with only MD, children who share comorbidity between RD and MD, and the control group. Similarities and differences were found between the groups. Deficits in verbal memory were found in both RD and MD. In
contrast, reduced processing speed was only associated with RD and temporal processing and visuospatial memory deficits were only found with MD. Another study found that language deficits appear to be prevalent in individuals with only RD and both RD and MD; RD and MD both experienced deficits with working memory (Cirino, Fuchs, Elias, Powell, & Schumacher, 2015). Though the research on learning disabilities and its impact on executive functioning is quite limited, Semrud-Clikeman (2005) argues that measures of this higher-ordered cognitive domain is important to consider in establishing a comprehensive neuropsychological profile. In conclusion, depending on the subtype, learning disabilities can affect various brain functions, though there is evidence to suggest that either one or both may hinder overall learning and academic achievement.

Comorbidity of Concussions, ADHD, and Learning Disabilities

Thus far, I have reviewed the literature on the neurocognitive effects of concussions, ADHD, and learning disabilities separately; however, it is important to recognize the potential interplay that these conditions may have on each other. Comorbidity is defined as two conditions, diseases, or illnesses occur simultaneously or sequentially in the same person (NIH, 2010). Comorbidity affects the course of the illness and the prognosis of the said conditions and may compound the deficits that exist if the disorder or injury were to occur on independently. As a result, comorbid disorders and injuries may complicate the neurological picture.

ADHD has a high comorbidity rate; estimates as high as 75-80% of individuals with ADHD have one or more co-morbid psychiatric disorder (Brown, 2009). As many as 10-25% of individuals with conduct disorder, oppositional defiant disorder, ADHD, major depression disorder, or dysthymic disorder also have learning disorders (American Psychiatric Association, 2013). Rates of ADHD and learning disability overlapping range from as low as 10% to as high
as 92% (Biederman, Newcorn, & Sprich, 1991); RD and ADHD co-occur at the rate of 40% (Wilcutt & Pennington). Though there is much overlap in deficits between RD and ADHD (inattentive type), processing speed is the only shared predictor of cognitive functioning (McGrath et al., 2011; Wilcutt, Betjemann, McGrath, Chhabildas, Olson, DeFries, & Pennington, 2010). Decrements in processing speed with individuals with a comorbidity of the two disorders are comparable to individuals with only RD (Shanahan et al., 2006).

Symptomatology of concussions are nonspecific; in other words, symptoms of ADHD and other disorders may often mimic that of concussions (Iverson, 2014). However, preliminary studies show that ADHD may not always exacerbate the neuropsychological effects of concussion. Covassin, Eblin, Deitrick, and Whalen (2014) found no differences on neurocognitive performances (e.g., verbal memory, visual memory, motor processing speed, and reaction time) of concussed athletes who have been diagnosed with concussed athletes without a diagnosis of ADHD. In contrast, with a study that examined comorbidity of concussions and learning disability, results indicated that particularly with those who had a history of multiple concussions and a diagnosed learning disability were more prone to perform more poorly on two neuropsychological tests that measured executive functioning, processing speed, and working memory than those who did not have a learning disability or only had one concussion (Collins et al., 1999). More research is needed in terms of comorbidity between concussions, LD, and ADHD. Iverson (2014) argues that the differential diagnosis between the three conditions are already complex as individuals have similar neuropsychological presentations; co-existing disorders would surely cloud the diagnostic picture even further. Because of the potential cognitive symptoms for individuals with these neurological conditions, it is imperative that there are evidenced-based interventions to address the difficulties that they may face.
Cognitive Training

Cognitive training in response to brain injury, illness, or disease has come a long way since its inception, though much more knowledge is needed regarding the value of different types of rehabilitation program, the optimal timing for its initiation, and the optimal duration of the program. The success of cognitive training approaches to altered brain function has largely coincided with neuroscience’s evolving understanding of the mechanisms of brain plasticity (i.e., functional and structural changes). Burgeoning evidence demonstrates efficacy for therapeutic interventions for focal brain lesions such as stroke and TBI (Cappa, Benke, Clarke, Rossi, Stemmer, & van Heugten, 2005; Cicerone et al., 2005) and general age-related decline (Anand et al., 2010). For example, speech therapy has been shown to rehabilitate expressive and receptive verbal abilities for individuals who have different types of aphasia (language disorder) as a result of lesions to the language centers of the brain (Robey, 1998). In addition, a meta-analytic study examining attention-specific training after traumatic brain injuries demonstrated that acquired deficits of attention are treatable (Park & Ingles, 2001). Other efficacious treatments include cognitive training for memory disorders, unilateral spatial neglect, and apraxia (Cappa et al., 2005). There are two basic strategies to cognitive rehabilitation (Rohling, Faust, Beverly, & Demakis, 2009). The first attempts to retrain the cognitive processes that have been directly affected by injury, illness, or disease. The premise of this type is the conceptual belief that neural circuits can be rehabilitated if only partially damaged. The second strategy focuses on developing new cognitive skills that compensate for the deficit areas using retained brain functions and functional reorganization of the brain. Similar to what has been achieved for the body with consistent physical fitness training, research demonstrates that complex, stimulating
activity such as that of cognitive rehabilitation can bring about increased cerebral blood flow, connectivity, and white matter changes to certain regions of the brain (Chapman et al., 2015).

Due to the way the brain is nested in the cranium, the frontal lobes are extremely vulnerable during mild to moderate traumatic brain injuries (Levin et al., 1987). Moreover, cognitive deficits seen in ADHD and learning disabilities may be linked to neural systems in the frontal lobes (McGrath et al., 2011; Willcutt et al., 2010). The frontal lobe is responsible for many higher-ordered functions, including the ability to process large amounts of information in a way that is most cognitively efficient (Stuss & Knight, 2013). The question becomes, what type of rehabilitation is the most effective in terms of restoring or increasing academic functioning such as abilities to take in and learn reading material, lectures, movies, and the like? Would it be more beneficial to gain a general idea of the information presented or attempt to memorize the information verbatim with as much detail as possible? First, it is important to understand that those options are two distinct strategies.

Gist-reasoning, a type of top-down strategy, is the ability to abstract gist meanings from information through a variety of modalities whether visually, auditorily, or both. For example, a child is exhibiting gist-reasoning if he or she is able to listen to a bedtime story and be able to obtain the moral of the story, themes, or even construct a title for a story (Nichelli, Grafman, Pietrini, Clark, & Lee, 1995). Imaging data confirms that the pre-frontal cortices are heavily activated when engaging in top-down processes (Chen, Abrams, D’Esposito, 2006). Examples of top-down cognitive rehabilitation programs include Goal Management Training (Levine et al., 2000), Goal Oriented and Attentional Self-regulation (Novakovic-Agopian et al., 2011), Problem-Solving Training (Rath, Simon, Langenbahn, Sherr, & Diller, 2003), and Executive Plus Training (Gordon, Cantor, Ashman, & Brown, 2006). Conversely, memory for explicit
facts is a bottom-up strategy in which individuals attempt to remember the information at the content level. To continue the previous example, if a child is read the same bedtime story and memorizes how many characters there are, their names, the setting, the events that transpire, etc., he or she is engaging in rote memorization. Research has also empirically shown differences in capabilities between memory for gist and memory for details, with results varying across specific conditions. One such instance is that older adults tend to have relatively stable gist-reasoning capabilities but decline in memory for details as a normal function of aging (Adams, Smith, Nyquist, & Perlmutter, 1997). Gamino, Chapman, and Cook (2009) found that adolescents with moderate to severe TBI exhibited intact detail memory but impaired gist-reasoning. Similarly, results of a preliminary study confirmed the finding of impaired memory for gist in adults with TBI compared to normal adults (Vas and Chapman, 2010).

In order to effectively encode, store, and retrieve a great deal of information, individuals have shown a preference for abstracting general, global meanings or “gist” as compared to encoding details via rote memorization (Vas et al., 2011). Preliminary research demonstrates that by generating themes and gist meanings, information is more robustly stored and retrieved than attempting to memorize all the details (Cook et al., 2014; Vas et al., 2015). Gist-reasoning is highly mediated by the frontal lobe and is associated with other everyday executive function processes such as planning, organization, response control, and problem solving; thus, highly developed gist-reasoning skills are related to high quality of life in academic, career, and social domains (Vas et al., 2011). Emerging evidence from randomized clinical trials conducted by Chapman and colleagues has demonstrated initial feasibility for a program that is designed to strengthen cognitive flexibility and brain function (Chapman & Mudar, 2014; Chapman et al., 2015; Gamino, Chapman, Hull, & Lyon, 2010]. This training, which was developed to
strengthen the cognitive-brain mechanisms supporting resilience, involves a 9-hour evidenced-based high performance brain-training program labeled SMART (or Strategic Memory Advanced Reasoning Training).

The SMART program was developed to promote deeper understanding of information encountered in daily life. The intervention utilizes a strategy-based approach to train individuals to more effectively assimilate, manage, and utilize information, crucial skills for not only academic success but also strengthening overall brain function in daily life. Specifically, participants were trained in executive, higher-order thinking strategies of strategic attention, integration, and innovation that facilitate the ability to synthesize information and eliminate toxic habits that impair efficient brain operations. This intervention teaches three strategies to improve abstract gist reasoning skills from complex information: strategic attention, (b) integrated reasoning, and (c) innovation (Vas et al., 2011). Strategic attention involves blocking less relevant details to focus on and prioritize important information and tasks. Integrated reasoning teaches strategies to abstract and create novel meanings or goals from information or tasks, including gleaning practical actions/implementations for deeper-level processing. Innovation focuses on flexibly updating ideas and perspectives to understand complexities and nuances of situations/information, including generating and discovering novel concepts, ideas, and diverse goals and perspectives. These interconnected cognitive strategies provide a mental tool kit to increase the capacity the juggle, manipulate, and update massive and/or complex incoming data while inhibiting information overload and calming the mind to support learning and decision-making. Adopting these cognitive strategies has been shown to increase the brain’s intricate frontal lobe networks. These brain systems are responsible for planning, judgment, decision-making, problem solving, flexibility of thinking, emotional regulation, stress management, and
other executive functions. Individuals were taught the importance of continually utilizing healthy brain habits to harness their brain’s inherent capability to build resilience and to achieve regeneration in the face of injury and losses in capacity (e.g., stress, sleep deprivation, developmental disorders, or concussive blows).

