USING A COMPUTERIZED PROGRAM TO IMPROVE WORKING MEMORY IN INTERMEDIATE SCHOOL STUDENTS

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In Partial Fulfillment of the Requirements for

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A Dissertation

entitled

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by

Misty M. Swanger

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USING A COMPUTERIZED PROGRAM TO IMPROVE WORKING MEMORY IN INTERMEDIATE SCHOOL STUDENTS

By

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ASHLAND UNIVERSITY, 2013

Dr. Carla Edlefson, Chair

Working memory provides the important function of remembering and being able to process information. A child with low working memory may demonstrate deficits in academic achievement. A pragmatic interpretivist research approach asked if working memory and general intelligence could be improved for students. The purpose of this quasi-experimental study was to determine whether the computerized program *Jungle Memory*® could improve working memory for intermediate grade students. The study followed the Baddeley and Hitch theoretical framework of working memory. Data were collected from pre and post assessments in working memory and general ability. Verbal working memory and general ability did not increase after the intervention using the *Jungle Memory*® brain training program. Visuo-spatial working memory did increase with a medium effect size ($d=.51$). Pretests showed verbal working memory had a positive correlation with general ability ($r=.455$, $p<.01$). Posttests showed visuo-spatial working memory positively correlated with general ability ($r=.624$, $p<.01$). Verbal working memory and visuo-spatial working memory did not correlate, substantiating the Baddeley and Hitch framework of working memory mediated by the phonological loop and visuo-spatial sketchpad. The study did not substantiate an improvement in working memory for students with deficits in working memory ability.

DEDICATION

To my parents Donald and Virginia Roberts Swanger who instilled a commitment to education and modeled the work ethic necessary to achieve my goals. Gini Swanger exalted high expectations for her children and rendered in us the self confidence that we could achieve anything that we set our minds to doing. Thanks Mom for instilling in me the drive I needed to complete this dissertation.

ACKNOWLEDGMENTS

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INTRODUCTION

Teaching is both an art and a science. The science of teaching and learning has become popular with the growing trend of brain based educational programing and neuroscience information infiltrating classrooms and school districts. The first President Bush declared the 1990s as the decade of the brain. An explosion of research has been conducted and many people believe this research can influence educational practices. The recent field of mind, brain, and education is an attempt to integrate the separate but related areas of education, neuroscience, and cognitive psychology (Tokuhama-Espinosa, 2011). Psychology and education have intertwined for over a century with a multitude of theories in psychology crossing over into educational practices such as the discovery of localized brain regions for speaking and visual areas, Piaget's stages of development, and Bandura's social learning theory (Willingham & Lloyd, 2007). However, these separate but not equal fields have failed to merge and have produced many confusing implications in educational classrooms. Klingberg (2013) proclaimed that the integration of neuroscience in education could cause a revolution in teaching, but too often the science is misunderstood and teachers, politicians, and the public do not understand enough about the science to integrate the fields.

A plethora of misinterpretations and neuromyths proliferate schools and classrooms and cause alarm to neuroscientists who do not want to be misinterpreted or collaborate with educators if the value of the neuroscience is going to be oversold (Willingham, 2008). School districts are individualizing educational programs, attempting to use data to know more about individual students and implementing responses to intervention initiatives. Many teachers and school districts are implementing and utilizing programs labeled as brain based educational solutions. Evidence-based instructional strategies are important for teachers. Schools can spend an enormous amount of money on programming that claims to increase student achievement and grades, but which do not have the validation to substantiate these claims. The relationship between neuroscience and education needs to be examined in depth. Hence, this dissertation is the culmination of research on mind, brain, and education programs. It is a quasi-experimental study in a significant educational concept that emerged from the growth and popularity of neuroscience in the classroom: working memory.

WORKING MEMORY: A BARRIER TO LEARNING

Working memory provides the important function of remembering and being able to process information. It is vital to school and life success because working memory is the temporary system that holds information in order to carry out cognitive tasks (Alloway, Gathercole, Willis, & Adams, 2004). Frequently in the practice of education, teachers lament that students are lacking in the memory and attention necessary for adequate learning to occur. In reality, these teachers are most often concerned with working memory and the significance for students to be able to retain information in their working memory before it is transformed into a permanent memory.

A child with low working memory may demonstrate deficits in academic achievement, coming up with solutions to problems, verbal ability, paying attention, maintaining focus or monitoring his or her own work (Alloway et al., 2009a). Deficits in working memory are a barrier to academic success; therefore, teachers who recognize the difference between attentional problems and working memory deficits can appropriately target interventions to help the child succeed.

Moreover, a student with a strong working memory has an advantage in a school setting. Working memory is responsible for reading comprehension, listening to a lecture, completing math problems, playing a musical instrument, following directions, and remembering locations. From my personal experience, students who have deficits in working memory have academic difficulties that are often overlooked or confused with regulation and behavioral issues. Many children with working memory deficits are misidentified as unmotivated, inattentive, lazy, not capable of higher-level work, or having Attention Deficit Hyperactivity Disorder (ADHD) (Alloway, Gathercole, Kirkwood, & Elliott, 2009b).

PURPOSE AND RESEARCH QUESTIONS

The purpose of this quasi-experimental study is to determine whether the computerized program *Jungle Memory*® can improve working memory for intermediate grade students at a school located in Central Ohio. Three research questions were addressed by the study.

Working memory is an important component of school success. It is the foundation for student reading comprehension. Working memory underpins the student's ability to apply math facts to story problems and real world math. It is important for a student who listens to a school lecture, writes a research paper, and recalls directions to navigate a map. Working memory is essential for school and life success.

Working memory is a component of many intelligence tests, but it is not synonymous with intelligence. According to Piirto (2007), intelligence is having the ability to solve problems, having verbal strength, and having a basis for general social awareness. General intelligence (*g*) is often divided into two categories: crystallized intelligence (*Gc*) and fluid intelligence (*Gf*). *Gf* is the ability to problem solve as well as match patterns and reason, while *Gc* is knowledge and skills (Alloway, 2012; Denckla, 1996; Klingberg, 2010). The use of a non-verbal intelligence test is a reference to the type of test given to a student and not the ability of an individual taking the assessment. Non-verbal intelligence tests can be used to assess general ability (Naglieri, Brulles, & Lansdowne, 2008).

THEORETICAL FRAMEWORK

The theory of pragmatism is guiding the study. The pragmatic worldview is based on the belief that knowledge and truth are subjective and based upon experience, culture, attitude, economics, and situations (Merriam, 2009). Pragmatism is not devoted to one worldview or philosophy, rather it is an approach often used to guide research that allows the researcher to study the "what" and "how" of a situation (Creswell, 2003). Pragmatism allows the researcher to focus upon the problem of a student who has a deficit in working memory and to ask whether working memory can be enhanced or improved for a student. An interpretivist approach will also be utilized. This approach asserts that people create their own social meaning for a situation or setting (Hesse-Biber & Leavy, 2010).

This study followed the Baddeley and Hitch (1974) theoretical framework on working memory, in which working memory is a multicomponent system. There are four components of working memory, as depicted in Figure 1.1: the phonological loop, visuo-spatial sketchpad, episodic buffer, and the central executive (Baddeley, 2012).

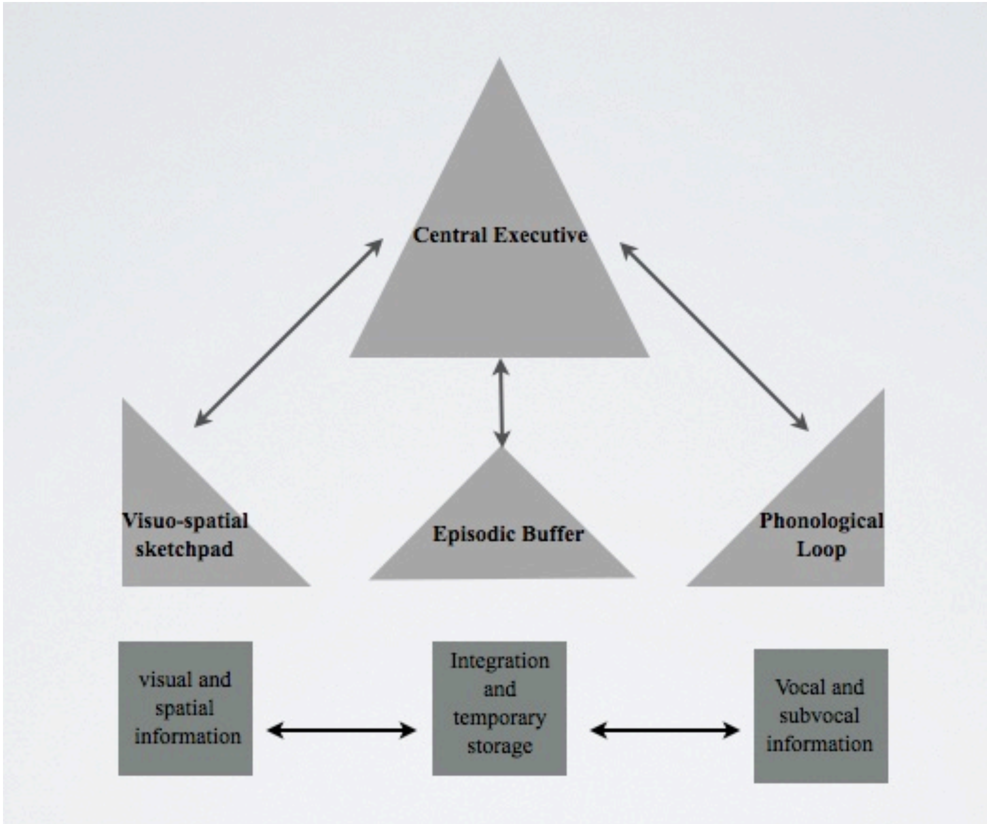


Figure 1.1. Baddeley Hitch Model of Working Memory
Figure is adapted from Baddeley (2012).

Not all brain function is localized, but with advances in neuroimaging more brain functions can be associated with specific structures. The regions of the brain most associated with working memory are the frontal and parietal lobes as studied by neurophysiological and neuroimaging studies (Klingberg, 2010). Table 1.1 is a basic and general overview for readers, and is not intended to be all inclusive of brain structure or function.

Table 1.1
General overview of brain structure and function as related to working memory (Klingberg, 2013; Posner & Rothbart, 2007).

Brain Structure	Basic brain function
Amygdala	Basic emotions
Anterior Cingulate	Motivation
Broca's Area	Spoken language
Cerebellum	Coordination and movement
Hippocampus	Encodes long-term memory
Intraparietal Cortex	Represents number
Parietal Lobe	Sensory and activated with phonological loop and visuo-spatial sketchpad
Prefrontal Cortex (AKA – Central Executive)	Central executive, planning, judgment, problem solving
Occipital Lobe	Visual area
Temporal Lobe	Verbal and sound base and language
Wernieke's Area	Language Comprehension

Attention closely relates to working memory. In an educational setting, directing and sustaining attention is paramount for academic success. Executive functioning, effortful control, and self-regulation also closely relate to working memory. Baddeley (2000) added the episodic buffer to the theory of working memory in order to highlight the significance of the central executive as the attention control for working memory. Klingberg (2013) said if starting all over again, Baddeley would rename working memory as working attention.

Recent interest has emerged in the fields of education, cognitive psychology, and neuroscience surrounding the training of working memory. Claims that working memory can be improved have led to an increase in research and has become a highly debated topic in the past year. According to researchers working memory, intelligence, academic achievement, and ADHD symptoms have been enhanced by brain-training programs. (Gathercole, Dunning, & Holmes, 2012; Hulme & Melby-Lervag, 2012; Jaeggi, Buschkuehl, Jonides, & Shah, 2012; Klingberg, 2012; Morrison & Chein, 2012; Shipstead, Hicks, & Engle, 2012a). Indeed, psychological assessment, computer, and educational companies are promoting the use of computerized games as tools for increasing student achievement and working memory ability. These debates and claims led to the research questions of this study:

Research question 1**.** Can the brain-training program *Jungle Memory*® improve working memory?

Research Question 2. Accepting the use of the social construct of intelligence, can ability scores as indicated on the NNAT-2 increase by the use of the brain-training program *Jungle Memory*®?

Research Question 3. Is there a relationship between general ability (g) and working memory?

OVERVIEW OF METHODOLOGY

The purpose of this quasi-experimental study is to determine whether the computerized program *Jungle Memory*® can improve working memory for intermediate grade students at a school located in Central Ohio. The quasi-experiment is a pretest-posttest design study without a control group. The independent variable is the intervention program, *Jungle Memory*®, an online brain-training game and program (Jungle Memory, 2011a). The dependent variables are defined as the working memory and ability scores for each participant.

The *Automated Working Memory Assessment 2* (2011) was used to assess the working memory of each participant. The *Naglieri Nonverbal Ability Test Second Edition* (2011)was used to assess each participant's general ability.

Conceptual Postulates

Working memory is imperative to learning and has significant consequences for a child with a deficit. The brain has plasticity and is able to change both structurally and functionally because of both environment and experience (Posner & Rothbart, 2007). Evolutionary psychology has demonstrated that training can adapt and shape the brain (Klingberg, 2010). Therefore, theoretically the areas of the brain responsible for working memory can be developed for improvement. However, I am not prepared to claim that working memory can be improved to the point of far transfer that increases a student's ability score or academic achievement.

Parents, teachers, and school districts should be discerning in accepting claims that any brain based or brain-training program will benefit students. A well-meaning individual can fall victim to the use of a picture, logo, or slogan like brain-based teaching, when in reality there is not a regulatory agency or group to police the onslaught of books, companies, and games marketed as brain-based. Technically, all learning is brain-based, but teachers and superintendents alike need to discern good science from the pseudo-science. Recognizing the validity of a brain-training program and understanding research are imperative in an era of educational accountability and limited resources. The importance of this study is to assist school districts in deciding whether working memory improves through the use of the *Jungle Memory*® brain-training program.

SIGNIFICANCE OF STUDY

This study was significant in that it provided schools and educators an opportunity to discern the effectiveness of a brain-training program on a general population of students. *Jungle Memory*® was chosen for the study as it has not been utilized in many independent research studies and is a more affordable program for school districts or families looking for a brain-based working memory training program. This study is significant in that it was not initiated by the makers of *Jungle Memory*® nor funded by any entity related to the brain-training program. Moreover, the study was significant in that it did not target a special needs population like gifted, special education, or children identified as having ADHD, as previous studies utilizing the *Jungle Memory*® brain based program have done (Alloway, 2012; Alloway, 2011b; Alloway & Elsworth, in press; Alloway, Bibile, & Lau, in press). The study also measured general ability (*g*), whereas the majority of working memory studies tested for fluid intelligence (*Gf*) utilizing the Ravens Progressive Matrices.