Evidence reveals that top-down SMART generalizes to enhance single cognitive processes such as working memory, toggling between information, and inhibition without specific focus on these domains (Cook, Chapman, Elliot, Evenson, & Vinton, 2014). Clinical trials of SMART have identified gains not only in healthy individuals but also found significant cognitive recovery from brain injuries experienced six months to decades prior to receiving the SMART program as part of randomized trials (Cook et al., 2014; Vas et al., 2011, Vas et al., 2015). Cook and her colleagues (2014) attempted to test the effects of SMART on adolescents who have been identified as having cognitive deficits secondary to chronic TBI. They were explored whether or not the participants who underwent SMART were a) able to better synthesize or abstract/gist meanings from complex information from various information modalities (e.g., written, visual, and verbal content) and b) generalize their gains to other untargeted or untrained domains of brain functioning, particularly mediated by the frontal lobe (i.e., executive functioning). Twenty adolescents (ages 12-20) who had sustained a mild, moderate, or severe TBI at least six months prior were randomized into either the gist reasoning training group ($n = 10$) or the memory training group ($n = 10$) which focused on rote memorization skills. The trainings were comprised of eight, 45-minute sessions spanning one month. It should be noted that there many exclusionary criteria that precluded individuals with other neurological disorders, severe psychiatric disorders, brain injuries, language difficulties, and learning disabilities from participating whereas a diagnosis of ADHD was not an
exclusionary factor. All participants were given outcome measures that were administered pre-training as a baseline and then upon completion of the interventions as a post-training. Each of the time sessions included the same battery of experimental and standardized neuropsychological tests and also a real-life functioning measure completed by the participants’ parents or legal guardian. Unlike the memory training group, the SMART group exhibited improved ability to abstract gist meanings from complex information and yielded improvement across other specific untrained executive functions (e.g., working memory, inhibition). The results also revealed that the SMART participants improved their performance after the intervention when it came to bottom-up processes (e.g., improved ability to recall detailed facts) whereas those in the memory training group did not result in improvements on any of the neuropsychological measures, although both groups showed improvement with real-life executive functioning behaviors. This findings of the study suggest that individuals, particularly adolescents, with a prolonged recovery of TBI may benefit from higher-order cognitive trainings such as SMART that emphasize developing top-down processes on their academic performance.

Data show that the SMART protocol enhances intellectual flexibility and strengthens brain function and structure at multiple levels, lessens severity and length of negative consequences arising from insult to the brain, and quickens recovery (Chapman et al., 2015; Chapman & Mudar, 2014). In addition to these promising immediate results, SMART has demonstrated long-term improvements on cognitive functioning. Vas and colleagues (2011) examined the effects of SMART on 24 adult TBI patients one year post-injury. The SMART intervention group ($n = 13$) was compared with an information-based Brain Health Workshop (i.e., non-strategic, information gathering; $n = 11$) as the control group, both trainings lasting 18 hours conducted over eight weeks. The results mirrored that of Cook et al. study. The top-down
processing approach of SMART as opposed to the bottom-up processing of the Brain Health Workshop showed significant gains in gist-reasoning and abstraction skills immediately after the training and, more importantly, sustained benefits even six months post-training. In addition, the gains of the SMART program extended to untrained aspects of executive functions of working memory, non-verbal reasoning, inhibition, cognitive switching, and improvements in daily functional activities. The results of the study preliminarily suggest that brief, top-down cognitive trainings such as SMART with adults who have sustained a TBI may enable recuperation of abilities in social functioning, work productivity, home management, and sense of general well-being. SMART has been shown to improve gist-reasoning skills with children diagnosed with ADHD (Gamino, Chapman, Hull, & Vanegas, & Cook, 2009), low-SES individuals (Gamino, Motes, Riddle, Lyon, Spence, & Chapman), veteran populations (Vas et al., 2015), and older adults who have experienced age-related cognitive decline (Anand et al., 2010). Importantly, there have not been any studies that have examined whether or not student-athletes, normal or clinical (e.g., concussions, ADHD, learning disabled), would benefit from SMART. The proposed study seeks to address this gap in the literature.

Purpose and Hypotheses

The primary focus of this study was to examine the neurocognitive training effects of SMART, a form of gist-reasoning training, in relation to college student-athletes who have a self-reported history of concussions, ADHD, and/or learning disabilities, and those identified as students who are academically performing below what might be expected of them (as determined by athletic department academic counselors). Specifically, I determined whether or not student-athletes who have participated in SMART would improve in the cognitive domains of attention, response inhibition, processing speed, working memory, narrative memory, verbal fluency,
visuospatial skills, and executive functioning over time, and would perform better in these areas than student-athletes who had not participated in the training.

Based on existing research (Chapman & Mudar, 2009; Cook et al., 2014; Gamino et al., 2010; Vas et al., 2011), I hypothesized that that SMART Brain student-athletes and the control student-athletes would perform significantly different on neuropsychological measures tapping into executive functioning (e.g., phonemic fluency, inhibition, working memory) and memory for details immediately after the training (Post-Test 1). I also predicted these improvements would persist for at least four months following the training (Post-Test 2).
CHAPTER 2

METHOD

Participants

The participants of the study were male and female student-athletes from an NCAA Division I university located in the southwestern United States. Student-athletes represented various team and individual sports (e.g., football, men and women’s basketball, men and women’s golf, women’s volleyball, women’s soccer), and athletes with the following conditions were targeted for inclusion: sport concussions and academic problems (e.g., attention deficit/hyperactivity disorder [ADHD], learning disability, students identified as academically “underachieving” loosely defined by academic counselors in the athletic department). The ages of the participants ranged from 18-22 years old and represented all years of school (e.g., freshmen to senior years). No student-athlete was disqualified due to race, ethnicity or sexual orientation. Detailed information regarding participant demographics are provided in the results section.

Instruments

Demographic questionnaire. The demographic questionnaire included questions regarding gender, age, current year in college, Hispanic/Latino/Spanish origin, and racial group. In addition, questions regarding handedness, colorblindness, and primary language were given. Given the importance of being able to distinguish colors on certain measures (e.g., Color-Word Interference Test, Matrix Reasoning), individuals who endorse they are colorblind were removed from the data analysis.

Wide Range Achievement Test – 4th Edition (WRAT-IV) - Word Reading subtest. The Word Reading subtest (Wilkinson & Robertson, 2006) were administered as a brief screener to
assess participants’ letter and word decoding through letter identification and word recognition. This subtest includes letter recognition (15 items) and word reading (55 items), and participants were asked to read the words on a page out loud in a clear manner. Participants must obtain five correct responses on the word reading before the administrator can exclude the preliminary items of letter recognition. The subtest was discontinued once the participant incorrectly reads 10 consecutive words or when they have completed reading all of the words. Both Blue and Green versions (i.e., alternate forms) of the subtest were administered Pre-Test and Post-Test 1, respectively. Total raw score is equal to the number of total correct responses (maximum of 70 points); raw scores were converted to standard scores using age based norms.

Research shows that the WRAT-IV has high levels of internal consistency, as measured by Cronbach’s alpha, ranging from .92 to .98 on the subtests in adult samples (Dell, Harrold, & Dell, 2008; Wilkinson & Robertson, 2006). Overall, the WRAT-IV reliability coefficients range from .87 to .93, demonstrating moderate levels of internal consistency. For both the Blue and Green versions, the reading composite score coefficients are high, ranging from .95 to .96. For all ages, the alternate form reliability coefficient is .88. In addition, immediate test-retest coefficients is .86 for all ages. Given that the WRAT-IV is relatively new, validity studies are limited in number; however, emerging evidence shows that the WRAT-IV exhibits an acceptable levels of content and divergent validity as many of the items have been maintained from the highly established WRAT-III and have been corroborated with experts from the field (Dell, Harrold, Dell, 2008). With respect to concurrent validity, studies have shown a moderate relationship (.72) between measures of full-scale IQ (e.g., Stanford-Binet Intelligence Scale – Fifth edition, Wechsler Abbreviated Scale of Intelligence, Kaufman Brief Intelligence Test – Second edition, etc.) and the reading subtest score. This measure is considered a “hold” test – a
neuropsychological test that is largely resistant cognitive declines secondary to brain injuries, dementia, or stroke and serves as an estimate for premorbid intelligence (Orme, Johnstone, Hanks, & Novak, 2004).

*Wechsler Individual Achievement Test – Third Edition (WIAT-III) – Word Reading subtest.* The WIAT-III Word Reading subtest (Breaux, 2009) measures speed and accuracy of single word reading. Participants were asked to read the words aloud but were not instructed to read quickly. The Word Reading total raw score reflects the number of words read correctly under untimed conditions; the Word Reading Speed total raw score reflects the number of words the student read in 30 seconds regardless of accuracy. This subtest has a maximum of 75 items but may be discontinued after four incorrect responses. Total raw score is equal to the number of total correct responses (maximum of 75 points); raw scores were converted to standard scores using age based norms.

Reliability coefficients for the WIAT-III were calculated using the split-half method (Crocker & Algina, 1986). Average reliability for people ages 17-19 was .97 for the Word Reading subtest. In addition, its average test-retest reliability (mean interval of 13 days) was .94. The WIAT-III has also been shown to have good validity, and correlates with other achievement and intelligence measures such as the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV). The correlation between the WIAT-III Total Achievement and the WAIS-IV Full Scale Intelligence Quotient is .82. The WIAT-III is also associated with pre-morbid functioning (Fuentes, McKay, & Hay, 2010).

*Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II).* The WASI-II (Wechsler, 2011) were administered to obtain estimates of participants’ general intellectual functioning. Three out of the four subtests from the WASI-II were given to participants:
Vocabulary (maximum of 31 items: assesses participants’ ability to define words; maximum raw score for this subtest is 59), Matrix Reasoning (maximum of 30 items; measures nonverbal reasoning and visuospatial skills in which participants were required to identify one of five response options to complete a matrix that would complete nonverbal designs in a logical manner; maximum raw score of 30), and Similarities (maximum of 24 items; assesses verbal abstraction in which participants were given two words and asked how they are related; maximum raw score of 45). Raw scores for each subtest were converted to T-scores.

The WASI-II has adequate reliability and validity (Wechsler, 1999). For adults (ages 17 to 89 years), the average internal consistency reliabilities measured by Cronbach’s alpha for the subtests range from .92 (Similarities) and .94 (Vocabulary and Matrix Reasoning). Subtest test-retest reliability coefficients were .77 (Matrix Reasoning), .86 (Similarities), and .90 (Vocabulary). In terms of validity, the WASI-II is highly correlated with other measures of intelligence and achievement (Wechsler Intelligence Scale for Children-Third Edition = .87 and Wechsler Adult Intelligence Scale-Third Edition = .92).

_Kaufman Brief Intelligence Test – Second Edition (KBIT-2)._ The KBIT-2 (Kaufman & Kaufman, 2004) were administered to obtain estimates of participants’ general intellectual functioning. All three subtests from the KBIT-2 were administered: Verbal Knowledge (maximum of 60 items; measures general fund of information and receptive vocabulary; maximum raw score of 60), Riddles (maximum of 48 items; assesses verbal comprehension, reasoning, and vocabulary knowledge; maximum raw score of 48), and Matrices (maximum of 46 items; measures abstract reasoning and understanding relationships among visual stimuli; maximum raw score of 46). The Verbal raw score is calculated by combining the Verbal
Knowledge and Riddles subtests; the Nonverbal raw score is composed of only the Matrices subtest. The Verbal and Nonverbal raw scores were converted to standard scores.