This study was also significant and will add to the body of work surrounding the use of the *Naglieri Nonverbal Ability Test Second Edition* (NNAT-2) as a measure of *g*. Very limited research has correlated working memory with *g* utilizing the NNAT-2. This study was performed within one intermediate school in Ohio and is intended to provide data to inform decisions about implementing the use of brain based working memory interventions as programming for students.

DefinItions

This study uses neuroscience and anatomical terminology that may not be clear to the reader, therefore the following definitions are provided:

Amygdala - Located at the end of the hippocampus in the temporal lobe. “It is connected to many areas of the brain and plays a critical role in learning, cognition, and the processing of emotional memories” (Jensen, 2005 p. 159).

Antisaccade Task – “ An executive attention task where subjects fixate in the middle of a visual display but must respond to target information briefly presented randomly to one side of the other of the display” (Engle, 2002 p. 21).

Attention deficit hyperactivity disorder (ADHD) – “A range of behavior disorders characterized by symptoms that include poor concentration, an inability to focus on tasks, difficulty paying attention, and impulsivity” (Tokuhama-Espinosa, 2011 p. 240).

Broca’s area – “The areas of the brain involved in the programming of motor movements for the production of speech sounds; also involved in syntax” (Tokuhama-Espinosa, 2011 p. 244).

Central Executive – a flexible system responsible for the control and regulation of cognitive processes. Often used interchangeably with the “prefrontal cortex” (Baddeley, 2012).

Cerebellum – “Structure located below the occipital lobe and next to the brain stem. It is linked to balance, posture, coordination, and muscle movements. More recent research has linked it to cognition, novelty, and emotions” (Jensen, 2005 p. 160).

Cingulate gyrus – “Structure lies directly above the corpus callosum. It mediates communication between the cortex and midbrain structures. It is involved with right-wrong, decision-making, and emotions. It helps us shift from one mind-body state to another” (Jensen, 2005 p. 160).

Cerebral cortex – “The outermost layer of the cerebrum. The cortex mediated all conscious activity including planning, problem solving, language, and speech” (Willis, 2007 p. 196).

Crystallized Intelligence (*Gc*) – A measure of intelligence “thought to reflect skills acquired through knowledge and experience and is related to verbal ability, language development, and academic success” (Alloway, 2012 p. 1).

Effortful control - “ A measure of individual differences in the ability to inhibit a dominant response to perform a subdominant response.” (Posner & Rothbart, 2007 p. 94).

Episodic Buffer – A component of working memory “assumed to be a limited-capacity temporary storage system that is capable of integrating information from a variety of sources. It is assumed to be controlled by the central executive” (Baddeley, 2000 p. 421).

Executive Function – “the CEO of the brain focusing attention on the pronounced increase in frontal lobe synaptic connectivity that leads to self-direction and self-control” (McCloskey, Perkins, & Van Divner, 2009 p. 11).

Fluid Intelligence (*Gf*) – A measure of intelligence that “refers to the ability to reason and to solve new problems independently of previously acquired knowledge” (Jaeggi et al., 2008 p. 1).

General Ability (*g*) – “That which allows people to solve different kinds of problems that may involve words, pictures, sounds, or numbers. These problems may involve verbal, quantitative, or nonverbal reasoning, memory, sequencing, patterning, connecting ideas, making insights, drawing inferences, and analyzing simple and complex ideas" (Naglieri et al., 2008 p. 119).

Hippocampus – "A cortical area of the brain classified as a part of the limbic system; located in the temporal lobe involved with long-term memory and important for converting short-term memory to more permanent memory" (Tokuhama-Espinosa, 2011 p. 269).

Intraparietal sulcus – "An area of the parietal cortex associated with processing and representation of numerical quantity with mature calculation strategies" (Ansari, 2010 p. 213).

Myelin – "A fatty, white shield that coats and insulates axons. It can make neurons more efficient allowing electrical impulses to travel faster" (Jensen, 2005 p. 160).

N-Back Test – A working memory task that requires the participant to attend to a series of information and recall each time an item was presented n times ago (Shipstead, Redick, & Engle, 2012).

Neurons – "Brain cells that receive stimulation from branches known as dendrites. They communicate with other neurons by firing a nerve impulse along an axon" (Jensen, 2005 p. 160).

Neurotransmitters – "The brain's biochemical messengers. They act as a stimulus that excites neighboring neurons or as an inhibitor to suppress activation" (Jensen, 2005 p. 160).

Nonverbal Test of Ability – "A nonverbal assessment of general intelligence (*g*) that uses figural matrices to measure ability without requiring a student to read, write or speak; students must rely on reasoning, not on verbal skills. This promotes fairness across gender, race, and ethnicity" (Naglieri et al., 2008 p. 119).

Parietal Lobe – "The top of the upper brain that deals with reception of sensory information from the opposite side of the body. It plays an important part in reading, writing, language, and calculation" (Jensen, 2005 p. 160).

Phonological Loop – A component of working memory "assumed to have developed on the basis of process initially evolved for speech perception and production. It is particularly suited to the retention of sequential information, and its function is reflected most clearly in a memory span task" (Baddeley, 2000 p. 419).

Plasticity – "The brain's ability to change structurally and functionally as a result of learning and experience" (Willis, 2007 p. 201).

Prefrontal Cortex – "The front part of the brain's frontal lobes. It responds to event and memory processing. This brain region is implicated in planning complex cognitive behaviors. The basic activity of this brain region is considered orchestration of thoughts and actions in accordance with internal goals" (Tokuhama-Espinosa, 2011 p. 295).

Raven's Matrices intelligence test – "A test to measure inductive reasoning ability. A matrix of figures is presented in which one position is empty. By deducing the relationship between rows and columns, the participant is required to infer what figure should be in the empty position of the matrix" (Klingberg, 2010 p. 317).

Self-regulation – "Learning that is guided by metacognition (thinking about one's thinking), strategic action (planning, monitoring, and evaluating), and motivation to learn" (Tokuhama-Espinosa, 2011 p. 303).

Stroop Test – A conflict task designed to "rely on executive attention to maintain the goal of naming the color of the letters of a word even when the word elicits a stronger tendency to say the word" (Engle, 2002 p. 22).

Temporal Lobe – "The lobe of the brain that is associated with auditory processing and olfaction. Located below the frontal and parietal lobes; involved in perception and recognition of auditory stimuli and memory. Concerned with recognizing and naming individual objects and responding to them with the appropriate emotions" (Tokuhama-Espinosa, 2011 p. 310).

Visuo-spatial Sketchpad – "It is a component of working memory that is assumed to hold information that is seen. It is used in the temporary storage and manipulation of spatial and visual information such as remembering shapes and colors, or the location or speed of objects in space." (Canadian Institute of Health Research, 2012).

Wechsler Abbreviated Scale of Intelligence (WASI) – "A battery of tests of vocabulary, judgment of similarities, block design, and matrix reasoning tasks" (Klingberg, 2010 p. 317).

SUMMARY

This chapter included the purpose and significance of the study. Chapter II will provide a review of the literature on working memory. An outline of the methodology is presented in Chapter III. The results and findings from the quasi-experiment are presented in Chapter IV. Chapter V provides a summary, conclusions, and recommendations.

CHAPTER II

LITERATURE REVIEW

INTRODUCTION

Four sections structure this review of literature. Section one outlines the Baddeley and Hitch theory of working memory. This theoretical framework defines and analyzes working memory. Additionally, the first section reviews other theories of working memory as compared to the Baddeley and Hitch theory. Questions to be addressed in this section include: What is working memory? How is working memory different from short-term memory? How does working memory link with long-term memory? Section two presents an overview of the education implications of working memory. It also highlights the significance of working memory for students in academic arenas. Section three outlines the significance of functions pertaining to the central executive. This section reviews the concepts of self-regulation, executive functions, and ADHD. Section four reviews the literature that claims working memory can be improved. The fourth section also explores the growing market for tools that claim to improve working memory and defines the importance of transfer in the training of working memory.

THEORIES AND MODELS OF WORKING MEMORY

Baddeley and Hitch Theoretical Framework

Baddeley and Hitch (1974) conceptualized working memory from the original theories of short-term and long-term memory. Short-term memory is considered temporary and long-term memory is the ability to archive boundless knowledge and information. Working memory derives from short-term memory, the idea that a person can hold a specific number of items within consciousness for a temporary amount of time

(Baddeley, 2012). The original working memory theory separated short-term memory as a storage area and working memory as the use and manipulation of information stored in memory (Baddeley, 2012). The original theory outlined a multicomponent view of working memory as the phonological loop, visuo-spatial sketchpad, and central executive system. (Alloway et al., 2009a).

Alloway (2009) defined working memory as “the capacity to store and manipulate information in the mind for brief periods of time” (p. 92). Each separate component of working memory has differing capacities and limitations; therefore, one can assess working memory as an overall ability or as individual components (Alloway, 2011c). The phonological loop processes verbal information and is temporarily stores it when an individual rehearses vocal and sub vocal information (Raghubar, Barnes, & Hecht, 2010). The visuo-spatial sketchpad holds and manipulates visual and spatial information, and Raghubar et al. (2010) referred to it as mental images created in the mind (p. 111). Based upon research from patients with short term memory deficits and controlled environments with student volunteers that were forced to participate in concurrent task trials, Baddeley and Hitch (1974) determined that both the phonological loop and visuo-spatial sketchpad are slave systems to the primary system of the central executive (Baddeley, 2012).

Baddeley contended the original publication of the multi component of working memory was hastily published because of his invitation to contribute to a chapter to an influential journal on advances in learning and memory (Baddeley, 2012). Therefore, Baddeley (2012) reflected that the multi component theory remains a work in progress, and 40 years later there are additional clarifications as he continues to learn, publish and refine the theory (p. 6). Baddeley’s conceptual framework of a theory is that it must be useful, similar to a roadmap that provides direction. It is not, however, stagnant because directions can change with development (Baddeley, 2012).

Baddeley, with his student Hitch, intended to study the relationship between short-term memory and long-term memory when in 1974 the psychologists proposed the original three-area idea of working memory (Baddeley & Hitch, 1974). The pair continued to study patients and memory to understand further the concept and limitations of working memory (Baddeley, 2012).

The original framework highlighted the significance of the central executive as the most important part of working memory as if it were a little man, known as Homunculus, organizing the human brain (Baddeley, 2003). Smedt et al. (2009) reinforced the significance of the central executive as the imperative component of working memory as it maintains the "control, regulation, and monitoring of complex cognitive processes" (p. 187). However, the development of the central executive as the intermediate between the phonological loop and visuo-spatial sketchpad was not a completed theory. To remain relevant and useful, the concept of working memory has remained a work in progress and is still under scrutiny and refinement (Baddeley, 2012).

Reformulated theoretical framework. In 2000, Baddeley reformulated the original multi-component working memory theory with the additional of the episodic buffer as a mitigating component (Baddeley, 2000). The episodic buffer integrates and temporarily stores information from the phonological loop and visuo-spatial sketchpad. The central executive remains the master system and the episodic buffer integrates the vocal components of the phonological loop and visual information held in the sketchpad (Baddeley, 2000), as shown in Figure 1.1.

T. P. Alloway et al. (2009a) promoted the episodic buffer as the area responsible for combining information into useable chunks of data, while the central executive remains the regulatory component that has to retrieve information from long-term memory (pp. 606-607). This augmented version of working memory theory maintains the limited ability of all aspects of working memory and a separation of short-term and long-term memory. The original multi component theory inaccurately assumed that the central executive did not have any storage capabilities and was only a mediator of attention (Baddeley, 2012). Baddeley (2000) maintained that the theory is still a work in progress and suggested extending phenomenological studies to understand better the significance of the episodic buffer and the role it holds in long-term memory and cognition.

Additional Theories of Working Memory

Whereas this literature review proposes the Baddeley and Hitch (1974) theoretical framework of working memory as the definitive model, there are additional theories of working memory. Engle (2002) postulated that working memory is more of an ability to control attention and the relationship between temporarily holding information in mind and maintaining the attention to perform a task. Engle's definition of working memory emphasized both the process of memory as well as executive attention (Engle, 2002). In this theory, working memory is more about the ability to devote attention to a task rather than the Baddeley and Hitch (1974) master and slave systems involving the phonological loop and visual spatial sketchpad.

A decade later, Shipstead, Redick, and Engle (2012) declared that what many researchers propose as working memory is actually short-term memory and the temporary storage of information. They based this conclusion on the different assessments and measures used to measure working memory. Shipstead, et al. (2012) defined working memory in broader terms as “a cognitive system that strongly relates to a person’s ability to reason with novel information and direct attention to goal-relevant information” (p. 1). This theory elaborates on working memory and suggested it is related to a person’s ability to maintain, allocate, and control attention (Raghubar et al., 2010). Shipstead, et al. (2012) claimed there is no clarification for a definition of working memory but an agreement that it is a dynamic system that requires the shifting of attention between varieties of informational sources (p. 187).

Additional models of working memory emphasize storage and location areas for memory formation. Object-oriented episodic record (O-OER) is a theory of working memory that emphasizes a single temporary storage location for information. The Feature Model of working memory uses the terms “primary” and “secondary memory” and only primary memory is a conscious process (Chein & Fiez, 2010). According to Cowan (2008), primary memory is a function of the central executive, based upon limited capacity and the need to break information into chunks or episodes, of which most people can maintain four to seven items at a time.

Baddeley (2012) acknowledged the many different working memory theories and defended the Baddeley and Hitch multi component theory of working memory by highlighting the similarities, as well as the differences, between the additional theories. The Engle theory as outlined in Shipstead et al. (2012) is too narrow, according to Baddeley (2012), and too focused on the inhibitory control of attention to prevent decay. In Engle’s original theory, an individual utilized attention to keep or suppress information. Engle (2002) concluded, “people with low WM spans are less capable than people with high WM spans of doing the mental work necessary to block distracting information" (p. 22).

Baddeley (2012) encouraged additional theories, yet asserted there are more similarities than differences in the theories and many of the differences are semantic or use contrasting terminology. The reformulated Baddeley model began a renewed interest in working memory as it bridged a cognitive psychology gap that existed between North American views that working memory is a top down driven system with attention at the top and the previous European view that was bottom up (Baddeley, 2012). The top down approach emphasizes the brain's prefrontal cortex as the mechanism for sustaining attentional control. The addition of the episodic buffer to the Baddeley and Hitch (1974) model acknowledged the importance of the prefrontal cortex as the attentional control necessary for working memory.

Recent trends in utilizing Functional Magnetic Resonance Imaging (fMRI) and advances in neurobiology have renewed interest and explanation of working memory deficits (Baddeley, 2003). Bunge and Wright (2007) suggested it is important to use fMRI to learn more about working memory and cognitive control. Observing working memory tasks and the related areas of the brain such as the frontal, parietal, and basal ganglia regions can provide scientific insight into the development of the person (p. 248). Based on the study, changes in working memory can be understood more as a top down approach where children who have less control over the prefrontal cortex (PFC) and weakness in working memory activate different brain regions than adults when completing visuo-spatial working memory tasks (Bunge & Wright, 2007). Although not all brain function is localized, essentially the frontal lobes of the brain control and maintain attention; the parietal lobes process information from the visual fields, and the basal ganglia modulates procedural learning and voluntary motor control (Klingberg, 2013; Posner & Rothbart, 2007).

Chein and Schneider (2005) researched neuroimaging and working memory to view increasing or decreasing activation in specified brain regions for verbal, nonverbal, and visuomotor actions. Chein and Fiez (2010) used fMRI to compare the differing theories and models of working memory. Brain imaging that purposely subjected individuals to interference tasks substantiated the idea of a multicomponent theory of working memory and produced localization images to enhance the understanding of where working memory processes occur in the brain. Interference tasks purposefully interrupt a research participant in the midst of completing an activity to measure attention and sustained attention.

Baddeley (2003) used neuroimaging research to confirm that both phonological and visuo-spatial working memory systems reside in the right hemisphere in typical developing people and the left hemisphere regions are activation areas more for the verbal working memory areas (p. 836). However, even with the promise of localization and support for the theories of working memory, Baddeley (2012) was hesitant to rely on imaging as it is usually only for atypical situations such as people with deficits, brain injury, or cognitive problems like Alzheimer's disease. He promoted the use of neuroimaging, but not in respect to changing or explaining working memory, as the studies to date have not successfully been replicated nor fully separated from short-term memory (Baddeley, 2012, p. 19). The Baddeley and Hitch (1974) model of working memory remains a work in progress. According to Baddeley (2012), it is only useful if it has application in a professional setting such as schools or the medical community.

The remaining sections of this literature review will focus on the educational implications brought on by working memory deficits as well as by other psychological impairments, and a review of studies that claim to have solutions to intervene and improve working memory.

Testing Working Memory

As a psychological concept, working memory can be assessed to determine limits, range, and capacity for individuals. Working memory can also be tested as a component of many full-scale intelligence tests or as an individual specialized working memory assessment. A standard working memory assessment may provide a variety of math problems and words at the end of the math problems. A person is expected to compute the algorithms for each math problem and say the words; at the conclusion of the calculations, the person has to recite the words held in memory (Klingberg, Forssberg, & Westerberg, 2002). This simple span task is an example of short-term memory and interference (Shipstead, Hicks, & Engle, 2012b).

Simple span tasks can also include visuo-spatial tasks in which an individual views items on a grid and must hold the location in memory over a short amount of time (Shipstead et al., 2012). More advanced assessments of working memory include n-back and running span assessments. The n-back task involves the recall of information from a series and what occurred a set number of times (n) previously. The n back task provides a running span of items and requires the tester to remember whether an image, letter, or word occurred a specified number (n) of times ago (Shipstead et al., 2012). An example of n back would ask the subject to view a series of letters as shown in Figure 2.2 and determine if it matches what was given a set time ago.

Series:

A C C C Y C Y C A

Correct Responses:

no-no-no-yes-no-yes-yes-yes-no.

Figure 2.2. An n back test for an n of 2.

A digit or letter recall task requires short-term verbal memory and requires the tester to listen to a sequence and recall the sequence after a set amount of time. To assess verbal working memory, an individual recalls digits or letters in a series backwards. The assessor may say to the subject 2,5,8,9 and the subject would repeat to the assessor 9,8,5,2. The same tasks can be assessed with letters, words, and a combination of letters, words, or numbers. Each of these tasks is a measure of verbal working memory (Alloway, 2011c). Visuo-spatial working memory assessments involve recalling the sequence of items in space or on a grid (Alloway, 2011c).

Antisaccade tasks for working memory require a subject to focus on a visual cue in the middle of a screen or display and respond to randomly targeted tasks that are outside of the line of sight (Engle, 2002). The antisaccade tasks require the subject to not shift attention, rather to maintain focus on a midline task (Denckla, 1996). Conflict tasks frequently are a component of working memory assessments. The Stroop test is a conflict task. The subject must say the color of ink that a word is written in. This task requires the subject to inhibit a dominant response and perform a subdominant task like saying "purple" to the word *orange* typed in purple ink (Posner & Rothbart, 2007).

Tasks that require manipulating information are significant in the testing of working memory rather than tasks that only expect taking in information and later being able to retrieve the same information (Conway, Macnamara, & Engel De Abreu, 2013). Complex span tasks are similar to dual tasks where the subject has to complete simple secondary tasks while maintaining information from the primary task. An example would be when a subject is expected to recall an array of shapes of differing colors while recalling digits presented in a specified order. The secondary task of recalling the colors and shapes is diverting the attention from the primary task of digit recall and taxing the attentional system. Complex span tasks are popular and can be done with colors, shapes, objects, words, or spatial relationships (Conway et al., 2013).

Simple span tasks do not require the subject to be presented with a secondary task for interference. A simple span task asks the subject to recall numbers or letters in a specified order. Simple span tasks are prevalent as components of many intelligence tasks like the WAIS and WISC (Conway et al., 2013). However, many proponents of the Baddeley and Hitch (1974) theory of working memory do not consider simple span tasks appropriate as measures of working memory (Conway et al., 2013). Visual array comparison tasks are utilized to measure working memory and can involve both simple and complex tasks. Subjects are shown visual images for a brief amount of time, under 1 second, and discern if the arrays of images are the same or different. An interruption feature can be used to divert attention to make the task complex or not utilized to keep the task simple (Cowan, 2008).

The *Automated Working Memory Assessment, 2nd edition* (AWMA-2, 2011) is a product from Pearson Assessment and has three versions for assessment: a screening test, a short form, and a long form (Alloway, 2011b). The full assessment contains verbal short-term memory, verbal working memory, visuo-spatial short-term memory, and visuo-spatial working memory components (Alloway, 2011c). Pearson Assessment also published the *Wechsler Intelligence Scale for Children-Fourth Edition Integrated* (WISC-IV, 2011) that contains a specific working memory battery of assessments. The working memory components of the WISC-IV include digit span, letter-number sequencing, and sequencing arithmetic subtests (PsychCorp, 2011).

Alloway (2011a) reported that the AWMA-2 and WISC-IV are highly correlated and the AWMA-2 is a better used assessment, as any teacher can administer it. It has immediate practical application in the classroom. The newest Pearson assessment, *Wechsler Preschool and Primary Scale of Intelligence - Fourth Edition* (WPPSI-IV), has been redesigned to include more emphasis on working memory that is age and cognitively appropriate (Pearson Assessment, 2012). Pearson Assessment (2012) insisted the emphasis on working memory in the WPPSI-IV is a result of the research concluding that working memory is paramount to academic success in schools. The educational implications of working memory are discussed in the next section.

EDUCATIONAL IMPLICATIONS

All learning is dependent upon memory. As mentioned earlier, frequently in education teachers lament that students are lacking in memory processes necessary for adequate learning to occur. Nonetheless, children with poor working memory are also well adjusted socially, have average to above average intelligence, and are frequently quiet in group lessons or activities (Gathercole, Alloway, Willis, & Adams, 2006). Many children with low working memory forget the content of classroom instructions, act as if they are daydreaming, abandon a complicated task, and make little academic progress in math and reading (Gathercole, et al. 2006). As such, many teachers who are not familiar with the concept of working memory and what may be a deficit in working memory confuse it with an attentional issue or inability to focus (Alloway et al., 2009b).

Working memory has limited capacity and allows a person to maintain information in a temporary manner until it can be used or it is lost (Alloway, 2009b). In order to perform tasks that require cognitive function such as learning, comprehending, or reasoning, a person needs working memory that is functioning at an optimal level. Unfortunately for many students with learning difficulties or deficiencies, it is their working memory that is lacking and therefore the culprit for many learning difficulties (Alloway, 2009a).

In many areas of educational psychology, the significance of working memory has supplanted short-term memory. Short-term memory is temporary storage and before information can be integrated into long-term memory, the information must be used. Working memory is the significant barrier that allows information to be sent to long-term memory or lost. The Baddeley and Hitch (1974) research has driven the field of memory and working memory by dividing the rehearsal system into the phonological loop and visuo-spatial sketchpad as shown in Figure 1.1 (Holmes, Gathercole, & Dunning, 2009a). Both are components of the central executive attention; the phonological loop holds verbal information while the visuo-spatial sketchpad holds information that is visual and spatial (Hoffman & Schraw, 2009) as shown in Figure 2.2.

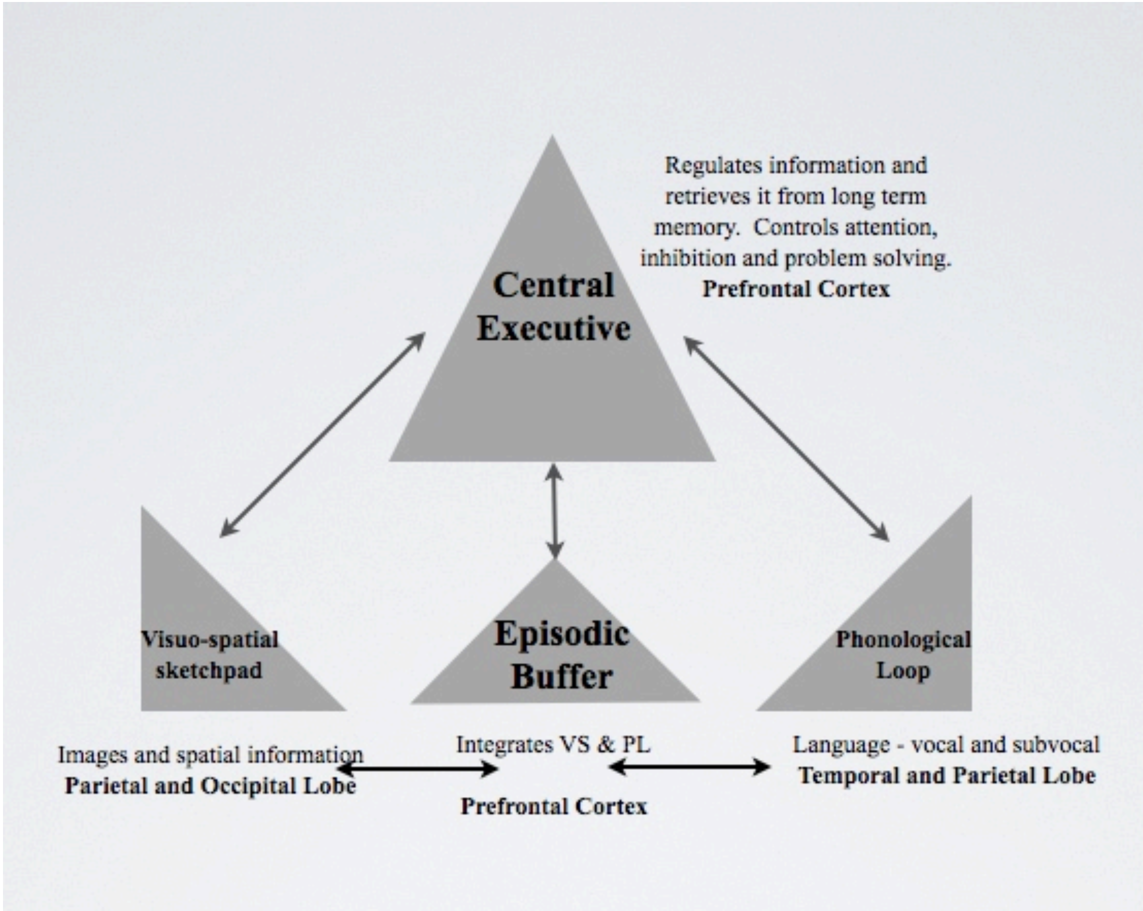


Figure 2.2. Baddeley Hitch Model of Working memory
Figure is adapted from Baddeley (2012) and Alloway et al. (2009a).

Working memory is an important aspect of education, as it is integral in all core subject learning such as reading and math, as well as problem solving and reasoning. Much of what occurs in a classroom is dependent upon a student's working memory (Alloway et al., 2009b). Teachers give multiple verbal instructions and students are required to listen before performing a task. Frequently a teacher fails to stop talking once he or she asks a child to complete a task and this interferes with working memory (Alloway, 2011a). Additional interferences can be attributed to other students interrupting the classroom, or a school-wide disruption like an announcement or alarm system. Interference and interruptions to a child's working memory are a natural part of schools.

Working Memory and Mathematics Learning Difficulty

In the classroom environment, a student with a working memory difficulty may have characteristics that mimic other learning difficulties. It may appear that a student is not paying attention or the student forgets instructions and directions given by an instructor. The student may be distracted or appear to have a short attention span. He or she may have difficulty specifically in reading and math. A child may have strong fluency skills in either reading or math, yet have poor comprehension and problem solving abilities (Alloway, 2009b).

It is extremely important in an educational setting to distinguish if the child's deficit is working memory and then to identify solutions to assist the student. Raghubar et al. (2010) reported similar findings as Alloway (2009b) from a longitudinal study of students with math difficulties. The evidence shows a difference in verbal and numerical problem solving that demonstrated a barrier other than calculation.

Ansari's (2010) research explained that students utilize different areas of the brain for math as they progress through school. As children mature, they begin to use the left parietal areas of the brain rather than the prefrontal cortex for mathematical processing. Hence, a younger child uses more working memory, whereas an older student has automatized routine math and can conduct more mathematical problem solving as they do not need to rely on the central executive for automatized work (Ansari, 2010). Meyer et al. (2010) echoed Ansari (2010), identifying the transition from 2nd to 3rd grade as a pivotal change in cognitive development. The younger student relies on the phonological loop and central executive for math and the older student is able to free up the central executive for more complex thinking and problem solving. Therefore, students who do poorly in math may not have the ability to complete the higher-level reasoning skills in mathematics due to not making the transfer away from working memory (Meyer et al., 2010).

Bull and Espy (2006) reasoned that children with poor arithmetic skills have poor counting strategies and are forced to hold more information within working memory, while stronger math students have more developed strategies and do not have to rely both the left parietal area and prefrontal cortex. Hoffman and Schraw (2009) claimed that having a good working memory does not ensure a student will be accurate, but having a poor working memory will doom mathematical accuracy, as there is more demand as math gets harder and students are expected to perform more challenging mathematical problems. Fuchs et al., (2003) explained, "As students master problem solving rules, they allocate less working memory to the details of the solution and instead devote cognitive resources to identify connections between novel and familiar problems and to plan for their work" (p. 293).

Alloway et al. (2009a) conducted a study in elementary schools and reported low working memory scores result in poor math and reading scores and contribute to a high risk of underachievement. As part of this same study, teachers rated students' classroom behavior. The students identified with low working memory were rated by the classroom teachers as being disruptive, inattentive, and distractible (Alloway et al., 2009a). Bull and Espy (2006) pointed out the children with poor math skills most likely have trouble with the central executive and cannot inhibit disruptions or distractions.