Internal-consistency reliability coefficients for adults aged 19 through 90 years were calculated using the split-half method. Mean average reliabilities are .92 for the Verbal Score and .91 for the Nonverbal score which suggest excellent reliability. Test-retest reliabilities for the Verbal score range from .88 to .93, and the Nonverbal score range from .76 to .89 (interval between tests ranged from 6 to 56 days). The KBIT-2 has been correlated with other cognitive ability tests such as the Wechsler Abbreviated Scale of Intelligence (WASI). For adults, the KBIT-2 Verbal score correlates very highly with the WASI Verbal Index Quotient (.80 and .86) and high with the Performance Index Quotient (.80).

Wechsler Adult Scale of Intelligence – Fourth Edition (WAIS-IV). The WAIS-IV (Wechsler, 2009) were administered to obtain estimates of participants’ general intellectual functioning. Four out of the 10 subtests from the WAIS-IV were given to participants: Vocabulary (maximum of 30 items: assesses participants’ ability to define words; maximum raw score for this subtest is 57), Matrix Reasoning (maximum of 26 items; measures nonverbal reasoning and visuospatial skills in which participants were required to identify one of five response options to complete a matrix that would complete nonverbal designs in a logical manner; maximum raw score of 26), Similarities (maximum of 18 items; assesses verbal abstraction in which participants were given two words and asked how they are related; maximum raw score of 36), and Digit Span (maximum of 24 items; examines attentional capacity, working memory, and mental flexibility; maximum score of 48. The Digit Span subtest is composed of three tasks: Digit Span Forward, Digit Span Backwards, and Digit Span Sequencing. For Digit Span Forward, the participant is read a sequence of numbers and recalls
the numbers in the same order. For Digit Span Backward, the participant is read a sequence of
numbers and recalls the numbers in reverse order. For Digit Span Sequencing, the participant is
read a sequence of numbers and recalls the numbers in ascending order from smallest to largest.
Each task consists of a maximum of eight items, and each item is composed of two trials. Both
trials are the same number of digits that are read, and each item becomes increasingly lengthy in
number of digits. Each task is discontinued once there are incorrect responses on both of the
trials of each item. Raw scores for each WAIS-IV subtest were converted to scaled scores using
age-based norms then converted to $T$-scores.

The WAIS-IV is a well-established scale, and it has fairly high internal consistency
(Wechsler, 2008). Subtest internal consistency reliability coefficients (Cronbach’s alpha) have
ranged from .85 to .94 across the subtests in samples of men and women ages 18-24 years. Over
a two to twelve week time period, the test-retest reliabilities ranged from .70 (seven subscales)
to .90 (two subscales). Inter-rater reliability coefficients were very high, all being above .90. In
terms of validity, the WAIS-IV is highly correlated with other measures of intelligence including

_Wechsler Memory Scale – Fourth Edition (WMS-IV) - Logical Memory I & II._ The
Logical Memory subtests from the WMS-IV (Wechsler, 2009) were administered to assess short-
term and long-term contextual (narrative) memory. Each subtest is comprised of two short
stories that were presented orally to the participants, and they were asked to freely recall each
story immediately upon hearing it, and then asked to freely recall the story again 20-30 minutes
later. Participants were asked to recall the stories verbatim; for each detail of the story that they
recall, they were given one point; there are a total of 25 details per story (maximum of 50 points
for each subtest). After the delayed free recall, the participants were asked 30 yes/no questions
about each of the stories in order to test their recognition of the details of the stories for a maximum of 30 points. For each subtest, raw scores were converted to scaled scores using age-based norms then converted to $T$-scores. For the recognition trial, which is based on the number of correct responses to the yes/no questions, a range of percentiles were calculated from the raw number of points.

The WMS-IV has demonstrated good reliability. Internal consistency reliability coefficients, calculated using Fisher’s $z$ transformation, range from .79 (20-24 year age group) to .84 (18-19 year age group) for Logical Memory I and range from .85 (20-24 year age group) to .87 (18-19 year age group) for Logical Memory II. For adults ages 16-69, test-retest reliability coefficients .74 for Logical Memory I and .71 for Logical Memory II. The WMS-IV Logical Memory subtests have been shown to have moderate concurrent validity with other measures of memory such as the California Verbal Learning Test – 2nd edition with correlations ranging from .39 to .51 (Wechsler, 2009).

Woodcock-Johnson – Third Edition (WJ-III) - Story Recall. The Story Recall subtest from the WJ-III Tests of Achievement (Woodcock, McGrew, & Mather, 2001) were used to measure aspects of oral expression, particularly language development and meaningful, contextual memory. Participants were asked to recall verbatim details of increasingly complex stories presented orally immediately upon being read the passage. Then after 30 minutes or more, participants were asked to recall as many details of the story as they can remember. Participants were read two stories initially (Stories 7-8) and be awarded points based on the number of details they can recall. Depending on how many points they score on the first two stories, the next two stories that were read were either more (Stories 9-10) or less (Stories 5-6) complex; a total of four stories that were read to the participants. The maximum score for
Stories 5-6 is 15, Stories 7-8 is 21, and Stories 9-10 is 41. The Retrieval Fluency subtest from the WJ-III Tests of Cognitive Abilities was used to assess long-term retrieval, the cognitive process of acquiring, storing, and retrieving information (Woodcock et al., 2009). Participants were asked to orally produce as many examples of a semantic category (e.g., foods and drinks, names, animals) as they can in one minute. The raw score was the number of items they were able to produce across the three categories. Using the raw scores, standard scores were calculated for the immediate recall and delayed recall trials using age-based norms then converted to $T$-scores.

The WJ-III has demonstrated good reliability and validity (Woodcock et al., 2001). For ages 18-29 years, the median reliability coefficients for Story Recall range from .87 to .88 and from .84 to .88 for Story Recall – Delayed. For the same age group, median reliability coefficients for Retrieval Fluency range from .85 to .88. In addition, the WJ-III has shown to be valid through correlational data, measuring academic skills and abilities similar to those measured by other achievement tests such as the Wechsler Individual Achievement Test (correlations range from .46 to .70) and intelligence tests such as the Wechsler Adult Intelligence Scale – Third Edition (correlations range from .45 to .69).

Wide Range Assessment of Memory and Learning – Second Edition (WRAML-2) – Story Memory subtest. The WRAML-2 Story Memory subtest (Sheslow & Adams, 2003) were administered. Two short stories were read to participants, then following each, are asked to recall as many parts of the story as they can remember. Approximately 15 minutes later, participants were asked to recall the details of both stories without additional exposure. After the delay condition, participants were asked to recall details of the stories using a multiple-choice format. Age-related scaled scores were provided separately for the immediate and delayed recall
on both stories combined. Scaled scores were also derived from the sum of the correctly recognized items on both stories.

Coefficient Alpha Reliability for the Story Memory subtest for ages 18-24.11 years is .92, .93 for Story Memory Delayed Recall, and .80 for Story Recognition. For a median interval of 49 days between test and retest administrations, $r = .75$ for Story Memory, $r = .78$ for Story Memory Delayed Recall, and $r = .62$ for Story Memory Recognition. The WRAML-2 was correlated with the Wechsler Memory Scale – III (WMS-III) and other measures of memory. Specifically with the WMS-III, the WRAML-2 has a moderately high relationship between the respective indexes, ranging from .45 to .66 for the WRAML-2 Verbal Memory Index across the WMS-III Primary Indexes (e.g., Auditory Immediate, Auditory Delay, Auditory Recognition).

*Delis Kaplan Executive Function System (D-KEFS).* The D-KEFS (Delis, Kaplan, & Kramer, 2001) were administered to assess key components of higher-level cognitive functions within verbal and spatial modalities. Four out of the nine subtests from the D-KEFS were administered: Trail Making Test, Verbal Fluency Test, Color-Word Interference Test, and Sorting Test. Alternate forms were used across testing sessions. Raw scores for each subtest were converted to scaled scores using age-based norms then converted to $T$-scores.

*Trail Making Test.* The Trail Making Test is a visual-motor sequencing task that has five different conditions to measure visual attention, cognitive flexibility, and speed of information processing. For Condition 1, participants were asked to visually scan the page and cross out a particular number as quickly as they can. For Condition 2, participants were asked to draw lines to connect the numbers in ascending order as quickly as they can. For Condition 3, participants were asked to draw lines to connect the letters in alphabetical order as quickly as they can. For Condition 4, which is the primary executive functioning measure, participants connected the
circles as quickly as they can in an ascending pattern, but alternated between numbers and letters (i.e., 1-A, 2-B, 3-C, etc.). Condition 5 is a simple motor speed task where participants were asked to draw the lines connecting the circles on a pre-determined path as quickly as they can. The length of time to complete the task and number of errors incurred on the task were recorded as the raw scores for each condition.

**Verbal Fluency Test.** The Verbal Fluency Test uses three different conditions to measure phonemic fluency, category fluency, and category switching with three conditions. Condition 1 is Letter Fluency in which participants must say as many words as they can that begin with a certain letter (three trials with a different letter each time). For Condition 2, participants must say as many words that belong to a certain category (two trials with a different category each time). Condition 3 has one trial that requires participants to say as many words as they can, alternating between two different categories each time. The total number of responses were tallied and recorded as the raw scores for each condition. Alternate forms were used across testing sessions.

**Color-Word Interference Test.** The Color-Word Interference Test has four different conditions to measure visual attention, processing speed, and ability to inhibit a dominant verbal response and has four conditions. Condition 1 requires participants to name colors as quickly as they can. For Condition 2, participants must read words as quickly as they can. Condition 3 requires participants to name the colors of the ink the words are printed in without reading the word. In Condition 4, participants alternated between inhibitory responses by naming the ink color of the word and non-inhibitory responses by reading the word. Raw score is the time in which it took participants to complete the task.
**Sorting Test.** The Sorting Test measures concept-formation skills, verbal and nonverbal problem-solving skills, and the ability to explain abstract concepts. Participants were presented with six cards and asked to categorize the cards into two separate groups as many times as they can (a maximum of eight correct sorts). In addition, they also described the reason why they classified the cards in a particular manner and were scored either a 0, 1, or 2 (a maximum of 16). Then, the examiner sorted the cards into two groups, and participants were asked to determine the categorization method. For this task, they were scored either a 0, 1, or 2 (a maximum of 16).

Raw scores are the number of correct sorts, the number of points for their description of the sorts, and the number of categorizations they were able to recognize.