A task that combined math skills with central executive functions used the Wisconsin Card Sorting Task. It presents stimuli tasks to participants and requires the participant to display flexibility in making the matches based upon feedback from a test administrator. The task is a neuropsychological test to measure executive functions and impulsiveness that regulated by the central executive (Bull & Epsy, 2006). The children with lower working memory processed information more slowly, did not eliminate the extraneous stimuli, and too often focused on the wrong items (Bull & Epsy, 2006).

Working Memory in the Reading Classroom

Reading disorders and disabilities are common in classrooms. Struggling in reading can be an indication of dyslexia, auditory processing disorder, working memory deficit, specific language impairment, or a combination of these (Alloway, 2011a; DeJong, 2006). Learning to read involves phonology and orthography, both of which rely on the phonological loop. Repetition is paramount to a beginning reader acquiring letters, sounds, and names. Reading development has a strong connection with both the central executive and the phonological loop (DeJong, 2006).

Poor reading comprehension often reflects a working memory deficit as students with working memory deficits struggle with both short-term memory and processing information. Children with low working memory ability tend to make more reading errors, integrate knowledge with less frequency, and acquire literacy skills more slowly (Gathercole et al., 2006). Learning to read begins the process of reading to learn. Without a strong reading foundation, students will struggle throughout all forms of education. Learning to read involves uncovering the code of phonemes and graphemes in order to decode a language.

Every aspect of reading and language from fluency to comprehension, even including sentence structure, involves working memory ability. For example, writing in the passive voice requires a reader to store information within working memory, while not only decoding individual words and meanings, but also recalling the subject and verb of a sentence. Text comprehension involves the ability to assess the meaning of words while determining the meanings of entire sentences and processing this simultaneously. The child with less working memory will often struggle in the classroom and thus appear overwhelmed or inattentive. The poor reading comprehension could actually be caused by limited working memory ability (Cain, 2006).

Neuroimaging studies reported the intraparietal cortex is activated for both verbal tasks and visuo-spatial tasks. A child learning to read must use the visuo-spatial sketchpad as he or she keeps place in a text or reads from a classroom word wall and transfers the words to a notebook or worksheet. Both verbal and visuo-spatial working memory is linked to reading comprehension (Klingberg, 2013). Learning to read is imperative for academic success; therefore, teachers must understand not only the building blocks of reading but also working memory in order to ascertain a child's learning needs (Gathercole et al., 2006).

Intelligence and Working Memory

A common misconception in education is that working memory and intelligence are synonymous. Studies have shown they are correlated but they are not the same (Alloway, 2009b; Alloway & Elsworth, in press; Gathercole et al., 2006; Jaeggi et al., 2008; Raghubar et al., 2010). Many intelligence tests have working memory components and researchers who are studying working memory use similar general ability tests that disaggregate the working memory components from other aspects of intelligence.

As mentioned earlier, *Gf* is the ability to problem solve, match patterns, and reason while *Gc* is knowledge and skills (Alloway, 2012; Denckla, 1996; Klingberg, 2010). Denckla (1996) insisted that executive functions and general intelligence are related, but not identical. The use of brain scans and working memory tasks indicate that *Gf* and working memory both utilize the prefrontal areas of the brain and the parietal lobes (Alloway, 2011b). Alloway (2011a) reported *Gf* and working memory share 20% variance in academic performance; therefore the constructs are related yet distinct (p. 8). Intelligence tests remains a routine part of education to identify students who have special needs such as a learning disabilities or giftedness. Academic and cognitive testing can differentiate whether a problem is a working memory disability, a learning deficit, or behavioral deficit.

Conway et al., (2013) reported the correlation between working memory and intelligence as significant because the constructs can be used for the prediction of behavior. Psychometric studies separate the differences between crystallized and fluid intelligences as differences in cognitive ability where *Gf* does not rely on prior experiences (Conway et al., 2013). They reported that scholars agree that working memory ability is highly correlated with fluid intelligence because each measure shares cognitive processes.

In training psychologists on the importance of working memory, the Pearson Assessment (2012) associated the crucial academic abilities with the age level of the student. For example, working memory in preschool is important for learning the alphabet and independently completing puzzles. An elementary student uses working memory for mental arithmetic and reading comprehension, while a college-age student must use working memory to maintain interest in a lecture or to study for an exam

(Pearson Assessment, 2012).

In a study of high-ability students, Alloway and Elsworth (2012) investigated the verbal and visuo-spatial working memory abilities of gifted and high ability children to discern if they had different profiles compared to average or low average children. This study emphasized a concern of Spearman's law of diminishing returns to ascertain if some abilities increase while others hit a plateau (Alloway & Elsworth, in press p.1). The study confirmed that working memory and general ability are not identical. The behavior of the gifted and high ability students presented evidence that this group of children do not have better control over inhibition which is a characteristic in students with ADHD. The study confirmed that working memory is a major predictor of how well a student will do academically regardless of IQ, socioeconomic status, and parental education levels.

Many researchers debate the use of intelligence testing within the educational setting and question whether testing is an appropriate proxy for working memory. Although working memory and intelligence are not synonymous, a longitudinal study predicted that working memory is a predictor of later educational success. The findings highlighted the significance for working memory at the age of five as a significant predictor of numeracy and literacy skills at age eleven (Alloway & Alloway, 2010). Engle (2002) surveyed college-age students and determined that working memory, not IQ, predicted college success. Further, Klingberg (2013) reported in a study controlling for intelligence that working memory is a "stronger predictor of mathematical ability than fluid intelligence" (chapter 5).

Working memory improves with age in typically developing people. The capacity continues to grow throughout childhood with as much as a 20% increase from age six to seven and does not plateau until later adulthood (Klingberg, 2013). The study by T. P. Alloway and R. Alloway (2010) asserted that in controlling for socioeconomic status and maternal educational levels, working memory is not only a stable measure, but also a measure that levels the playing field. Working memory measures what a child is capable of learning, where as many IQ measures assess what a person has previously learned (T. P. Alloway & Alloway, 2010). Alloway (2009) emphasized that working memory is more important than IQ in predicting how well a child will perform in literacy and numeracy.

Working Memory in the Regular Classroom

Gathercole et al. (2006) predicted that working memory placed a general constraint on reading and math ability because information the student needs is bottlenecked, and this causes the student to make multiple errors. Students with low working memory have trouble integrating new information and therefore are in need of short instructions, memory aids, routine, and structure to be successful. St. Clair-Thompson and Gathercole (2006) also emphasized the significance of working memory and executive functions. The prefrontal cortex regulates the ability to coordinate tasks, shift attention, initiate attention, and inhibit distractions. If a student has a poor working memory it is also difficult to have command of the executive functioning necessary for success in school. St. Clair-Thompson and Gathercole (2006) found that the student with poor working memory cannot monitor new information, such as teacher's talking, with the reading; therefore, the student performs poorly. The simultaneous information is not appropriately decoded because the student is not able to shift attention, to update his or her working memory, or to inhibit irrelevant details (p. 755).

Working memory is required in every classroom and all school activities. Verbal working memory is needed when a classroom teacher begins a class with instructions such as, “Please place your homework in the red bin, take out your primary source reading document, have two different colored markers to highlight your text, and do not forget we have a quiz over this on Thursday.” Students also use verbal working memory in a math lesson when a teacher introduces a pattern on a number chart, such as counting even numbers, or a student verbally rehearses multiplication facts. Classroom activities also require visual-spatial working memory tasks. The use of images in a history class to understand Westward expansion or the analysis of an image from the Great Depression requires the use of working memory as the student must contextualize the event in history and analyze how the image represents the history. Any recalling in chronological order, sequencing, and rehearsal of a play or poem involves the visual-spatial sketchpad (Alloway, 2011a). Both verbal and visual-spatial working memory are necessary for academic success (Alloway et al., 2009b).

Learning is dependent upon working memory. Schools and teachers must be aware of the signs and symptoms of working memory deficits in children. Children with deficits in working memory usually have normal intelligence quotient scores and are capable of learning (Alloway & Elsworth, in press). Knowing the characteristics of working memory deficits enables teachers to intervene and provide memory aids to facilitate learning. Working memory deficits often mimic other learning disorders. The next section of the literature review discusses executive functions, ADHD, and working memory.

EXECUTIVE FUNCTIONS, ADHD, AND WORKING MEMORY

Executive Functions

Working memory cannot be separated from attention. The addition of the episodic buffer in the Baddeley and Hitch theory recognizes a more prominent role for the central executive. Klingberg (2013) said that if Baddeley were to start all over again, he would rename working memory as working attention (chapter 1). Executive functions are frequently referred to as the brain's chief executive officer (McCloskey et al., 2009). Researchers provide multiple explanations and theories to explain and describe the executive functions and often entangle neuropsychology, cognitive psychology, and education psychology to describe the components of executive functions (Denckla, 1996). Denckla (1996) made three observations about of executive functions: a) the prefrontal cortex is the location in the brain that houses the executive functions; b) there is a clinical explanation for executive functions; and c) executive functions develop due to maturation from childhood to adulthood.

The clinical explanation of executive functions uses a deficit model in which an individual has a behavior problem that can be diagnosed (Denckla, 1996). McCloskey et al., (2009) synthesized the literature and theories of executive functions into an integrated model that includes, but is not limited to, the following functions:

- Cueing the inhibition of impulses
- Directing and focusing attentional processes
- Cueing the initiation of effort and judgment to determine the amount of effort needed to complete a task

- Cueing the flexible shifting of cognitive resources
- Directing the efficient use of fluid reasoning
- Monitoring and regulating the speed of information processing
- Monitoring the task performance for accuracy and efficiency
- Cueing the selection of verbal, nonverbal, and abstract processing
- Directing the use of working memory resources
- Directing the efficient and fluent production of language
- Directing the efficient placement of information into long term storage
- Cueing the engagement of appropriate social behavior
- Cueing the appropriate regulation of emotional control
- Cueing the engagement of cognitive capacities that enable hindsight and foresight (pp. 17-19).

In summary, Denckla (1996) described an individual with a deficit in executive functions as being "a day late and a dollar short" in most settings (p. 264).

Barkley (2012) said that executive functions describe psychological functions that are difficult to define and noted that there is no coherent theory to describe the exact functions that make up the concept. However, the components that develop to explain executive functioning involve inhibition, working memory, shifting, and planning (Barkley, 2012). Hence working memory is a cognitive component of executive functioning and possibly the foundation of other executive function components (Barkley, 2012).

Posner and Rothbart (2007) suggested that the human brain has an attentional system that is dived into an alerting network, an orienting network, and an executive network. Together these areas comprise attention and measure self-regulation. In an update to child neurologists, Denckla (2003) said that executive functions are the domain name for the frontal lobe of the brain. The frontal lobe is the top down circuitry of the brain that controls cognition; hence, executive function is synonymous with cognitive control. Augmenting the differences between the European and North American dichotomy of working memory, Denckla (1996) said that there is a need to avoid the "homunculus problem" and not presume executive functions are higher than other functions; rather they are central (p. 274). However, the addition of the episodic buffer to the Baddeley and Hitch model of working memory accepts the top down model of the brain circuitry because the central executive is purely an attentional component of working memory (Baddeley, 2006). Baddeley (2012) emphasized that the central executive is paramount as it focuses, switches, and divides attention.

Pennington, Bennetto, McAleer, and Roberts, Jr. (1996) suggested working memory is a component of executive functioning and called for a theory to be developed. Pennington et al., (1996) argued that executive functioning assessments were often mitigated by working memory tasks with some functions more affected than others in the successful completion of tasks. The integration of the episodic buffer into the working memory theory integrated executive functions and working memory (Baddeley, 2012). Cowan (2008) reported that working memory has a focus of control that is the same as the episodic buffer. Controlling attention is necessary due to the limited capacity of short-term memory and the possibility of decay of information processing if too many items compete for attention.

Advances in the use of the fMRI allow researchers to gain better understanding of the anatomy of the brain structures and neural networks associated with attention, self-regulation, and executive functions. Although attention is not isolated nor modulated by one specific area, on the basic level the prefrontal cortex is generally regarded as the structure in the brain that manages executive skills such as self-regulation, metacognition, planning, organizational skills, and attention. Orienting attention is the ability to align attention to an appropriate stimuli, and it is housed in the superior parietal cortex and superior colliculus areas of the brain (Rueda & Rothbart, 2009).

The anterior cingulate and basal ganglia are important for executive functions and effortful control. The former is known to regulate motivation, respond to novelty, and allow for self-monitoring and decision-making. The latter is responsible for modulating the prefrontal cortex (Rueda, Posner, & Rothbart, 2004). Two other significant brain structures relevant to the studies are the amygdala, known for its role in emotional responses, and the hippocampus for memory formation. The fMRI visualizes each of these brain structures, and has allowed neuroscience a better understanding of the attention network areas in the human brain.

The measure of attention is not only regulated by the anatomy of the brain, it is also modulated by the brain's chemistry. Posner and Rothbart (2007) confirmed both anatomical locations for the attentional network as well as the neurotransmitter responsible for typical attentional functions. The alerting network is modulated by norepinephrine, the orienting network by acetylcholine, and the executive alerting network by dopamine (Posner & Rothbart, 2007, p. 60). Hence, an abnormality in attention can be an anatomical issue, a chemical issue, or both.

Klingberg (2013) suggested the lack of myelination also causes trouble with executive functioning in many children. Myelin is a fatty substance that coats an axon and develops throughout childhood. As the human brain develops over time, the brain has more white matter, or myelin sheaths, that allow communication between the different structures of the brain to occur faster (Posner and Rothbart, 2007). An individual with poor working memory has thinner myelin sheaths, which contribute to slower processing of the central executive functions within the prefrontal cortex (Klingberg, 2013).

Attention Deficit Hyperactivity Disorder

Attention Deficit Hyperactivity Disorder is an anomaly of the frontal lobes, basal ganglia, and cerebellum. It is a psychological disorder that interferes with an individual's ability to provide and sustain attention. The University of South Carolina (2012) insisted that ADHD is a serious health problem in the United States. Three to five percent of all children are clinically diagnosed with ADHD (Klingberg et al., 2005).

Poor working memory is often confused with ADHD. Although the symptoms can be related, ADHD and working memory do not have to coincide. Denckla (2003) explained the difference in ADHD and working memory deficits: "Inhibition paves the way for and maintains the infrastructure of working memory. For learning, working memory is very central and necessary; but it is inhibition, necessary, yet not sufficient for learning, that is the therapeutic target for stimulant pharmacology" (p. 388). According to Denckla (2011), ADHD is multifactorial and "characterized by a delay in cortical maturation" (Lewis & Denckla, 2011). Attention Deficit Hyperactivity Disorder involves inattention or impulsiveness, or both, and is acknowledged as a biological, genetic, and chemical disorder. The disorder may benefit from medication, but working memory requires the ability to inhibit distractions in order to maintain information in mind to learn.

Most people with ADHD have difficulty with executive functions, but the reverse is not true. A deficit in executive function does not equate to having ADHD (Lewis & Denckla, 2011). Denckla (1996) described the features of executive function as the ability to "initiate activities by organizing for the task, sustain attention to a task, inhibiting the impulse to attend to distractions and shifting attention to new information which still retaining what has already been presented" (p. 263). The brain impairment of ADHD requires a medical diagnosis. The inability to allocate attention to the appropriate place and sustain attention is a deficit in the prefrontal lobe of the brain and, if diagnosed medically, is often treated by the use of pharmaceutical or cognitive therapies (Denckla, 1996).

The characteristics of students with low working memory can mimic ADHD; however, the student is neither impulsive nor hyperactive (Alloway et al., 2009b). Many teachers negatively view student failures to complete work, follow directions, remember daily routines, and reach academic potential. However these may be a result of limited working memory or low cognitive ability, not ADHD (Alloway et al., 2009a; Alloway & Passolunghi, 2011; Raghubar et al., 2010).

Self-Regulation

Barkley (2012) connects executive functions to self-regulatory behaviors that allow one to change behavior in order to accomplish a goal or societal expectation. McClosey et al., (2009) contended that executive functions control self-regulation capacities in school-age children. In order to learn the academic materials that are presented in schools, a student must first learn how to manage and maintain his or her own behavior, thus allowing for the opportunity to learn the content presented in schools. These behaviors are self-regulatory skills that develop over time and allow a student to perform at maximum potential. When children have difficulty maintaining their own behavior, focus, and control, learning can be impaired. A student's poor self-regulatory skills will impede his or her learning processes as his or her behavior inhibits him or her from performing at an acceptable level.

Educational success is dependent upon more than cognitive factors; some children lack the effortful control necessary to be successful in education. Self-regulation is a behavioral response from a broader construct of managing impulsivity, controlling emotional responses, and modifying actions to fit the expectations of a setting (von Suchodoletz et al., 2011). Effortful control, according to Posner and Rothbart (2007), "is a measure of individual differences in the ability to inhibit a dominant response to perform a subdominant response" (p. 94). If a student lacks effortful control, he or she may not be able to stop dominant responses such as talking out in class, not completing work, or even not paying attention to the teacher. Each of these has negative consequences on a student's overall success.

According to Klingberg (2013), teachers can utilize the findings from neuroscience in the school setting. When a student is not achieving, it is prudent to look at cognitive and neuroscience factors such as executive functions and learning abilities as well as a behavior to assist in designing appropriate interventions. Liew (2011) thought that a study of executive functions would focus on the student's "ability to engage in deliberate, goal-directed thought and action via inhibitory control, attention shifting or cognitive flexibility, and working memory" (Liew, 2011 p. 2). Closely related, effortful control is an aspect of a person's temperament and "refers to the voluntary control over approach or withdrawal behavior tendencies via attentional and inhibitory control mechanisms" (Liew, 2011 p. 2). A child can learn to differentiate between what he or she must to do versus what he or she wants to do. Liew and McTigue (2009) cited effortful control as a link between students and academic achievement. Effortful control can predict grade point averages for middle school students, as well.

Training and improving effortful control is important with the increase of high stakes testing programs. Preschools and early elementary schools often embed programs such as *Tools of the Mind* (Bodrova & Leong, 2007) and *Mind in the Making* (Galinsky, 2010) to supplement academic education with social-emotional learning. *Tools of the Mind* is a Vygotskian approach to equipping children with adult models of behavior that eventually lead to independence. Children need to learn to not just react but also become self-directed learners; if these techniques are modeled and practiced, they promote more effortful control (Bodrova & Leong, 2007). Rueda and Rothbart (2009) designed computerized exercises to train attention and produced significant gains with as little as two months of training (pp. 27-28).

The academic subjects of reading and math drive educational curriculum; yet, a child who does not come to school prepared to pay attention and inhibit any inappropriate dominant responses may quickly fall behind. Many children often expect an instant response and immediate feedback similar to what toys and technology provide. In a school setting, instant feedback is not always possible, nor warranted. The ability to delay gratification has proven to be a better predictor of later life success than test scores and

IQ (Liew, 2011). Without appropriate self-regulation and effortful control, many children are entering school settings already behind their peers. In today's educational settings, children must learn how to pay attention and to do tasks that they would rather not do. These are skills often learned in school.

CAN WORKING MEMORY BE TRAINED FOR IMPROVEMENT?

Previously, it was believed that working memory is both a fixed trait as well as heritable. Research on brain plasticity and cognitive enhancement is expanding within psychological research. Recent studies and programs have set out to find a training mechanism for working memory and asking if the training is successful. Claims that working memory can be improved have led to an increase in research and whether it can be improved has been a debated topic recently (Gathercole et al., 2012; Hulme & Melby-Lervag, 2012; Jaeggi et al., 2012; Klingberg, 2012; Morrison & Chein, 2012; Shipstead et al., 2012a).

Working memory training consists of either strategy training or core training. Strategy training attempts to teach approaches to maintain and retrieve information from working memory through targeted techniques like rehearsing information, mnemonic devices, repetition, practice, and chunking. Morrison and Chein (2011) wrote that core training trains the specific component of working memory to strengthen the specific domains of working memory. Strategy training is supplemental and trains academic subjects rather than working memory, whereas core training involves targeting the specific components of working memory like the phonological loop and visuo-spatial sketchpad (Morrison & Chein, 2011).

Surrounding the debate about brain-training is the concept of near and far transfer effects. Near transfer occurs when a subject improves on the immediate task for which he or she is training. To obtain far transfer, a subject improves not only on the training task, but also on subsequent tasks that are related to the construct.

Jaeggi et al., (2012) described the transfer effect of working memory tasks in an exercise metaphor. To improve the cardiovascular system, an individual can run, bike, or do aerobics. An individual who only runs may increase distance and running ability, but that will also affect the amount the same person is able to ride his or her bike. Barnett and Ceci (2002) reported that transfer is theoretically paramount for any educational research. The training of knowledge versus skill is highly debated, but educational institutions rely on the ability of students to transfer a skill such as writing from one discipline to another and to apply knowledge as well as higher order thinking skills across disciplines (Barnett & Ceci, 2002). If brain-training is to be useful, it must demonstrate that the program is generalizable as well as having far transfer effects (Melby-Lervåg & Hulme, 2012). The remaining section of the literature review is devoted to the research and claims regarding the training of working memory.

***Cogmed* Working Memory Training**

Much of the recent research on training and improving working memory has emphasized the training of the prefrontal and parietal cortex via computerized game based training by a program called *Cogmed*, which set out to show that working memory has the same plasticity as other areas of the brain, and deficits can be improved (Klingberg, 2010). It should be noted that Klingberg, from the Department of Neuroscience at the Karolinska Institute, is also a paid consultant for the company who designed *Cogmed*. However, others from the field of cognitive psychology and neuroscience have now replicated the studies (Gathercole et al., 2006; Gathercole et al., 2012; Holmes & Gathercole, 2010). *Cogmed* is a for profit product, acquired by the educational company Pearson and has most recently been marketed as training for children with ADHD (Pearson Assessment, 2011).

In an early experiment with training working memory, Klingberg, Forssberg and Westerberg (2002) showed a marked improvement in working memory ability for children with ADHD as well as adults who were not diagnosed with ADHD (Klingberg et al., 2002). After utilizing the *Cogmed* program, the participants were given working memory tests, the Stroop test to measure executive functions, and the Raven's Progressive Matrix to measure intelligence. In the more recent testing completed by Klingberg, a significant amount of time has been linked to understanding the dopamine system and its impact on working memory (Klingberg, 2010). An additional trial of 53 children diagnosed with ADHD reported improvements in working memory and attentional control. The parents reported better behavior after the use of *Cogmed* for five weeks, although the teachers of the students did not report recognizing or noticing any differences in the children (Klingberg et al., 2005). *Cogmed* is continuing to help improve working memory capacities but there is continuing work and research being completed to determine length and spacing of training (Klingberg, 2010).

A research study utilizing *Cogmed* required participants to participate for 35 minutes a day over 6 weeks during school time and showed working memory deficits almost completely reversed (Holmes et al., 2009a). What remained unclear was whether the adaptive training taught skills and strategies for the students to utilize to improve their own working memory impairments or whether the improvements can be maintained. However, the evidence is present that the participants had marked improvements in working memory ability (Holmes, et al., 2009).

In a similar and related study, Holmes and Gathercole (2010) tested and compared the potential of *Cogmed* as a behavioral intervention versus the use of medication for children with working memory impairments and ADHD. The use of pharmaceuticals showed an increase only in the visuo-spatial memory performance; conversely, the computerized training showed significant improvements in all areas of working memory. The dramatic gains in working memory could be the intervention of the computerized program as well as the individual and focused attention that the participants received because of the experiment (Holmes et al., 2009).

Ironically, the majority of the training utilizing *Cogmed* has been completed in either Sweden or the United Kingdom, two countries with very low diagnostic rates for children with ADHD. In the United States, Chein and Morrison completed a study in 2010 to test the malleability of working memory (Chein & Morrison, 2010). In this study, the participants also utilized the *Cogmed* program for a four-week training and had a marked improvement in working memory as well as increased in reading comprehension (Chein & Morrison, 2010). Even though this study did not focus on participants who were known to have a deficit in working memory and the participants were paid for their participation, the individuals involved did have marked improvements in the Stroop test as well as the Nelson-Denny reading comprehension test from their pretest to posttest analysis (Chein & Morrison, 2010).

Cogmed recommends training for at least 30 to 45 minutes a day for five weeks. The program is adaptive to allow the difficulty of the tasks to match the subject's ability (Pearson Assessment, 2011). The training effects are greater with the adaptive version of the training versus studies that did not use an adaptive feature and during which all participants received the same intervention (Brehmer, Westerberg, & Bäckman, 2012).

The *Cogmed* training elicits concerns over research methodology as well as far transfer effects. *Cogmed* claims to increase working memory, but many researchers dispute this claim and argue the training only increases the ability of the subjects to control attention, hence only influencing near transfer. Further methodological concerns with the *Cogmed* research involve the use of no contact control groups. The increase in working memory ability could merely be a result of Hawthorne effects due to the perception and participant's awareness of the study (Redick et al., 2012; Shipstead, Redick, & Engle, 2010; Shipstead et al., 2012a).

Working Memory Training with Positive Results

In addition to *Cogmed,* other brain and working memory training programs are available and have been researched. Whereas none of the studies on improving working memory is making claims to cure working memory deficits, many have demonstrated some areas of improvements for the participants. Jaeggi, Buschkuehl, Jonides and Perrig (2008) designed a working memory-training program specifically designed for n-back training. The researchers claimed not only to increase working memory, but to also have far transfer effects of increased fluid intelligence as measured by the Ravens Progressive Matrix Assessment. The initial study involved 70 healthy young adults in adaptive dual task training. Jaeggi et al. (2008) contended that the training required participants to inhibit irrelevant stimuli and therefore taught them to control attention.

In an attempt to replicate the original study, Jaeggi, Buschkuehl, Jonides and Shah (2011) completed a similar research project with 62 children. The second project emphasized a child friendly version of the n back game, a longitudinal component, and contact with the control group. The intervention for the experimental group involved adaptive training while the control group completed general knowledge and vocabulary training. The training confirmed that training has both near and far transfer effects at the conclusion as well as after a three month follow up session (Jaeggi, Buschkuehl, Jonides, & Shah, 2011).

Jaeggi et al. (2011) reasoned the training does not necessarily improve working memory ability; rather it influences the regions of the brain that control attention. fMRI data suggested prior to working memory training, subjects had activation in the prefrontal and parietal cortex, but after training these areas show less activation resulting from less need to control and inhibit attention. Further, the many studies which have fMRI data attached do show increased activity of the prefrontal and parietal regions after the working memory training has been completed, which implies a link to success of the training (Olesen, Westerberg, & Klingberg, 2003).

Jungle Memory® is another commercial working memory training program. The program claims to increase academic success and provide assistance for ADHD, with scientific evidence to support the claims. The adaptive computer game targets children ages seven to sixteen and works in as little as eight weeks (Jungle Memory, 2011b). Alloway (2012) reported successful training utilizing *Jungle Memory*® for a small sample of 15 special needs students, each of whom had an individualized education plan

(IEP). The control group did not demonstrate any improvement; however, the experimental group improved vocabulary, math, and working memory scores (Alloway, 2012).

Altogether, brain-training and working memory programs are popular commercial products. Online subscriptions to programs like *Cogmed*, *Jungle Memory*®, and *Lumosity* are available in individual, educational, or clinical settings. Moreover, a plethora of similar programs is available as computer and iPad applications. A search of working memory in the I-Tunes store yielded seven apps from separate companies. Two online games created by a Canadian media service claimed to increase working memory and increase academic performance (Tvo parents, 2012). Whereas many of the commercial products do not contain warning or caution of the effectiveness, many researchers do provide caution that the claims are overreaching (Chooi & Thompson, 2012; Melby-Lervåg & Hulme, 2012; Morrison & Chein, 2011; Prins, Dovis, Ponsioen, ten Brink, & van der Oord, 2011; Shipstead et al., 2012b).

Meta Analysis Review of Working Memory Training

Countering the positive press of brain-training and working memory training are three separate recent meta analyses of working memory trainings (Melby-Lervåg & Hulme, 2012; Shipstead et al., 2012; Shipstead et al., 2012a) and an entire issue of the *Journal of Applied Research in Memory and Cognition* was devoted to articles and commentary on the topic of Cogmed evidence.

Similar theoretical and methodological concerns are found in each of the working memory reviews: differing theoretical frameworks of working memory, far transfer effects, use of non contact control groups, small sample sizes, use of adaptive versus non adaptive training, and measurement of working memory ability (Melby-Lervåg & Hulme, 2012; Morrison & Chein, 2012; Redick et al., 2012; Shipstead et al., 2012; Shipstead et al., 2012a). Shipstead, Redick, and Engle (2012) reviewed 16 separate studies for the transfer effects of the working memory training. The authors favored the n back tests as measures of working memory since n back focuses on sustained attention. The authors do not believe the transfer effects are acceptable because of the use of controlled attention as the definition of working memory and proclaimed there is insufficient evidence of the efficacy of the studies. Many of the reviewed studies proclaimed to increase the attention span of the subjects; however, Shipstead, Redick, and Engle (2012) insisted this is not substantiated beyond the test or measure.

Shipstead, Hicks, and Engle (2012) noted the commercial promise of brain-training programs and reported the ethical concerns regarding the promotion and sale of programs by the same researchers who studied the effectiveness of the program. There is concern that educational institutions and parents cannot parse the good from the bad science and the research community is obligated to be forthcoming and not mislead the public who frequently fund the studies (Shipstead et al., 2012a). In an additional critique of *Cogmed*, Hulme and Melby-Lervag (2012) rejected the claim that working memory training is effective and summarized five points: a) there is no evidence of increased fluid intelligence, b) it is inappropriate to use Stroop testing as an attentional measure, c) there appears to be no far transfer to academic subjects, d) there is no convincing evidence for improved ADHD symptoms, and e) there is a lack of evidence of increased in working memory ability (p. 197). In addition, Morrison and Chein (2012) agreed the *Cogmed* claims are not substantiated and reported concern over the involvement of science with commercial product development.