D-KEFS reliability and validity. Overall, the D-KEFS normative data show good reliability and validity (Delis et al., 2001). Studies have shown that the Trail Making Test had internal consistencies that ranged from .69 (16-19 year age group) and .78 (20-29 year age group). Average time between administrations (test-retest) was 25 ± 12.8 days. Test-retest reliability coefficients for Trail Making Test Conditions 1-5 ranged from .20-.82 (8-19 year age group) and from .36-.73 (20-49 year age group). Verbal fluency for men and women ages 16-19 years and 20-29 years had internal consistencies of .80 to .85 (Condition 1-Letter Fluency Total), .60 to .61 (Condition 2-Category Fluency Total), .43 to .48 (Condition 3-Category Switching Total Correct), and .53 to .59 (Condition 3-Category Switching Total Switching). Test-retest reliability coefficients for Verbal Fluency Conditions 1-3 ranged from .53-.70 (8-19 year age group) and from .24-.81 (20-49 year age group). The Color Word Interference Test had internal consistencies of .75 (16-19 year age group) and .82 (20-29 year age group). Test-retest reliability coefficients for Conditions 1-4 ranged from .77-.90 (8-19 year age group) and from .52-.86 (20-49 year age group). Lastly, the Sorting Test for ages 16-19 years and 20-29
years had internal consistencies of .72 to .78 (Condition 1-Free Sorting Confirmed), .73 to .77 (Condition 2-Free Sorting Description), and .74 to .75 (Condition 2-Sort Recognition Total). Test-retest reliability coefficients for the Sorting Test Conditions 1-2 ranged from .49-.67 (8-19 year age group) and from .46-.55 (20-49 year age group).

The DKEFS subtests have been demonstrated to be valid in numerous neuropsychological studies (Delis et al., 2001). The correlations for each of the subtests indicate that better performance on one variable is associated with better performance on the other. Correlation studies exhibited relatively low positive correlations between the subtests, suggesting that each subtest is a unique aspect of executive functioning. Likewise, the D-KEFS subtests when compared to the California Verbal Learning Test – Second Edition and the Wisconsin Card Sorting Test, show low to moderate correlations, suggest some degree of variance in measuring different aspects of executive functioning. For specific statistics regarding reliability and validity, see the D-KEFS Technical Manual (Delis et al., 2001).

**Multilingual Aphasia Examination – Controlled Word Association (COWA) subtest.** The COWA (Benton, Hamsher, & Sivan, 1978) is an oral fluency test that requires participants to make verbal associations to different letters of the alphabet by saying all the words they can think of that begin with a certain letter. Three letters of progressively increasing associative difficulty are presented, and participants are given one minute each to produce as many associations as they can. The total number of acceptable responses for the three letters constitute the raw score on the test. Percentiles were calculated based on the raw score and subsequently converted to $T$ – scores.

Ruff, Light, Parker, and Levin (1996) found that the COWA had high reliability with a coefficient alpha of .83. Moreover, the test had high test-retest reliability over the span of six
months ($r = .74$). Although the COWA has different versions and is similar in terms of procedures to other measures of word fluency such as FAS, there are no formal studies that examine correlations to other types of phonemic fluency tests (Ruff et al., 1996).

**Trail Making Test A & B.** Similar to the D-KEFS Trail Making Test, Trail Making Test A & B (Reitan, 1985) assesses visual attention, cognitive flexibility, and speed of information processing on a visual-motor sequencing task. Part A tests visual scanning, numeric sequencing, and visuomotor speed; Part B tests cognitive demands including visual motor and visual spatial abilities and mental flexibility. Part A requires mainly visuoperceptual abilities, whereas Part B reflects working memory and task-switching ability, indicators of executive function (Sanchez-Cubillo, Perianez, Adrover-Roig, Rodriguez-Sanchez, Rios-Lago, Tirapu, & Barcelo, 2009). For Part A, participants were asked to draw lines to connect the numbers in ascending order. Part B required participants to connect the circles in an ascending pattern, but alternate between numbers and letters (i.e., 1-A, 2-B, 3-C, etc.). The length of time to complete each part and the number of errors incurred were recorded separately for both Part A and Part B. The time to complete the task were converted to $T$ – scores using norms adjusted for age, gender, education, and race (Heaton, Miller, Taylor, & Grant, 2004).

The Trail Making Test A & B has demonstrated good reliability and validity, similar to the D-KEFS Trail Making Test, as they were both derived from the original Halstead-Reitan battery (Delis et al., 2001; Reitan, 1985). Alpha coefficients have been found to be above .70 (Reynolds, 2002). Moreover, test-retest reliability scores have generally been above .70, ranging from .70 to .78, and the inter-rater reliabilities from .96 to .98. This test was administered to 200 patients with clear evidence of brain damage (e.g., multiple sclerosis, traumatic head injury, extrinsic brain tumor, epilepsy, etc.) and compared to a control group without brain damage.
Results indicate that patients without brain damage performed significantly better than patients with brain damage on both Parts A and B, which suggest good construct validity.

*Wisconsin Card Sorting Test (WCST).* The WCST (Heaton, Chelune, Talley, Kay, & Curtiss, 1993) is a task of executive functioning and measures problem-solving ability through the ability to learn from corrective feedback, utilize deductive reasoning, and think flexibly. Participants were administered the abbreviated computerized version of the WCST. This measure requires participants to match response “cards” to one of four stimulus “cards” without instruction of the matching principle (three possible sorting categories: Color, Form, and Number). Participants were given feedback as to whether each response is correct or incorrect. Once participants have made a specified number of “correct” matches to the initial sorting principle, the sorting principle is changed without warning, requiring participants to benefit from the feedback that is presented to develop a new sorting strategy. A total of 64 trials were administered for the WCST. Percentiles were calculated for the number of categories completed and a $T$–score can be derived from the number of Perseverative Errors (i.e., an incorrect response in which participants persist with the old principle instead of using feedback to determine the new, correct sorting principle).

The WCST has demonstrated moderate to excellent reliability (Heaton et al., 1993); interscorer reliabilities of .88, .97, and .75 for Perseverative Responses, Perseverative Errors, and Nonperseverative Errors, respectively, have been reported. Reliability coefficients, in a sample of normal children and adolescents, ranged from .39 to .72 and averaged .57 with a median of .60, suggesting fair reliability for Perseverative Responses and Percent Perseverative Errors and moderate to good reliability for the rest of the WCST scores. In terms of validity, the WCST has demonstrated good concurrent validity and is a valid measure of executive function in
neurologically impaired populations (e.g., seizure disorders, brain injuries, attention deficit disorder, psychiatric disorders, etc.; Heaton et al., 1993). For an extensive review of reliability and validity, see the WCST Technical Manual (Heaton et al., 1993).

Procedure

The Internal Review Board (IRB) approval was obtained in October of 2014. In collaboration with the University of Texas at Dallas (UTD) Center for Brain Health®, which developed the SMART Brain Training program that was tested in this study, and Conference USA, which provided funding for the project, specific student-athletes from the University of North Texas were selected by the Athletic Department administrators to participate. Student-athletes were selected based on their endorsements to a variety of conditions (e.g., concussion, ADHD/learning disabilities, identified as academically “underachieving” by academic counselors).

The reasons for selection into the study of the UNT student-athletes were “blind” to all involved parties (i.e., researchers, evaluation program administrators). Athletes were scheduled by the UNT Athletic Department and the primary author to complete neuropsychological testing (see Table 1), which included the previously described neurocognitive measures. In addition to the primary author, three other clinical psychology doctoral students who had training in neuropsychological assessment served as the test administrators. All researchers were trained to proficiency in the assessment measures and supervised by a licensed psychologist who taught the neuropsychology assessment courses at the University of North Texas.

The researchers also were “blind” to the participants’ random assignment into the two comparison groups: (a) the SMART training protocol or (b) a wait-list control (this group of athletes were offered the opportunity to participate in the SMART program following completion
of the study). The neuropsychological outcome measures for both groups were administered at baseline (Pre-Test), within one to three weeks immediately following completion of the training session (Post-Test 1), and three to four months after the completion of the intervention (Post-Test 2). Each assessment session included different batteries of standardized cognitive tests (to minimize practice effects), but measured similar abilities of neuropsychological functioning.

Table 1

<table>
<thead>
<tr>
<th>Outcome Measures</th>
<th>Pre-Test</th>
<th>Post-Test 1</th>
<th>Post-Test 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Ability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Premorbid Level of Achievement</td>
<td>WRAT-IV – Word Reading (blue form)</td>
<td>WRAT-IV – Word Reading (green form)</td>
<td>WIAT-III – Word Reading</td>
</tr>
<tr>
<td>Vocabulary</td>
<td>WASI-II – Vocabulary</td>
<td>WAIS-IV – Vocabulary</td>
<td>KBIT 2 – Verbal Knowledge</td>
</tr>
<tr>
<td>Semantic Fluency</td>
<td>D-KEFS – Verbal Fluency Condition 2</td>
<td>D-KEFS – Verbal Fluency (alternate) Condition 2</td>
<td>WJ-III – Retrieval Fluency</td>
</tr>
<tr>
<td>Attention</td>
<td>WMS-IV – Logical Memory I</td>
<td>WJ-III – Story Recall</td>
<td>WRAML2 – Story Memory</td>
</tr>
<tr>
<td>Working Memory</td>
<td>WAIS-IV – Digit Span</td>
<td>WAIS-IV – Digit Span</td>
<td>WAIS-IV – Digit Span</td>
</tr>
<tr>
<td>Phonemic Fluency</td>
<td>D-KEFS – Verbal Fluency Condition 1</td>
<td>D-KEFS – Verbal Fluency (alternate) Condition 1</td>
<td>MAE – COWA</td>
</tr>
<tr>
<td>Mental Flexibility</td>
<td>D-KEFS – Trail Making Condition 4</td>
<td>Trail Making Test Part B</td>
<td>D-KEFS – Trail Making Condition 4</td>
</tr>
<tr>
<td>Nonverbal Abstract Reasoning</td>
<td>WASI-II – Matrix Reasoning</td>
<td>WAIS-IV – Matrix Reasoning</td>
<td>KBIT 2 – Matrices</td>
</tr>
<tr>
<td>Verbal Abstract Reasoning</td>
<td>WASI-II – Similarities</td>
<td>WAIS-IV – Similarities</td>
<td>KBIT 2 – Riddles</td>
</tr>
<tr>
<td>Problem Solving</td>
<td>Wisconsin Card Sorting Test</td>
<td>D-KEFS – Sorting Test</td>
<td>D-KEFS – Sorting Test (alternate)</td>
</tr>
<tr>
<td>Memory</td>
<td>WMS-IV–Logical Memory II</td>
<td>WJ-III – Story Recall Delayed</td>
<td>WRAML2 – Story Memory Delayed Recall</td>
</tr>
</tbody>
</table>

51
At each testing time, participants completed all the assessments with one designated examiner. At the pre-test assessment, athletes were provided written consent to participate; all athletes consented. Next, examiners described the general purpose of the study, which was to study the efficacy of a cognitive intervention to improve learning, memory, attention, and other aspects of brain functioning. Athletes then completed a series of paper-and-pencil measures, including demographics and other psychosocial variables (e.g., depression, resilience, grit, coping strategies), followed by the neurocognitive tests. Researchers randomized the presentation of the neurocognitive tests such that the measures of language, processing speed, memory, and executive function were counterbalanced. Upon completion of the testing, which lasted two hours on average, athletes were paid $25 for their participation. The test protocols were scored by the examiners themselves, and the participants’ data were imported into a spreadsheet software program and then analyzed with a statistical software program.