In an attempt to replicate the 2008 n back training gains (Jaeggi et al., 2011) that reported increased gains in fluid intelligence, Chooi and Thompson (2012) performed a similar study with 130 college-aged psychology students. The results confirmed an increase in near transfer as the subjects increased working memory scores; however, no significant increases in fluid intelligence resulted (Chooi & Thompson, 2012).

Moreover, the meta analytic review conducted by Melby-Lervag and Hulme (2012) compared 227 research records utilizing a variety of training programs. However, only 23 of the studies reviewed were deemed applicable for consideration in the meta analysis due to not having true experimental designs. The authors reasoned that training programs may yield short-term gains, but the gains are not generalizable to all populations and do not report adequate evidence for scholastic achievement. Melby-Lervag and Hulme (2012) suggested the training designs are limited in the amount of time for the intervention. Hence, the near transfer benefits are not adequate based on the methodology and lack of longitudinal data.

Is Working Memory Training Effective?

Not all researchers refuted the success of working memory-training programs. Even those who wrote negative commentaries, like Morrison and Chein (2012), remain optimistic about the possibilities of successful brain-training programs. Klingberg (2012) contested the debate over theoretical differences in defining working memory and insisted all working memory researchers agree that working memory ability is not fixed and therefore can be augmented. Increasing working memory is therefore possible and translates into increased control over attention, which leads to benefits in school and everyday life. Additional studies with longitudinal data have been completed and are under review for publication that substantiate far transfer effects and the impact for schools and educational training. Gathercole, Dunning, and Holmes (2012) agreed that there are the discrepancies in using the gold standard of research with large sample sizes and randomized studies, yet proclaimed it is not a reality with the expense of the studies, programs, and availability of fMRI techniques.

Many of the researchers pointed out that working memory training is too new to fully comprehend the promise and possibilities for education (Gathercole et al., 2012; Gibson, et al., 2012; Jaeggi et al., 2012; Morrison & Chein, 2012; Shipstead et al., 2012b) The promise of the training is in the training of attention needed for all ages of education. Our understanding the construct of working memory remains fluid; before something can be changed, it must be understood (Gibson et al., 2012). However, Gibson et al. (2012b) suggested an alternative theoretical basis for working memory based upon the concepts of primary and secondary memory. Training programs such as Cogmed are more suited for primary memory that is recognized at the conscious level and not secondary memory, which is only available in the subconscious level (Gibson et al., 2012).

Jaeggi et al. (2012) commented on the newness of the training and significance of any training program utilizing adaptive techniques to strengthen working memory. If any form of exercise is better than no exercise for the cardiovascular system, then any working memory training that increases student achievement and attention is better than none at all. Whereas, Jaeggi et al. (2012) reasoned there should be concern to not confuse the marketing research with the scientific research, the team insisted that future investigation should not be concerned about whether the brain-training is working, but instead be concerned about how it moderates for far transfer (Jaeggi et al., 2011).

Alloway (personal communication, 2012) said that the future research in working memory should center upon the ability to transfer the skills from the computer application to the classroom. The goal of education is for the student to have the ability to transfer knowledge for application and not just the sake of knowledge. Students may need to be taught how to transfer and the working memory intervention may need explicit transfer rather than passive or implicit transfer.

The explicit teaching of far transfer is effective when students are taught to do it with metacognitive skills. When students are specifically taught how to transfer knowledge they allocate less working memory to the process of the learning and are able to devote cognitive resources to learning new content (Fuchs et al., 2003). Researchers, clinicians, and teachers should explain the concept of transfer and explicitly teach the student how the training activity impacts the student's own learning (Gathercole et al., 2012).

***Jungle Memory*® Dissertation**

Much of the debate over the effectiveness of working memory training is attributed to the theoretical framework used for working memory. The *Jungle Memory*® brain-training program follows the Baddeley and Hitch (1974) reformulated theory of working memory. *Jungle Memory*® utilizes adaptive core strategy training and is a cost effective intervention compared to working memory brain-training programs. It is designed to be user friendly and appropriate for school-aged children (Jungle Memory, 2011a). Jaeggi (personal communication, 2012) advised against the use of dual n-back training program that is available free because it is difficult and frustrating to participants.

Motivational issues often distort the studies when using dual n-back training (Jaeggi, personal communication, 2012).

The *Jungle Memory*® program utilizes three training activities in an interactive and adaptive game format. Motivational features are included in the game with participants earning badges for at the completion of trainings levels. Participants can move through thirty different levels for each game (Alloway et al., in press) The first game trains verbal memory, word recognition, and processing speed. The second game trains visual spatial working memory and the third game utilizes math skills and sequential memory to train working memory (Alloway et al., in press; Jungle Memory, 2011a). The activities in the game align to the beta version of Automated Working Memory Assessment (AWMA-2) utilized to assess verbal and visuo-spatial working memory.

Just as *Cogmed* is affiliated with the working memory researcher Klingberg, *Jungle Memory*® is affiliated with the working memory researcher, Alloway. However, the *Jungle Memory*® brain-training program has educational and classroom resources to augment the on-line games and provides teachers with strategies and classroom interventions (Jungle Memory, 2011b). A subscription to *Jungle Memory*®, also provides a 10 part video and booklet series to educate parents and teachers about working memory. These resources, as well as additional training, assist teachers and school personnel in the understanding of working memory deficits.

Utilizing the *Jungle Memory*® brain-training program in this quasi-experimental dissertation study will help in answering the following research questions:

Research Question 1. Can the brain-training program *Jungle Memory*® improve working memory?

Research Question 2. Accepting the use of the social construct of intelligence, can ability scores as indicated on the NNAT-2 increase by the use of the brain-training program *Jungle Memory*®?

Research Question 3. Is there a relationship between general ability (*g*) and working memory?

CHAPTER III

METHODOLOGY

INTRODUCTION

The purpose of this quasi-experimental study is to determine if the computerized program *Jungle Memory*® can improve working memory for intermediate grade students at an intermediate school located in Ohio. The quasi-experiment is a pretest-posttest design study without a control group. The independent variable is the intervention program, *Jungle Memory*®, an online brain-training game and program (Jungle Memory, 2011a). The dependent variables are defined as the working memory and ability scores for each participant. This chapter presents the design of the research study, the research questions, a description of the sample, and a description of the working memory and ability assessment instruments.

PARTICIPANTS

The participants for this study will be a convenience sample of volunteer students from intermediate grades in Ohio. Although close enough to a major city to be considered a suburb, the city and the school demographically district more resemble an urban area than a suburban area. The city is 15 square miles and the population is 32,145. This is a significant increase of over twenty percent from the last census (US Census Bureau, 2010). The population is close to eighty-five percent Caucasian, but minority groups have risen since the 2000 census. The median income is $47,713.

The Intermediate School houses grade 5 and 6 students from the school district and is rated as Excellent with Distinction from the Ohio Department of Education for the

2010-2011 and 2011-2012 school years. The building houses 813 Students. Eighty-six percent of the students are Caucasian and ten percent are Black or multiracial.

The participants or the parents of the participants self-selected to be a part of the study. Information and registration to participate in the study was offered on a password-protected website that available to the families of the intermediate school (See Appendix A). Two parent information sessions in January 2013 provided information about the research project and gave parents and participants the opportunity to complete consent forms (See Appendix B and C). Up to 50 participants were accepted into the study. Participants who completed the working memory and general ability pre assessment were accepted into the study with the goal of completing 40 full pre-assessments by February 1, 2013.

Before this investigation, the Human Subject Review Board approved an application for human subjects research in January of 2013 (See Appendix A). The building principal and school district superintendent gave approval for the investigation and supported the research being conducted (See Appendix D).

RESEARCH QUESTIONS AND NULL HYPOTHESES

As already mentioned in the introduction to this project, working memory is an important component of school success. It is the foundation for student reading comprehension. Working memory underpins the student's ability to apply math facts to story problems and real world math. It is important for a student who listens to a school lecture, writes a research paper, and recalls directions to navigate a map.

Working memory is a component of many intelligence tests but it is not synonymous with intelligence. According to Piirto (2007), people agree that intelligence is having the ability to solve problems, having verbal strength, and having a basis for general social awareness. General intelligence (*g*) is often divided into two categories—crystallized intelligence (*Gc*) and fluid intelligence (*Gf*). *Gf* is the ability to problem solve, match patterns, as well as reason, while *Gc* is knowledge and skills (Alloway, 2012; Denckla, 1996; Klingberg, 2010). The use of a non-verbal intelligence test is a reference to the type of test given to a student and not a reference to the ability of an individual taking the assessment; non-verbal intelligence tests remain an assessment of general ability (Naglieri et al., 2008). Intelligence testing remains controversial and many attempts have failed to dispel the use of *g* as a general measure of intelligence (Piirto, 2007).

Research Question 1

Can the brain-training program *Jungle Memory*® improve working memory?

Research Question 2

Accepting the use of the social construct of intelligence, can ability scores as indicated on the NNAT-2 increase by the use of the brain-training program *Jungle Memory*®?

Research Question 3

Is there a relationship between general ability (*g*) and working memory?

Null Hypothesis 1. There will be no difference in pre- and posttests of working memory for students who complete the *Jungle Memory*® brain-training program.

Null Hypothesis 2. There will be no difference in pre- and posttests of general ability (*g*) scores as measured by the Naglieri Nonverbal Ability Test Second Edition (2011) for students who complete the *Jungle Memory*® brain-training program.

Null Hypothesis 3. There is no relationship between general ability (*g*) and working memory.

Null Hypothesis 4. There will be no difference in pretests and posttests of verbal working memory for students who complete the *Jungle Memory*® brain-training program.

Null Hypothesis 5. There will be no difference in pretests and posttests of visuo-spatial working memory for students who complete the *Jungle Memory*® brain-training program.

Experimental Procedure

A pretest-posttest quasi-experimental design was conducted to discern whether the *Jungle Memory*® program can affect the working memory and ability scores of intermediate grade students at a school district in Central Ohio. A pretest and posttest method was utilized in the experiment as shown in Figure 3.1. *The Automated Working Memory Assessment* (AWMA-2) assessed each participant's working memory. *The Naglieri Nonverbal Ability Test Second Edition* (NNAT-2) (2011) assessed each participant's general ability.

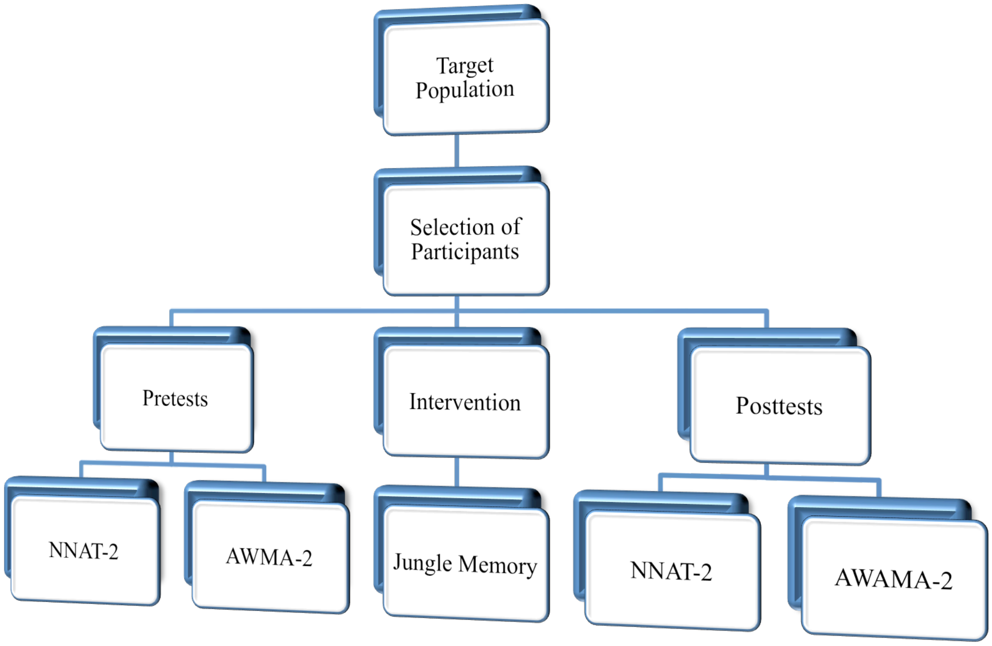


Figure 3.1. Experimental Procedure for working memory quasi-experiment

The quasi-experiment participant group participated in the treatment *Jungle Memory*®, a computerized adaptive working memory-training program, three times a week for eight weeks. At both the beginning and the end of the intervention, all participants completed a working memory assessment with the AWMA-2 and an ability assessment with the NNAT-2.

The independent categorical variables in the study that could not be manipulated were the gender and age of the participants. The *Jungle Memory*® training was the independent variable that was manipulated and controlled. The dependent variables were the working memory and ability results. The dependent continuous variable was the gain score from the posttest and pretest scores. The scores were converted to z scores for standardization and normal distribution based on the population.

Instruments

The beta AWMA-2 is an online assessment published by Pearson Assessment. The design of the AWMA-2 utilized a structural equation model was trialed for five years, was normed to include racial and ethnic diversity, and was standardized to include individuals ages 5-79 (Alloway, 2011c). The AWMA-2 has three versions: screener, short, and long form. The test measures verbal short-term memory, verbal working memory, visuo-spatial short-term memory, and visuo-spatial working memory. The short version was utilized for both the pre and post assessments. The AWMA-2 short version has four sections: processing letter recall, Mr. X, digit recall, and dot matrix. The long version adds backwards digit recall, backwards dot matrix, letter recall, and block recall to the assessment. Verbal short-term memory is assessed with the digit and letter recall and verbal working memory is assessed with backward digit recall and processing letter recall. Visuo-spatial short-term memory is assessed with the dot matrix and block recall tests while the visual-spatial working memory is assessed by the Mr. X and backward dot matrix tests (Alloway, 2011c).

Each component of the assessment is automated depending upon the age of the participant and has a discontinue rule for each section. Each section allows the participant to complete up to nine items if he or she has not been discontinued by the assessment. The assessment is also automated to score and norm each assessment at the completion. The AWMA-2 is a reliable instrument based upon the correlation coefficients for test-retest reliability. It also is deemed a valid instrument to assess working memory as compared to the *WISC-IV* working memory index (Alloway, 2011c).