*SMART intervention protocol.* The SMART program incorporated the training of three evidenced-based executive, higher-order cognitive functions: strategic attention, integrated reasoning, and innovation (Vas et al., 2011). These interconnected cognitive functions, which consist of nine total strategies, provided a tool kit to increase capacity to juggle, manipulate, and update massive and/or complex incoming data while inhibiting information overload and focusing the mind to support deeper understanding and integration of information. The training is designed to challenge students to incorporate higher-order cognitive tactics, allowing them to work more flexibly while increasing frontal lobe networks and integrity.

The student-athletes randomly assigned to the SMART brain training condition were divided into two groups (for scheduling purposes) and each group completed a total of 7.5 hours of training during five group sessions (1.5 hours each session conducted once per week). See
Table 2 for an overview of the schedule. Two trainers/facilitators were assigned to each group (a total of four clinicians rotated depending on the schedule). Three of which are Master’s or Ph.D.-level certified speech-language pathologists specializing in cognitive communication; the other clinician has a Master’s degree in education. All facilitators have been trained in the administration of the SMART brain protocol. To ensure adherence to the program, the facilitators stressed the importance of attending every session. Sessions were both didactic and interactive in nature. Training materials included Microsoft Powerpoint slides that were projected and hard copies of varying lengths such as handouts, articles or other reading texts. Take-home materials were offered for their long-term reference (e.g., laminated sheet with all of the strategies and descriptions, book about brain training, etc.).

The SMART brain program began with an introduction to the three foundational areas – strategic attention, integrated reasoning, and innovation. Next, student-athletes were given an overview to the learning objectives for the program: (a) understand, practice and identify ways to continually adopt the core mental strategies that enhance cognitive capabilities, (b) identify healthy brain habits and what it means to maximize cognitive performance, (c) evaluate the consequences of cognitive habits that can impede brain performance, and (d) use tactics as a framework to aid core cognitive functions. For the training as a whole, the strategies were introduced in a sequential manner (see Table 2).

Strategies were continually reinforced at each level of the program, thus mastery of each strategy were not necessary to move on to the next stage. During the group sessions, participants engaged in reading materials provided in sessions, provided written responses when asked, and participated in group discussions. More importantly, discussions emphasized how to apply the SMART strategies in their daily lives, as they learned them, whether academic, athletic, or
otherwise. Sessions regularly began with a review/discussion as to ways the student-athletes were using these strategies.

Table 2

*Strategic Memory and Reasoning Training (SMART) Program*

<table>
<thead>
<tr>
<th>Sessions</th>
<th>Process</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Introduction</td>
<td>general overview</td>
</tr>
<tr>
<td></td>
<td>Science of SMART</td>
<td>measures, connectivity, cognitive performance</td>
</tr>
<tr>
<td></td>
<td><strong>Strategic Attention</strong></td>
<td>prioritizing, strategic filtering/inhibiting massive data input, cultivating a resilient brain</td>
</tr>
<tr>
<td>2-4</td>
<td><strong>Integrated Reasoning</strong></td>
<td>rapidly toggling between details and big ideas; abstracting and synthesizing information from multiple sources, implementing deeper-level processing of material; tying new information to one’s own pre-existing knowledge base and experiences</td>
</tr>
<tr>
<td>5</td>
<td><strong>Innovation</strong></td>
<td>flexibly updating ideas and perspectives to better understand the complexities and nuances of situations/information; creating new knowledge and fostering curiosity</td>
</tr>
</tbody>
</table>

Data Analysis

Raw scores of each neuropsychological measure were converted to $T$-scores so that standardized comparisons could be made for each neurocognitive ability across pre-test, Post-Test 1, and Post-Test 2 sessions. To determine the similarity of the SMART Brain and control groups, I compared groups on their demographic variables (e.g., sex, age, race/ethnicity),
characterization measures (e.g., history of ADHD, learning disability, and/or concussions, etc.), and the neuropsychological measures. Student t-tests were utilized to compare SMART group and the wait-list control groups on the variables of age, pre-morbid level of achievement, and neurocognitive abilities. Chi-square analyses were run to compare groups across sex, race/ethnicity, and characterization variables (e.g., history of ADHD, LD, and/or concussions).

For the main analyses, neuropsychological performances were compared at Post-Test 1 while controlling for pre-test performances to examine the effects of the intervention on cognitive functioning. Thus, one-way analyses of covariance (ANCOVAs) were used to examine the differences between groups on the T-scores of the various neuropsychological measures. Post-Test 1 differences were the primary focuses which allowed for analyses with a larger sample size when accounting for attrition. As secondary analyses, neuropsychological performances (T-scores) were compared at Post-Test 2 while controlling for pre-test performances to determine whether those effects were maintained across time. Levene’s test and normality checks were carried out, and the assumptions were met. Effect sizes were calculated with partial $\eta^2$. For all analyses in this study, alpha was set at .05 given the exploratory nature of this study. I conducted an a priori power analysis for ANCOVA analyses using the program G*Power which revealed that 1302, 210, and 84 participants would be necessary to detect a small, medium, and large effect size, respectively (Cohen’s $f = 0.1, f = 0.25, f = 0.4$) at the .05 level. Analyses were performed using SPSS version 23.0.
CHAPTER 3

RESULTS

Participant Demographics

Our sample included 56 athletes who completed baseline testing, 40 Post-Test 1, and 19 Post-Test 2 (see Figure 1 for a flow chart of participation). The 56 student-athletes had a mean age of 20.16 years (SD = 1.19); 27 (48.2%) were female and 29 (51.8%) were male. In terms of race/ethnicity, 28 (41.8%) were Caucasian, 25 (37.3%) African Americans, 1 (1.5%) American Indian or Alaska Native, and 2 (3.0%) “other.” Regarding neurological conditions, there were eight athletes who endorsed a history of concussion, one reported ADHD, and no participant had a learning disability.

Figure 1. Flow diagram of participation. SMART indicates Strategic Memory and Reasoning Training; Control indicates wait-list control. Drop-outs due to random factors.
Analyses

Preliminary analyses. The t-tests revealed groups were comparable (see Table 3) on their pre-test scores, and chi-square tests revealed no significant differences between groups with regards to sex. The variables of race/ethnicity and history of ADHD, LD, or concussions were excluded from chi-square analyses due to homogeneity and insufficient sample sizes. Thus, demographic and characterization variables were not included for further inferential analysis.

To examine whether attrition was due to random factors at each time session, neuropsychological performances and demographic variables between completers and non-completers were compared. Between completers and non-completers, there were no significant differences with regards to sex ($\chi^2 (1) = 1.030, p = .310$) and race (e.g., Caucasian or African American; $\chi^2 (1) = 1.344, p = .719$) at Post-Test 1. Additionally, there were no sex ($\chi^2 (1) = 2.572, p = .109$) or race (e.g., Caucasian or African American; $\chi^2 (1) = .832, p = .842$) differences between completers and non-completers at Post-Test 2. There were no significant differences on baseline scores (all $p$’s $>.183$) between those who completed Post-Test 1 testing versus those who did not complete this test suggesting participant dropout was due to random factors. There were also no significant differences on baseline scores (all $p$’s $>.114$) between those who completed Post-Test 2 testing versus those who did not complete this test again suggesting attrition was due to random factors.

Table 3

Comparability of SMART (n = 15) and Wait-list Control (n = 41) at Pre-Test

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean (M)</th>
<th>Standard Deviation (SD)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>20.00</td>
<td>1.36</td>
<td>.477</td>
</tr>
<tr>
<td>SMART</td>
<td>20.22</td>
<td>1.13</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-morbid Achievement (T-score)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>49.33</td>
<td>5.98</td>
<td>.118</td>
</tr>
<tr>
<td>Control</td>
<td>50.39</td>
<td>9.35</td>
<td></td>
</tr>
</tbody>
</table>
Table 3 (continued)

<table>
<thead>
<tr>
<th>Variables</th>
<th>$M^b$</th>
<th>$SD^b$</th>
<th>$t^c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary (T-score)$^d$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>52.27</td>
<td>6.65</td>
<td>.712</td>
</tr>
<tr>
<td>Control</td>
<td>53.17</td>
<td>8.46</td>
<td></td>
</tr>
<tr>
<td>Semantic Fluency (T-score)$^e$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>61.53</td>
<td>10.85</td>
<td>.465</td>
</tr>
<tr>
<td>Control</td>
<td>59.46</td>
<td>11.79</td>
<td></td>
</tr>
<tr>
<td>Attention (T-score)$^f$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>44.53</td>
<td>9.20</td>
<td>.730</td>
</tr>
<tr>
<td>Control</td>
<td>45.54</td>
<td>8.70</td>
<td></td>
</tr>
<tr>
<td>Working Memory (T-score)$^g$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>49.67</td>
<td>9.41</td>
<td>.828</td>
</tr>
<tr>
<td>Control</td>
<td>51.54</td>
<td>9.17</td>
<td></td>
</tr>
<tr>
<td>Processing Speed (T-score)$^h$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>57.13</td>
<td>4.74</td>
<td>.111</td>
</tr>
<tr>
<td>Control</td>
<td>55.20</td>
<td>6.82</td>
<td></td>
</tr>
<tr>
<td>Phonemic Fluency (T-score)$^i$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>52.00</td>
<td>10.52</td>
<td>.307</td>
</tr>
<tr>
<td>Control</td>
<td>55.22</td>
<td>11.64</td>
<td></td>
</tr>
<tr>
<td>Mental Flexibility (T-score)$^j$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>51.40</td>
<td>7.01</td>
<td>.648</td>
</tr>
<tr>
<td>Control</td>
<td>52.10</td>
<td>6.92</td>
<td></td>
</tr>
<tr>
<td>Inhibition (T-score)$^k$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>54.47</td>
<td>5.87</td>
<td>.615</td>
</tr>
<tr>
<td>Control</td>
<td>53.85</td>
<td>7.30</td>
<td></td>
</tr>
<tr>
<td>Nonverbal Rewm (T-score)$^l$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>52.67</td>
<td>5.34</td>
<td>.310</td>
</tr>
<tr>
<td>Control</td>
<td>52.12</td>
<td>7.22</td>
<td></td>
</tr>
<tr>
<td>Verbal Reason (T-score)$^m$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>51.40</td>
<td>9.55</td>
<td>.132</td>
</tr>
<tr>
<td>Control</td>
<td>49.51</td>
<td>6.64</td>
<td></td>
</tr>
<tr>
<td>Memory (T-score)$^n$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>43.00</td>
<td>10.23</td>
<td>.625</td>
</tr>
<tr>
<td>Control</td>
<td>43.49</td>
<td>8.76</td>
<td></td>
</tr>
</tbody>
</table>

a. $df = 54$

b. All test means and standard deviations are based on T-scores, and thus have an $M$ of 50 and an $SD$ of 10.

c. Pre-morbid Achievement: WRAT-IV Word Reading (blue form)

d. Vocabulary: WASI-II Vocabulary

e. Semantic Fluency: D-KEFS Verbal Fluency – Condition 2

f. Attention: WMS-IV Logical Memory I

g. Working Memory: WAIS-IV Digit Span

h. Processing Speed: D-KEFS Trail Making – Condition 2

i. Phonemic Fluency: D-KEFS Verbal Fluency – Condition 1

j. Mental Flexibility: D-KEFS Trail Making – Condition 4

k. Inhibition: D-KEFS – Color Word Interference – Condition 3

l. Nonverbal Reasoning: WASI-II Matrix Reasoning

m. Verbal Reasoning: WASI-II Similarities

n. Memory: WMS-IV Logical Memory II
Analyses of Post-Test 1. For the analyses of Post-Test 1 data, the results of the ANCOVAs revealed no significant effects of the SMART training on all neurocognitive abilities at Post-Test 1 after controlling for pre-test scores, with one exception (see Table 4). There was a significant difference in working memory scores, $F(1,37) = 6.273, p = .017$, with the intervention group scoring higher than the wait-list control group.

Table 4

Adjusted Means and Standard Errors of SMART ($n = 15$) and Control ($n = 25$) at Post-Test 1

<table>
<thead>
<tr>
<th>Variables</th>
<th>Adjusted Mean</th>
<th>Std. Error</th>
<th>$F^*$</th>
<th>$P^*$</th>
<th>partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary ($T$-score)$^d$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>54.46</td>
<td>1.60</td>
<td>.410</td>
<td>.526</td>
<td>.011</td>
</tr>
<tr>
<td>Control</td>
<td>53.16</td>
<td>1.24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semantic Fluency ($T$-score)$^e$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>56.65</td>
<td>3.04</td>
<td>.761</td>
<td>.389</td>
<td>.020</td>
</tr>
<tr>
<td>Control</td>
<td>53.29</td>
<td>2.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attention ($T$-score)$^f$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>51.51</td>
<td>2.59</td>
<td>.176</td>
<td>.678</td>
<td>.005</td>
</tr>
<tr>
<td>Control</td>
<td>50.13</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Working Memory ($T$-score)$^g$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>57.59</td>
<td>1.64</td>
<td>7.168</td>
<td>.011*</td>
<td>.162</td>
</tr>
<tr>
<td>Control</td>
<td>52.00</td>
<td>1.27</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processing Speed ($T$-score)$^h$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>58.39</td>
<td>2.18</td>
<td>.044</td>
<td>.835</td>
<td>.001</td>
</tr>
<tr>
<td>Control</td>
<td>57.81</td>
<td>1.69</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phonemic Fluency ($T$-score)$^i$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>58.65</td>
<td>2.07</td>
<td>3.500</td>
<td>.069</td>
<td>.086</td>
</tr>
<tr>
<td>Control</td>
<td>53.73</td>
<td>1.60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mental Flexibility ($T$-score)$^j$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>57.02</td>
<td>2.52</td>
<td>.009</td>
<td>.924</td>
<td>.000</td>
</tr>
<tr>
<td>Control</td>
<td>56.71</td>
<td>1.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inhibition ($T$-score)$^k$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>53.63</td>
<td>1.28</td>
<td>1.530</td>
<td>.224</td>
<td>.041</td>
</tr>
<tr>
<td>Control</td>
<td>55.65</td>
<td>1.01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonverbal Reason ($T$-score)$^l$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>57.60</td>
<td>1.56</td>
<td>3.109</td>
<td>.086</td>
<td>.080</td>
</tr>
<tr>
<td>Control</td>
<td>54.09</td>
<td>1.23</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbal Reason ($T$-score)$^m$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>54.68</td>
<td>1.76</td>
<td>3.039</td>
<td>.090</td>
<td>.078</td>
</tr>
<tr>
<td>Control</td>
<td>53.41</td>
<td>1.36</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 4 (continued)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Adjusted Meanc</th>
<th>Std. Errorc</th>
<th>Fb</th>
<th>Pb</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Memory (T-score)a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>53.91</td>
<td>2.92</td>
<td>.482</td>
<td>.492</td>
<td>.013</td>
</tr>
<tr>
<td>Control</td>
<td>51.33</td>
<td>2.26</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. * denotes p < .05  
b. df_between = 1, df_within = 37  
c. All test means and standard deviations are based on T-scores, and thus have an M of 50 and an SD of 10.  
d. Vocabulary: WAIS-IV Vocabulary  
e. Semantic Fluency: D-KEFS Verbal Fluency – Condition 2 (alternate)  
f. Attention: WJ-III Story Recall  
g. Working Memory: WAIS-IV Digit Span  
h. Processing Speed: Trail Making Test – Part A  
i. Phonemic Fluency: D-KEFS Verbal Fluency – Condition 1 (alternate)  
j. Mental Flexibility: Trail Making Test – Part B  
k. Inhibition: D-KEFS – Color Word Interference – Condition 3  
l. Nonverbal Reasoning: WAIS-IV Matrix Reasoning  
m. Verbal Reasoning: WAIS-IV Similarities  
n. Memory: WJ-III Story Recall Delayed

Analyses of Post-Test 2. Similar to the analyses for Post-Test 1, with two exceptions, all ANCOVAs were nonsignificant (see Table 5). For working memory, there was a significant group main effect after controlling for pre-test scores, F(1,17) = 5.995, p = .026. These findings suggest that the SMART training effects on working memory still existed after four months. Further, the main effect for attention also was significant, F(1,37) = 5.995, p = .026 at Post-Test 2 after controlling for pre-test performances, suggesting improvement on this ability over the long-term despite no benefit immediately following completion of the program.

Table 5

Adjusted Means and Standard Errors of SMART (n = 7) and Control (n = 12) at Post-Test 2

<table>
<thead>
<tr>
<th>Variables</th>
<th>Adjusted Meanc</th>
<th>Std. Errorc</th>
<th>Fb</th>
<th>Pb</th>
<th>partial η²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary (T-score)d</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>47.39</td>
<td>2.90</td>
<td>.410</td>
<td>.526</td>
<td>.011</td>
</tr>
<tr>
<td>Control</td>
<td>48.52</td>
<td>2.22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semantic Fluency (T-score)e</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>48.87</td>
<td>2.25</td>
<td>1.920</td>
<td>.185</td>
<td>.107</td>
</tr>
<tr>
<td>Control</td>
<td>44.91</td>
<td>1.70</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 5 (continued)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Adjusted Mean&lt;sup&gt;c&lt;/sup&gt;</th>
<th>Std. Error&lt;sup&gt;c&lt;/sup&gt;</th>
<th>F&lt;sup&gt;b&lt;/sup&gt;</th>
<th>P&lt;sup&gt;a&lt;/sup&gt;</th>
<th>partial η² &lt;sup&gt;2&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attention (T-score)</strong>&lt;sup&gt;f&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>59.87</td>
<td>3.17</td>
<td>6.39</td>
<td>.022*</td>
<td>.285</td>
</tr>
<tr>
<td>Control</td>
<td>49.74</td>
<td>2.41</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Working Memory (T-score)</strong>&lt;sup&gt;g&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>59.60</td>
<td>2.41</td>
<td>6.106</td>
<td>.025*</td>
<td>.276</td>
</tr>
<tr>
<td>Control</td>
<td>52.07</td>
<td>1.84</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Processing Speed (T-Score)</strong>&lt;sup&gt;h&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>58.49</td>
<td>4.56</td>
<td>.019</td>
<td>.891</td>
<td>.001</td>
</tr>
<tr>
<td>Control</td>
<td>59.30</td>
<td>3.44</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Phonemic Fluency (T-score)</strong>&lt;sup&gt;i&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>59.88</td>
<td>2.81</td>
<td>.262</td>
<td>.616</td>
<td>.016</td>
</tr>
<tr>
<td>Control</td>
<td>58.07</td>
<td>2.15</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mental Flexibility (T-Score)</strong>&lt;sup&gt;j&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>60.39</td>
<td>3.43</td>
<td>1.993</td>
<td>.177</td>
<td>.111</td>
</tr>
<tr>
<td>Control</td>
<td>54.27</td>
<td>2.62</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Inhibition (T-Score)</strong>&lt;sup&gt;k&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>57.88</td>
<td>1.73</td>
<td>.154</td>
<td>.700</td>
<td>.010</td>
</tr>
<tr>
<td>Control</td>
<td>58.74</td>
<td>1.32</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Nonverbal Reason (T-Score)</strong>&lt;sup&gt;l&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>50.96</td>
<td>2.88</td>
<td>.304</td>
<td>.589</td>
<td>.019</td>
</tr>
<tr>
<td>Control</td>
<td>48.94</td>
<td>2.18</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Verbal Reason (T-Score)</strong>&lt;sup&gt;m&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>46.71</td>
<td>2.95</td>
<td>.338</td>
<td>.569</td>
<td>.021</td>
</tr>
<tr>
<td>Control</td>
<td>48.71</td>
<td>2.22</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Memory (T-score)</strong>&lt;sup&gt;n&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SMART</td>
<td>59.50</td>
<td>3.69</td>
<td>2.690</td>
<td>.120</td>
<td>.144</td>
</tr>
<tr>
<td>Control</td>
<td>51.88</td>
<td>2.81</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. * denotes p < .05
b. df<sub>between</sub> = 1, df<sub>within</sub> = 16
c. All test means and standard deviations are based on T-scores, and thus have an M of 50 and an SD of 10.
d. Vocabulary: KBIT 2 Verbal Knowledge
e. Semantic Fluency: WJ-III Retrieval Fluency
f. Attention: WRAML2 Story Memory
g. Working Memory: WAIS-IV Digit Span
h. Processing Speed: D-KEFS Trail Making – Condition 2
i. Phonemic Fluency: MAE COWA
j. Mental Flexibility: D-KEFS Trail Making – Condition 4
k. Inhibition: D-KEFS – Color Word Interference – Condition 3
l. Nonverbal Reasoning: KBIT 2 Matrices
m. Verbal Reasoning: KBIT 2 Riddles
n. Memory: WRAML2 Story Memory Delayed
CHAPTER 4

DISCUSSION

Review of the Findings

At baseline testing, there were no significant differences in terms of age, sex, and pre-morbid level of achievement across student-athletes suggesting comparability between the SMART and the wait-list control groups. Furthermore, groups did not significantly differ on their performances for any outcome measures at baseline testing. Taken together, these results suggest that student-athletes in each respective group were similar to each other with respect to demographic makeup and neuropsychological functioning at the start of the present study, and thus, the groups can be statistically compared.