The *Naglieri Nonverbal Ability Test-2* is a culturally sensitive, nonverbal assessment of general ability (Naglieri, 2011). It contains figural matrices to measure a student's nonverbal reasoning and problem solving ability. According to the test author the NNAT-2 is based on extensive research and it "provides a reliable and valid evaluation of a student's ability" (Naglieri, 2011 p. 2), though there are differing opinions (Lohman, 2008). The paper and pencil version of the NNAT-2 was administered to each participant as a pretest and posttest. The NNAT-2 was completed within a 30-minute period and the 2011 norms were used. .

Intervention

The *Jungle Memory*® brain-training program is a commercial product available to schools and parents through the company Memosyne, Ltd. The program advertises that it will improve working memory, grades, and IQ (Jungle Memory, 2011a). The intervention was completed within an eight-week period with each participant practicing and playing the games for up to thirty minutes, three times a week.

The program utilizes three training activities in an interactive and adaptive game format. Motivational features are included in the game with participants earning badges at the completion of trainings levels. Participants can move through thirty different levels for each game. The first game trains verbal memory, word recognition, and processing speed. The second game trains visual spatial working memory and the third game utilizes math skills and sequential memory to train working memory (Alloway et al., in press; Jungle Memory, 2011a).

The games are modeled after a class of training program that utilizes core training rather than strategy training. Strategy training is supplemental to the domain strategy and trains academic subjects and not working memory, whereas core training involves targeting the specific components of working memory (Morrison & Chein, 2011). For example, a person training for a marathon may also do cardiovascular training via swimming or biking as supplemental training, yet the core training to prepare for a marathon is actually to *run* multiple miles at a time.

Jungle Memory® follows the core-training regimen and is designed to minimize automization of tasks; hence it changes so the participant cannot memorize or become accustomed to a routine in the game. It includes stimuli that span multiple working memory domains, adapt to participant's proficiency, require maintenance of information with interference tasks, and include high cognitive engagement (Morrison & Chein, 2011). The program claims to train the central executive that in turn is strengthening the working memory processes. It also claims to enhance the production of neurotransmitters necessary for working memory: dopamine and serotonin (Jungle Memory, 2011a).

Jungle Memory® offers parents a money back guarantee if participants do not advance beyond a specified level and a peace of mind guarantee if not completely satisfied (Jungle Memory, 2011a). The program also offers educational resources for parents and schools in the form of booklets and videos explaining working memory and its importance in education.

Research Design

Creswell (2008) emphasized that true experimental design with random assignment is the most rigorous and preferred type of study. However, in educational research, true experimental design is not always feasible or practical due to many constraints like the time of the school year or perceived fairness to the participants;

therefore, the pre-posttest design can yield the best results if true experimental design is not an option (National Center for Technology Innovation, 2012). Shadish, Cook and Campbell (2002) reported that the no control group pre-posttest design is common in research. An additional reason to utilize the no control group quasi-experimental method is the possible threat to internal validity caused by the diffusion between experimental and control groups. The intermediate grade participants in the study make it difficult to guarantee that there will not be contamination between the groups. Therefore, a one-group pretest-posttest design was utilized with a double pretest. Figure 3.2 outlines the design of the study. Shadish, et al. (2002) suggested the use of the double pretest could reduce the plausibility of maturation and regression effects; therefore, both the AWMA-2 and NNAT-2 were utilized as pretests.

$\{O_{1A}\ O_{1B}\}\quad X\quad \{O_{2A}\ O_{2B}\}$

Figure 3.2. The design of a one-group pretest-posttest quasi-experimental study

In Figure 3.2, $_A$ represents the AWMA-2 assessments and $_B$ represents the NNAT-2. Based upon previous research, the intervention of Jungle Memory® is expected to increase the working memory score; however, there is doubt that any intervention can increase ability score. Shadish et al., (2002) reported the one-group pretest-posttest design is an appropriate research design as working memory is expected to change due to intervention while ability is not. The quasi-experimental design without a control group can produce an effect size since the intervention is only expected to impact one of the variables.

Data Analysis

A within participants design was used to evaluate the effectiveness of the *Jungle Memory*® program for both the working memory assessment as well as the ability scores. The collected data had multiple variables to determine whether there was any significance to the intervention. The purpose of the study was to determine whether the *Jungle Memory*® program increased the working memory and ability scores of the participants. The independent variables were the *Jungle Memory*® training program and the participant categories such as gender and age. If ability scores need to be controlled for, the ability score could be converted into categorical independent variables with three levels: below average, average, and above average based on the sample. The dependent variables were the working memory and NNAT-2 ability scores for each student. Paired samples t-tests were analyzed for the pretest and posttest means. These provided information to discern whether there was a statistically significant difference between the two groups at the end of the intervention (Pallant, 2010).

To determine whether there was a relationship between working memory and ability scores, a correlation utilizing Pearson correlation coefficients (r) was conducted. Pallant (2010) reported the correlational statistic assists in describing the strength and direction of any relationship between two variables. If working memory and ability are correlated, then ability will need to be controlled for in determining the effect size of any mean increases in verbal or visuo-spatial working memory.

The working memory and ability pretest and posttest scores were also analyzed with a two-way within subjects ANOVA to discern any effects of the intervention and to investigate the interaction effects of the data (Pallant, 2010). The analysis used ANOVA with the training condition as within factor on gain score (posttest minus pretest) as the dependent variable to analyze it as a function of the intervention. Pallant (2010) reported that this allows for the option for main effects and interaction effects of both the ability score and the working memory assessment. Table 3.1 outlines the statistical tests used and the research questions for the tests.

Table 3.1
Research Questions and Data Analysis

Research Question	Null Hypothesis	SPSS Technique	Reason
1. Can the brain-training program *Jungle Memory*® improve working memory?	1. There will be no difference in pre- and posttests of working memory for students who complete the *Jungle Memory*® brain-training program.	Paired Samples T-test (Compare mean scores from pre and post)	To determine if there is a change in score from pre- to posttest. If yes then to determine significance and effect size.
2. Accepting the use of the social construct of intelligence, can ability scores as indicated on the NNAT-2 increase by the use of the brain-training program *Jungle Memory*®?	2. There will be no difference in pre- and posttests of general ability (*g*) scores as measured by the Naglieri Nonverbal Ability Test Second Edition (2011) for students who complete the *Jungle Memory*® brain-training program.	Paired Samples T-test (Compare mean scores from pre and post)	To determine if there is a change in score from pre- to posttest. If yes then to determine significance and effect size.

Research Question	Null Hypothesis	SPSS Technique	Reason
3. Is there a relationship between general ability (*g*) and working memory?	3. There is no relationship between general ability (*g*) and working memory.	Pearson correlation coefficient (*r*)	To determine if there is a relationship and if so the direction and strength.
1. Can the brain-training program *Jungle Memory*® improve working memory?	4. There will be no difference in pretests and posttests of verbal working memory for students who complete the *Jungle Memory*® brain-training program.	Two-way within subjects (Repeated) ANOVA	To test the main effect of ability on specific component of WM. If there is a correlation from #3, I will need to determine the levels for ability score to have (3 categories Average, Above and Below). IV: Gender and Ability Score DV: Posttest minus Pretest Score on Verbal WM score only
1. Can the brain-training program *Jungle Memory*® improve working memory?	5. There will be no difference in pretests and posttests of visuo-spatial working memory for students who complete the *Jungle Memory*® brain-training program.	Two-way within subjects (Repeated) ANOVA	To test the main effect of ability on specific component of WM. If there is a correlation from #3, I will need to determine the levels for ability score to have (3 categories Average, Above and Below). IV: Gender and Ability Score DV: Posttest minus Pretest Score on visuo-spatial WM score only

Threats to Validity

There is a lack of a control group in this study; therefore, random assignment was not utilized. As a result, there are risks to the validity of the quasi-experimental study. The participation in the study is a convenience sample of parents and students who self-select to participate. Self-selection is an internal threat as the participants are interested in the topic and the outcome of the research study. Additional threats to validity include the possibility of a practice effect, as similar measures were utilized for the pretests and posttests. History, maturation, and regression to the mean were additional threats to the internal validly of the study (Creswell, 2008). Furthermore, the students were aware that they were participating in a research study; therefore, the Hawthorne effect could be a potential threat as the behavior and effort of the students may be affected by the research conditions.

Statistical controls for ability scores were implemented to explain how treatment outcome covariation is a risk to the validity of the study (Shadish et al., 2002). Attrition was a risk to internal validity; if the participants decided to drop out or not complete the eight-week intervention due to lack of interest, time, or commitment, the results were excluded from the study. However, only three participants failed to complete the study and the pretest and posttest scores were withheld from the statistical analysis. To counter the risks to the validity of the study, I was transparent in the acknowledgement of the risks and honestly reported the internal and external threats to validity throughout the process.

SUMMARY

A quasi-experimental methodology is utilized to determine if the *Jungle Memory*® brain-training program can increase working memory and ability scores in intermediate grade students in a Central Ohio school district. A pretest-posttest design with a double pretest evaluated the two hypotheses: students who complete the Jungle Memory brain-training program will increase their working memory score and ability scores of students who complete the *Jungle Memory* ® brain-training program will increase at the conclusion of the intervention-training program.

CHAPTER IV

FINDINGS AND RESULTS

INTRODUCTION

This chapter focuses on the analysis and interpretation of the data collected from the participants in the quasi-experimental working memory in education study. Participants were expected to complete two pretests and posttests. *The Automated Working Memory Assessment 2* (2011) assessed each participant's verbal and visuo-spatial working memory. *The Naglieri Nonverbal Ability Test Second Edition* (2011) assessed each participant's general ability. Upon completion of the pretests, participants engaged in a treatment intervention for eight weeks utilizing the *Jungle Memory*® adaptive working memory-training program. The content of this chapter will focus on answering the research questions and hypotheses.

GENERAL DESCRIPTION OF THE DATA

Thirty-five intermediate aged students (21 female) started and completed the study with fidelity. To complete the study with fidelity, participants completed the pretests and posttests in a monitored environment to ensure standard testing protocols and completed the *Jungle Memory*® adaptive working memory-training program for eight weeks. Three students were disqualified from the study for not completing the *Jungle Memory*® training program with fidelity. The mean age of the participants was 11 years and 2 months. As reported by the parents at the start of the study, six students were eligible for an IEP or qualified under the *Americans with Disabilities Act* for a 504 plan. Parents also reported that 23 students had been identified as gifted by the school district in an academic area by scoring in the 95th percentile on a nationally normed standardized academic assessment. The determination of giftedness was made according to the *Ohio Operating Standards For Identifying And Serving Gifted Students Ohio Administrative Code 3301-51-15,* March 2008. Further, using the same criteria from the state of Ohio, the parents reported six of the students were identified as superior cognitive with general ability scores above 127 on the standardized scale; two of the superior cognitive students were identified as twice exceptional -- a student identified as gifted with also a disability.

The pre- and post- assessments were collected and analyzed. Participant descriptive statistics, means, and standard deviations on the measures are provided in Table 4.1. All cognitive measures were scored as standard scores (M=100, SD=15) (Pallant, 2010). The means of the participants were above the national mean of 100 on each of the assessments. Therefore, the population in this study was above average on the pretests as well as the posttests.

Table 4.1

Descriptive Data of the Sample

Assessment	Mean	N	Std. Deviation
NNAT-2 Pretest	107.23	35	14.761
NNAT-2 Posttest	106.94	35	12.374
AWMA-2 Verbal Working Memory Pretest	106.80	35	12.233
AWMA-2 Verbal Working Memory Posttest	108.49	35	11.490
AWMA2 Visuo-spatial Working Memory Pretest	106.06	35	16.650
AWMA2 Visuo-spatial Working Memory Posttest	115.63	35	17.649

ANSWERING THE RESEARCH QUESTIONS

Research question 1 asked if the brain-training program *Jungle Memory*® could improve working memory. Paired samples T-tests to compare the mean pretests and posttests scores were analyzed to determine if there was a change in the score from the pretest to the posttest. If a change in score was significant, the effect size using Cohen's d was computed to ascertain the value of the effect size (Pallant, 2010). A one-tailed test of significance was used because the research question was directional, asking about an improvement in the scores (Creswell, 2008). Figure 4.1 shows the difference in standard scores pre and post training for the ability and working memory assessments.

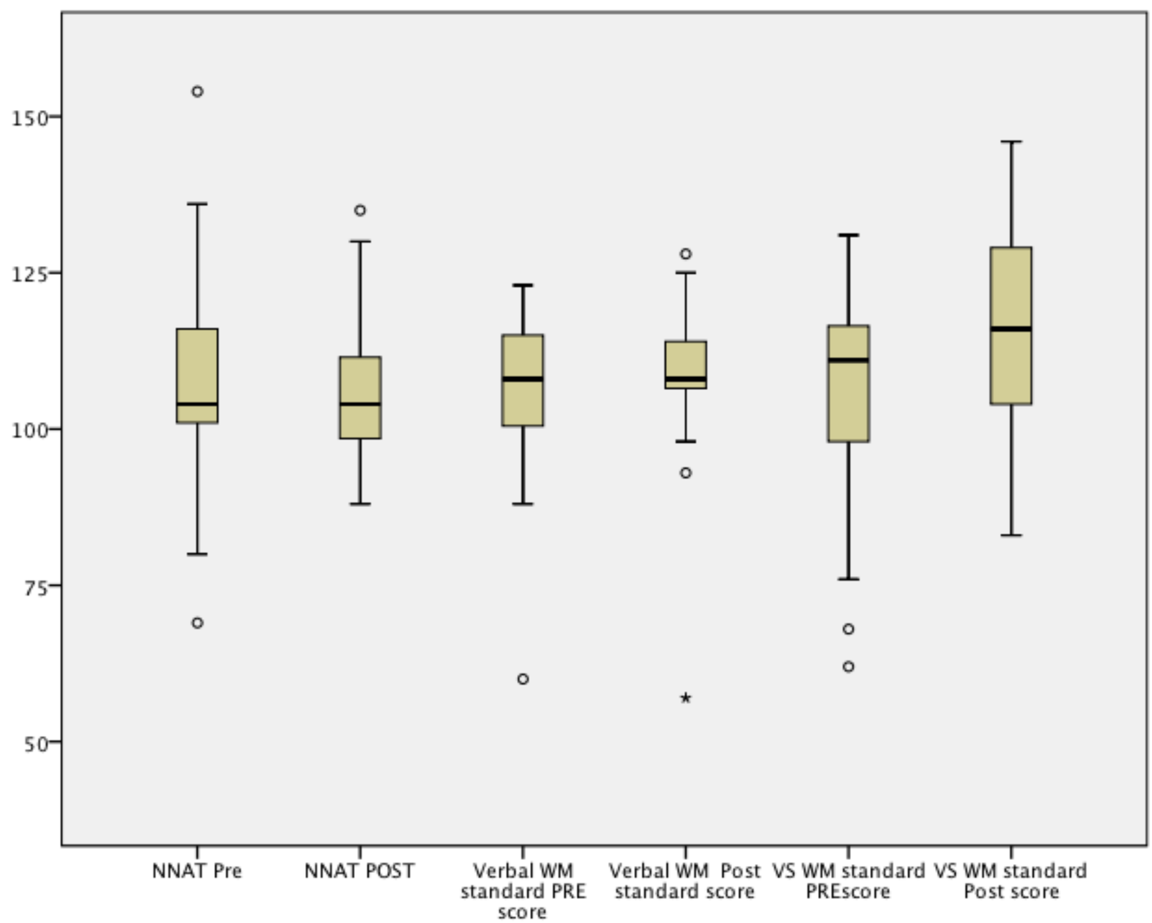


Figure 4.1 The differences in standard scores pre and post training for the ability and working memory assessments.