My main hypothesis was that SMART, compared to the wait-list control, would significantly improve student-athletes’ performances on aspects of executive functioning (e.g., working memory, inhibition, and phonemic fluency) and contextual memory. Thus, in order to reject the null hypothesis, we would expect to see differences between groups on these specific neuropsychological scores at Post-Test 1 and Post-Test 2 after controlling for baseline scores. The results showed a significant group main effect for working memory scores at Post-Test 1. Additionally, at Post-Test 2, SMART participants had higher working memory and attention scores compared to wait-list control participants. These findings suggest SMART was effective in enhancing performance on measures of working memory, and these improvements were sustained across a four-month timeframe. Although SMART was not found to be effective in improving attention initially, increased scores on measures tapping into attention were noted four months following the intervention. In other words, attention appeared to improve significantly as time progressed suggesting a delayed effect of SMART.
Previous studies have shown promising results in light of top-down gist reasoning training particularly for individuals who exhibit higher-order cognitive deficits due to ailments such as TBI and ADHD (Cook et al., 2014; Gamino et al., 2009; Vas et al., 2011). Past research regarding one such gist reasoning training, SMART, which uses cognitive control processes of strategic attention, integration, and innovation, has shown its effectiveness in improving the ability to abstract meaning from complex information and enhance bottom-up processes (e.g., improved ability to recall important details of that information). Proponents of SMART contend that clustering ideas and information into more abstract concepts helps individuals encode details at a deeper level for learning and memory retention (Vas et al., 2011). Additionally, these studies have demonstrated that SMART generalizes to specific untrained executive functions improvement including cognitive switching, working memory, inhibition, verbal fluency, and memory for details (Anand et al., 2010; Cook et al., 2014). The present study attempted to replicate the methods of the prior SMART studies in a student-athlete population, specifically to examine whether SMART would have an effect on untrained neurocognitive abilities.

Regarding top-down cognitive training such as gist-reasoning training, while its main purpose is to improve broad cognitive processes through the teaching and development of strategies, extant evidence has also shown a “spillover” benefit to specific processes (Vas et al., 2015). Generalization to untrained tasks suggest that gist-reasoning strategies target complex functions that have ecological value. Consistent with the previous studies (Cook et al., 2014; Vas et al., 2011), SMART appeared to improve working memory scores at a statistically significant level, and these gains were maintained across time. Working memory is the cognitive process that controls the temporary storage and manipulation of information (Baddeley, 1992); it has also been correlated with attentional control and is thus often considered as an aspect of
executive functioning (Lezak et al., 2012). Strategy-driven approaches such as SMART have been shown to strengthen cognitive control by filtering unnecessary information thereby improving cognitive efficiency and increasing the capacity to abstract pertinent information rather than working to encode, store, and retrieve specific details (Vas et al., 2015). Therefore, this improved efficiency allows for the management of complex data, and working memory is heavily involved in this process (Chapman, Gamino, Cook, Hanten, Li, & Levin, 2006; Cook, Chapman, & Levin, 2008).

The current study also found that SMART was beneficial for attention. Attention reflects the brain’s capacity to selectively process information from the environment (Lezak et al., 2012). One of the main tenants of the SMART program, which is covered within the first week, is the process of “Strategic Attention.” Participants were taught strategies to improve Strategic Attention by the “intentional management of input by blocking distractions and irrelevant input, and factoring in regular mental breaks” (Vas et al., 2015). Essential to this process is also limiting the use of multitasking which decreases cognitive efficiency in filtering and selectively attending to the task at hand. As I have defined it in this study, attention is akin to “short-term memory” which is the capacity to hold pieces of information for a brief period of time (Lezak et al., 2012) and was measured by immediate contextual narrative memory. Although there is overlap between this type of attention and working memory, researchers consider these two processes to be distinct from one another; while attention actively selects the information to be encoded, working memory involves encoding, storage, and manipulation of information (Fougnie, 2008).

What was surprising about the findings of the current study was that attention improved over the long-term despite no initial effect immediately following the completion of SMART.
The results revealed that SMART participants performed better on a measure of attention compared to controls at Post-Test 1. Albeit this difference was not statistically significant, it could signify a trend in which attention steadily improves over the course of time. The sample included college student-athletes 18-23 years of age, an age group that is nestled in a larger age group considered to be the “multitasking generation.” Due to the advent of technology and social media, the multitasking generation, compared with Generation X and Baby Boomers, is more likely to engage in multitasking behaviors, which could have both positive and negative consequences on cognitive functioning (Carrier, Cheever, Rosen, Beneitez, & Chang, 2008). Given that Strategic Attention and limiting the use of multitasking were strong areas of focus in SMART, it could be that through education and more importantly, long-term practice of these strategies at home and at school, may have contributed to improved attention over the course of a few months.

In a manipulation check, results of this study were compared with the research conducted on the same sample at the UTD Center for BrainHealth, the institution responsible for the development and implementation of SMART. In conversation with Dr. Lori Cook (personal communication, January 2, 2017), Director of Pediatric Brain Injury Programs and co-developer of the SMART program at the UTD Center for BrainHealth, SMART participants were given their own developed measures from pre-test and post-test: Scale of Advanced Reasoning (evaluates the ability to comprehend and interpret detail and “big picture” information from different types of texts), Proverb Interpretation (measures abstract thinking), and Picture Lesson Generation (measures abstract thinking, mental flexibility, and the ability to integrate current knowledge with novel information). They found that SMART participants (n = 16) significantly improved performances from pre-test to post-test on these measures tapping into the abilities of
detailed-level recall \( t(15) = 2.128, p = .050 \), summary coherence \( t(15) = 2.330, p = .034 \),
generalization \( t(15) = 2.298, p = .036 \), proverb interpretation \( t(15) = 4.463, p = .00046 \), and
picture lesson generation \( t(15) = 4.006, p = .001 \). These findings demonstrate the SMART was
in fact received by individuals who participated in the intervention, and the findings of the
current study can be interpreted as such. However, contrary to what was demonstrated in the
extant literature, the results of the present study did not show SMART was particularly more
effective in improving in phonemic fluency, inhibition, or memory. With regards to memory, the
Fuzzy Trace Theory suggests that gist and memory for details are independent of one another
(Brainerd & Reyna, 1990). Therefore, gist-reasoning training may not have significant spillover
for memory for details. Additionally, despite the fact that SMART improved performance on
phonemic fluency and inhibition measures in previous studies and that SMART has been shown
to increase connectivity and cerebral blood flow in the neural structures responsible for these
cognitive abilities (Chapman et al., 2013), the nonsignificant findings in the current study may
reveal that SMART was truly not beneficial in improving performance with these untrained
tasks. However, it is more likely that statistical effects were not found due to differences in
methodology, sample, research setting, and/or limitations.

The first major difference between the current study and past SMART studies is test
selection. In the present study, I chose to administer different versions of particular tests (e.g.,
WRAT-IV Reading Blue vs. Green) in which alternate versions of these tests were normed on
the same population thereby reducing error and keeping in line with the tests’ overall validity
and reliability. However, in the case that different versions were non-existent, similar tests that
tap into the same neurocognitive construct were utilized (e.g., WMS-IV Logical Memory vs.
WJ-III Story Recall) which may introduce more error and could vary in terms of validity and
reliability (Lezak et al., 2012). The intention behind administering similar tests, but not the same, was to limit serial assessment effects. Practice effects may overestimate benefits of treatment effects given that participants may improve their performances on measures if they are repeatedly exposed to the same stimuli, and even in some cases of tests that are novel in procedure, alternate versions can bring about practice effects as well (Beglinger et al., 2005). Thus, test selection is an important factor to consider in the interpretation of results.

The second difference is that the current study lacked a “true” comparison group where participants were actively participating in another treatment and instead utilized a wait-list control group. My research design, similar to previous studies, was a true experiment where there were randomization of subjects to groups and a control group; however, in other iterations of the SMART program (Cook et al., 2014; Gamino et al., 2010; Vas et al., 2011), they included an active comparison group such as Memory Strategy Training, which was focused on encoding, rehearsal, and retrieval practice, or New Learning Training, which provided psychoeducation on brain functions and influences on cognition. In the aforementioned studies, each found that SMART participants improved ability to abstract novel meanings from lengthy texts and also improved memory for details when compared to these types of control groups (Chapman & Mudar, 2014). Additionally, they improved their performances on neuropsychological measures tapping into executive functioning even though these processes were not specifically targeted during cognitive training. People assigned to wait-list control conditions may have the perception that they should “wait” to change or improve until the intervention whereas individuals in other control conditions that do not employ a wait-list control group (i.e., other treatment or “placebo” groups) tend to see improvements (Cunningham, Kypri, & McCambridge, 2013). As such, studies utilizing a wait-list control condition may overestimate
treatment effects of the intervention and accordingly need to be interpreted with caution (Cunningham, et al., 2013). However, despite the possible overestimation of results, the current study failed to find differences between the intervention and control groups.

The third difference is that the present study, to the best of my knowledge, is the first investigation of SMART by independent researchers. Unlike past research regarding SMART, the researchers and test administrators of this study did not having any competing or vested interest in the development of the SMART program are less inclined to have researcher allegiance. Researcher allegiance is defined as the researcher’s belief in the superiority of a particular treatment and that this treatment is associated with improvements (Munder, Brütsch, Leonhart, Gerger, & Barth, 2013). This bias in research can be a threat to internal validity and has been shown to influence outcomes in research (Munder et al., 2013). Therefore, it is important to consider researcher allegiance as a potential opposing explanation for findings.

Limitations

Limitations in this study may help to explain the non-significant results. First, this study involved a very small sample. As a priori power tests indicate, 88 participants were needed to discover a large effect size (Cohen’s $f = 0.4$) at the .05 level. Sixty student-athletes were initially recruited by the athletic department and based on available time-slots set by the researchers, the student-athletes were scheduled for testing sessions by the department’s academic counselors. The researchers sent reminder phone-calls, emails, text messages to the student-athletes the week and day before testing. Despite obtaining grant funding from Conference USA to provide monetary incentives for participation, the most common reason for the attrition was due to random factors (e.g., scheduling conflicts, no-shows, etc.). At baseline, 56 student-athletes were assessed, and of those, 40 participants returned for Post-Test 1 which occurred immediately after
the conclusion of the SMART program. Post-Test 2, four months after the conclusion of the SMART program, only included 19. Low power, as in the case of the current study and many other studies in neuroscience, results in a lower chance of discovering effects that are genuinely true and by definition, leads to a higher probability of false negatives (Button, Ioannidis, Mokrysz, Nosek, Flint, Robinson, & Munafò, 2013). To check whether my nonsignificant results were due to a lack of statistical power, I conducted post-hoc power analyses which indicated that a sample of 40 participants would require an 69.3% probability to detect a large effect size (.4) as significant at the .05 level. Thus, it is unlikely that nonsignificant findings were due to a small participant pool. Regardless, because post-hoc power analyses are controversial as opponents of this method contend that post hoc power does not necessarily add any new information nor provides an accurate estimate of true power (Lenth, 2007), future studies should look to increase power by obtaining adequate sample sizes.

The second limitation is that due to attrition, there were unequal groups of SMART and controls at Post-Test 1 [SMART (n = 15); control (n = 25)] and Post-Test 2 [SMART (n = 7); control (n = 12)]. The problem with unequal groups is the issue of confounding which can affect random assignment of subjects to conditions; subsequently if randomization of subjects to groups is compromised, alternative explanations for treatment effects cannot be ruled out (Lane, 2016). In the analyses for each testing session, I compared the neuropsychological scores of those who completed measures with those who dropped out at that particular time period. The results demonstrated no significant differences between those who completed measures and those who did not, which suggests that there were at least no differences in cognitive functioning between them. However, there may be unknown factors that could potentially confound the study as the exact reasons for why participants dropped out of the study remain unclear.
The third limitation is that despite the fact that multiple ANCOVAs were run, Bonferroni adjustments were not applied. The purpose of Bonferroni adjustments is to create more stringent criteria \((p < .05)\) to account for the rise in \(\alpha\), Type I error, when computing multiple tests (Weisstein, 2004). Perneger (1998) argued against using Bonferroni adjustments as these corrections increase Type II errors, do not answer the null hypotheses in question, and depend on how many tests are run which is irrelevant to interpretation. Also, the current study was exploratory in nature; therefore, less stringent criteria were utilized. However, it is important to recognize the problem of not using corrections. If Bonferroni adjustments were used in the current study, the \(\alpha\) level would have been 0.0045455. Because these corrections were not incorporated, the probability of finding one or more significant differences in 11 tests was 0.4312 (43.12\%). Thus, it is possible that the null hypotheses were rejected when they were in fact true. In other words, even though it was found that SMART had an effect on improving performance on neuropsychological measures of working memory and attention, it is possible that SMART does not truly have an effect, and the significant results were spurious.

Fourth, participant makeup may have hindered the statistical efficacy of the SMART program. In our study, no participants endorsed a history of a learning disability and only 1 individual, out of 19, acknowledged being diagnosed with ADHD in the current study, therefore these conditions will not be mentioned further. With regards to mild TBIs, eight student-athletes endorsed a history of concussion(s) at baseline and even fewer, four student-athletes, in the final analysis. This is contrasted with studies that have a homogenous population such as Cook et al.’s article (2014) where they found positive neurocognitive effects of SMART on adolescents with chronic, residual deficits due to mild, moderate, or severe TBI. Concussions, or mild TBIs, as the name implies, are less severe than moderate or severe TBIs (Iverson & Lange, 2011). The
World Health Organization’s definition of mild TBIs are characterized by one or more of the following symptoms: “confusion or disorientation, loss of consciousness for 30 minutes or less, post-traumatic amnesia for less than 24 hours, and/or other transient neurological abnormalities such as focal signs, seizure, and intracranial lesion not requiring surgery.” The student-athletes in this study did not indicate any brain injuries with a loss of consciousness greater than 30 minutes, thus their reported brain injuries are most likely mild TBIs. Studies have shown that athletes (sport-related concussions) and trauma patients (all other concussions that required hospitalization) perform more poorly on neuropsychological measures within the initial days and up to one month of the concussion (Iverson & Lange, 2011). Some studies have estimated that as many as 25–35% of these individuals might experience persistent neurocognitive and behavioral problems at 3 to 6 months post trauma (Raymond & Bennett, 1999; Raymond, Bennett, Hartlage, & Cullum, 1999). However, conflicting literature has found that neuropsychological impairments are typically not seen in athletes 1-3 weeks following the injury or in trauma patients after 1-3 months (Iverson & Lange, 2011). Since the majority of recovery from the mTBI occurs within the first several months, measureable neuropsychological deficits are not expected following that timespan (Iverson & Lange, 2011). Due to the extended time span of the current study, participants’ concussions were more likely to be remote than acute in nature, and therefore may have returned to a normal neuropsychological baseline.

There is little empirical evidence to suggest that “normal” populations such as people who are free from any brain disorder, injury, or disease actually benefit from cognitive training (Ball et al., 2002). Typically, with cognitive training, there is a target skill or cognitive function to be improved, remediated, or rehabilitated (Jaeggi, Buschkuehl, Jonides, & Shah, 2011). Cognitive rehabilitation for stroke or brain-injured patients, for example, may be helpful in
recovering or restoring impaired neurocognitive functioning and/or to develop compensatory strategies to work around these deficits (Cicerone et al., 2013). Individuals with cognitive functioning that is within normal limits (i.e., low average, average, high average range) can experience benefits in their everyday lives from cognitive training or general strategies to increase cognitive efficiency (e.g., focusing on one task at a time, practicing active listening strategies, taking regularly scheduled breaks to avoid the “crash”). However, for individuals whose cognitive functioning is already within a standard deviation of the average range, statistical tests cannot adequately capture these functional improvements as there is a ceiling effect. In other words, there is less room to “grow” within the normal population, especially high functioning college students (such as the individuals in the present study) who have comparatively greater cognitive efficiency than those with neurological conditions.

The last limitation of the current study is that effort tests, also known as performance validity tests (PVTs), were not formally administered during any of the evaluations over time due to limited time to administer the testing battery. Neuropsychological tests, in general, were developed to validly and reliably measure behavior to make inferences about one’s cognitive functioning (Bigler, 2012). As neurological and psychological processes can create disturbances in one’s neuropsychological performance, effort can also alter one’s performance by reducing their ability to engage in the task at hand, and in doing so can underestimate one’s cognitive abilities and exaggerate cognitive impairment (Heilbronner, Sweet, Morgan, Larrabee, Millis, & Conference Participants, 2009). PVTs have become a standard in test administration in recent years and can serve as a validity check to accurately assess one’s neuropsychological profile (Heilbronner et al., 2009). External PVTs are stand-alone measures that are added onto a test battery; internal PVTs are built into the tests (Meyers, Volbrecht, Axelrod, & Reinsch-Boothby,
One such internal PVT is the WAIS-IV Digit Span subtest, which has been demonstrated to be effective in detecting malingered neurocognitive dysfunction, utilizes various validity indexes (e.g., maximum forward and backward both trials correct, longest digits forward greater than longest digit backwards, difference between longest digit forward and longest digit backward should be no greater than 3; Iverson & Franzen, 1994). Reliable digit span (RDS) is one of the most well-validated clinical indicators of malingering: it is calculated by summing the last forward and backward digit strings in which both trials were completed without error (Heinly, Greve, Bianchini, Love, & Brennan, 2005). RDS scores of 6 or less are rare in nonmalingering patients with a variety of neurological conditions, therefore scores in this range may be an indicator of poor effort (Heinly et al., 2005). In the present study, none of the 19 individuals in the final analysis had RDS scores less than 9; however, reduced engagement cannot be completely ruled out. There are many reasons as to why people may give suboptimal effort (e.g., financial compensation, escaping responsibilities, psychosocial reinforcement; Slick, Sherman, & Iverson, 1999). Psychological disorders such as depression, PTSD, and anxiety have also been found to be related to reduced engagement (i.e., attention) as well (Scott, 2011). PVTs can signal the detection of individuals who perform more poorly than those with true neurological disorders such as mTBIs, LDs, or ADHD and may exaggerate their symptoms (Bigler, 2012). Including an external PVT in our testing battery may have identified these individuals; therefore, they would have been excluded from our study.

Future Directions

There is rich area for growth with respect to neurocognitive training in general, but more specifically with the SMART program. Past randomized controlled studies include typically developing adolescents (Gamino et al., 2010), adolescents with TBI (Cook et al., 2014; Gamino
et al., 2009), adults with TBI (Vas et al., 2011), cognitively healthy older adults (Chapman et al., 2015), and adults with mild cognitive impairment (Mudar et al., 2013). Much research can be done with different population characteristics (e.g., age, sex, race, psychological conditions, neurological disorders) and in various contexts (e.g., controlled lab setting, work, school, etc.). Future studies can also examine the cumulative effects of SMART in combination with another intervention such as other types of neurocognitive training, cognitive behavioral therapy, medication, mindfulness, etc.

Future directions can include looking at the underlying neurobiological mechanisms of change as a result of gist-reasoning training. Chapman and colleagues (2015) were the first to examine neuroimaging of individuals before and after SMART participation and found increases in global and regional cerebral blood flow and greater functional connectivity in the frontal lobe which is associated with top-down cognitive processes). Moreover, they found increased structural connectivity in the white matter tracts, particularly in the left uncinated fasciculus, a neuroanatomical pathway that is believed to connect memory neural structures with structures responsible for abstraction skills. Although structural or functional changes on MRI, fMRI, or CT scans are not always necessarily implicated with the accurate prediction of neuropsychological performance, neuroimaging can serve as an additional data point to potentially explain brain-behavior relationships (Lezak et al., 2012). As such, future research can include the use of imaging technology and how SMART may impact cerebellar structures and functions.

Conclusion

I explored the neurocognitive training effects of gist-reasoning training, namely SMART, with a student-athlete population. Student-athletes who underwent SMART and wait-list control
student-athletes were compared on performances of neuropsychological measures tapping into cognitive domains of language, attention, processing speed, memory, and executive functioning. Participants were assessed at baseline \((N = 56)\), immediately after the intervention (SMART \(n = 15\); control \(n = 25\)), and three to four months after the intervention (SMART \(n = 7\); control \(n = 12\)). Results showed that participants benefited from SMART with respect to working memory immediately following the intervention after controlling for baseline scores. The benefits of working memory also persisted after four months. Additionally, SMART was beneficial in improving attention, but only after four months after the intervention. The findings of the current study were consistent with previous studies which showed positive effects of SMART on working memory with a variety of populations (e.g., children, adolescents, older-adults, Veterans, brain-injured patients); however, the current study did not see improved performance on other aspects of executive functioning which contradict prior research. These findings were consistent with previous literature regarding SMART, which highlighted efficacy across adolescent and older adult samples with various conditions (e.g., ADHD, TBI, cognitive impairment). Differences in methodology, sample, and research settings between the prior studies with the current study may elucidate the variance in findings. Limitations and future directions were discussed.
REFERENCES


Athlete Network. Presidents who were college athletes. Retrieved from:


Sports Neuropsychology Concussion Symposium: A Multidisciplinary Integration of Science and Practice. Poster presented from Dallas, TX.


Ernst & Young Global Limited (2015). Retrieved from:


http://neuroscience.uth.tmc.edu/s4/chapter08.html