A paired-samples t-test was conducted to evaluate the impact of the *Jungle Memory*® brain-training intervention on students' working memory scores. The verbal working memory assessment mean increase was not statistically significant ($M = 1.686$, $SD = 7.49$) and $t(34) = 1.33$, $p = .192$, which is not greater than critical value of 1.69 on a one-tailed critical values of t analysis. However, there was a statistically significant increase in visuo-spatial working memory scores from the pre assessment ($M=106.06$, $SD = 16.650$), $t(34) = 3.012$, $p < 0.005$ (one-tailed) to the post assessment ($M=115.63$, $SD = 17.649$). The mean increase in visuo-spatial working memory scores was 9.571 with a 95% confidence interval ranging from 3.114 to 16.029. The standardized effect size index, d, was .51; therefore, the result was a medium effect size.

The following null hypotheses were answered based on the results:

- Retain Null Hypothesis 4**:** There will be no difference in pre- and posttests of verbal working memory for students who complete the *Jungle Memory*® brain-training program.
- Reject Null Hypothesis 5: There will be no difference in pretests and posttests of visuo-spatial working memory.

Rejecting null hypothesis 5 could result in a Type 1 error and be a false positive even though the p value was less than 0.005.

Research Question 2 accepted the social construct and definition of intelligence as previously defined and asked whether ability scores as indicated on the NNAT-2 could increase by the use of the brain-training program *Jungle Memory*®. A paired-samples t-test was conducted to evaluate the impact of the Jungle Memory intervention on students' ability score. A one-tailed test of significance was used since the research question was directional asking about an increase in the scores (Creswell, 2008). There was no statically significant difference in the pretest (M = 107.23, SD = 14.761) to the posttest (M = 106.94, SD = 12.374). Therefore, I accept the Null Hypothesis 2: there will be no difference in pretests and posttests of ability scores for students who complete the *Jungle Memory*® brain-training program.

Research question three considered the possibility of a relationship between general ability (*g*) and working memory. The relationship on the pre assessment between ability *(g)*, as measured by the NNAT-2 and verbal working memory, as measured by the AWMA-2, was investigated using Pearson product correlation coefficient. Table 4.2 is the correlation matrix for the ability and working memory pre and posttests. Pallant (2010) defined a large correlation as r=.50 to 1.0 and a medium correlation as r=.30 to .49.

Table 4.2
Pearson Correlation coefficients for the ability and working memory assessments

	1	2	3	4	5	6
1. NNAT-2 Pretest	_	.772**	.389*	.455**	.425**	.565**
2. NNAT-2 Posttest		_	.247	.292	.344*	.624**
3. AWMA2 Verbal Pretest			_	.803**	.310	.297
4. AWMA2 Verbal Posttest				_	.242	.241
5. AWMA2 Visuo-spatial Pretest					_	.400*
6. AWMA2 Visuo-spatial Posttest						_

Note: N=35; **p<. 01; *p<. 05

Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity (Pallant, 2010). Each of the three assessments correlated positively to itself on the pretest and posttest measures as shown in Figure 4.2.

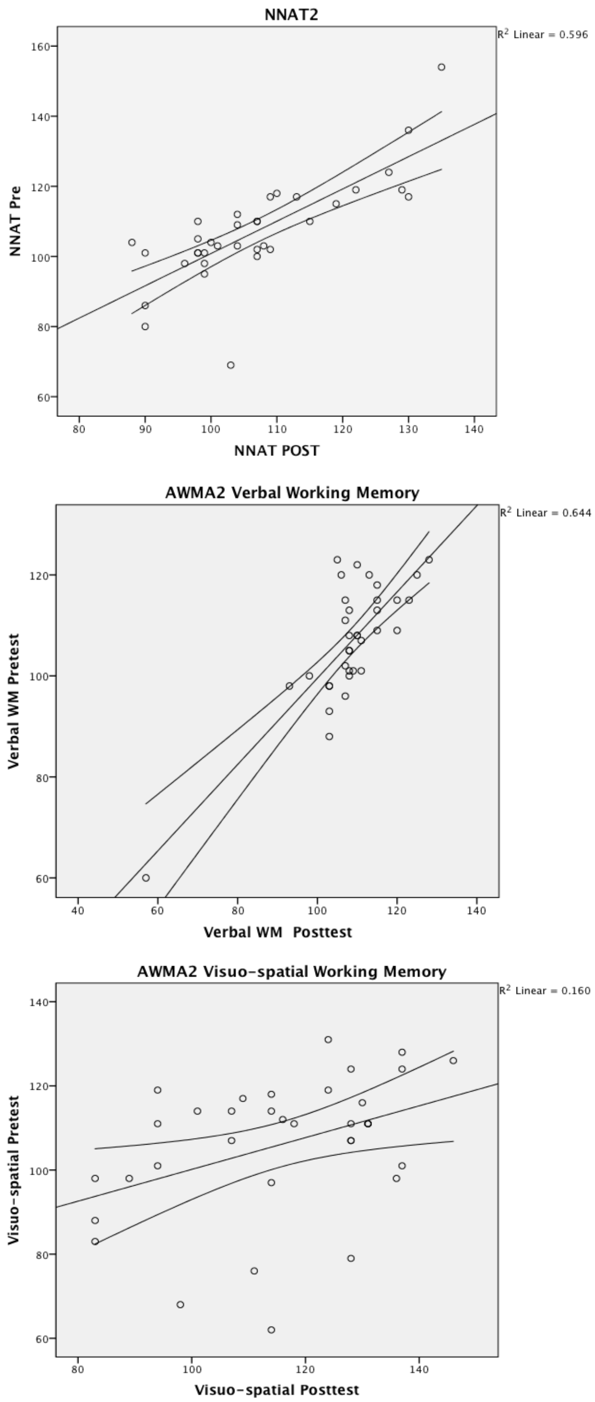


Figure 4.2. Pearson correlation coefficients for pretests and posttests

The relationship on the pre and post assessment between ability (*g*), as measured by the NNAT, and visuo-spatial working memory, as measured by the AWMA, was investigated using Pearson product correlation coefficient. Preliminary analyses were performed to ensure no violation of the assumptions of normality, linearity, and homoscedasticity. On the pretests, there was a medium positive correlation between (*g*) and verbal working memory, r=. 389, n=38, $p < 0.05$. There was a medium positive correlation between the two variables, r=. 425, n=38, $p<0.01$, with (*g*) associated with visuo-spatial working memory. These data are demonstrated in Figure 4.3.

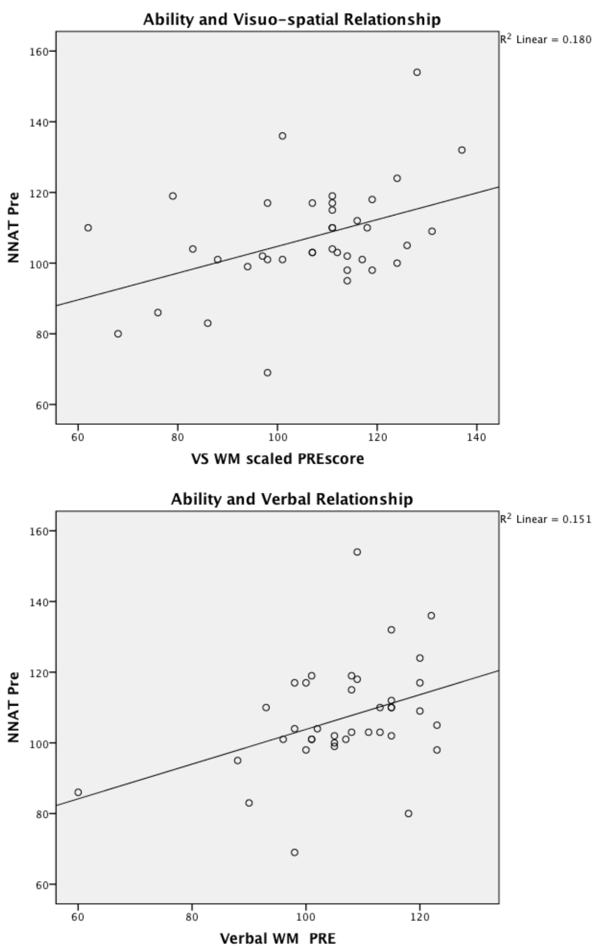
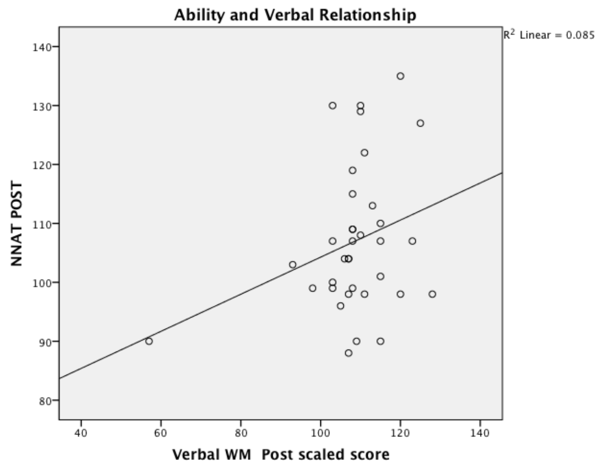


Figure 4.3. Pearson correlation coefficients for pre assessments of ability and visuo-spatial working memory and ability and verbal working memory.

On the post assessments, the relationship between ability (*g*), as measured by the NNAT 2, and visuo-spatial working memory, as measured by the AWMA-2, was investigated using Pearson product correlation coefficient. There was a large, positive correlation between the two variables, r=. 624, n= 35, p<0.01 with ability associated with visuo-spatial working memory. There was not a relationship between *g* and verbal working memory on the posttests. These data are demonstrated in Figure 4.4.



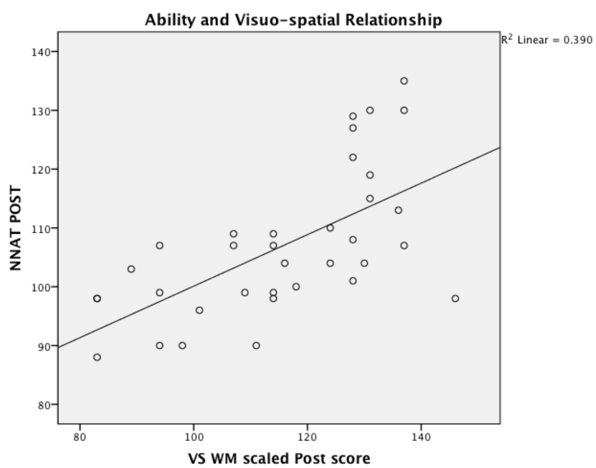


Figure 4.4. Pearson correlation coefficients for ability and visuo-spatial working memory and ability and verbal working memory.

Because of the correlational data, I reject Null Hypothesis 3: there is no relationship between general ability (g*)* and working memory.

As a result of the significant results of the increase in the visuo-spatial working memory after the *Jungle Memory*® intervention and the large positive correlation between *g* and visuo-spatial working memory, a mixed between-within subjects analysis of variance was conducted to explore the impact of NNAT-2 ability level and gender on the AWMA-2 visuo-spatial working memory post assessment.

Participants were divided into three approximately equal ability groups according to their NNAT-2 pretest scores (Group 1: Above Average NNAT-2 >114, Group 2: Average NNAT-2 102-113, and Group 3 Below Average NNAT-2 <102). The labels of the three groups represent the population for above average, average, and below average and is not representative of the general population where 100 is average and the standard deviation of 15 would be used to disaggregate above and below average scores (Naglieri et al., 2008; Salkind, 2012).

Table 4.3
NNAT Score Groups for ANOVA

	Above Average	Average	Below Average
Group 1	NNAT-2 >114		
Group 2		NNAT-2 102-113	
Group 3			NNAT-2 <102

There was no significant interaction between ability level and gender, Wilks' Lambda = .88, F (2,29) = 1.98, p = .16, partial eta squared = .12. There was a statistically significant main effect for ability level on visuo-spatial working memory, F (2, 29) = 5.4, p= <. 005 on a one tailed test; however, the effect size was small (partial eta squared = .27). Post-hoc comparisons using the Tukey HSD test indicated that the mean score for the above average group (M=128.7, SD = 8.80) was significantly different from the below average group (M=101.18, SD=15.90). The average group (M= 117.64, SD 15.95) also was significantly different from the below average group. The above average and average groups did not different significantly from each other. The main effect for gender, F (2, 29) = .1.29, p=. 29 did not reach statistical significance.

Table 4.4
Visuo-Memory Working Memory based on NNAT ability levels and Gender

	VS WM Pre Intervention		VS WM Post Intervention	
	N	M	N	M
NNAT Above Average Total	10	108.9	10	128.7
Male	6	106.17	6	128.5
Female	4	113	4	129.0
NNAT Average Total	14	107.57	14	117.64
Male	5	118	5	121.2
Female	9	101.78	9	115.67
NNAT Below Average Total	11	101.55	11	101.18
Male	5	94.60	5	103.60
Female	6	107.33	6	99.17
Total	35	106.06	35	115.63
Male	16	106.25	16	118.44
Female	19	105.89	19	113.26

SUMMARY OF FINDINGS

General ability (*g*) as measured by the NNAT-2 and working memory as measured by the AWMA-2 are correlated. The relationship between *g* and visuo-spatial working memory is large and exists on both the pre and posttests. The completion of the *Jungle Memory*® brain-training program did not affect either ability or verbal working memory scores. The pre and posttest results were not statistically significant and the eight-week intervention failed to influence the participant's mean scores. However, the *Jungle Memory*® brain-training program did significantly increase the participants' visuo-spatial working memory scores. The participants' mean scores increased significantly from 106.06 to 115.63 and demonstrated that the completion of *Jungle Memory*® brain-training program did increase the visuo-spatial working memory scores of the participants.

CHAPTER V

DISCUSSION

INTRODUCTION

Working memory is critical for the academic success of children in schools (Alloway et al., 2009a). Deficits in working memory cause many children to miss important learning benchmarks and fall behind their peers throughout the school career. However, the concept of working memory is relatively new in American education and not widely understood (Dehn, 2011). The purpose of this quasi-experimental study was to determine whether the computerized program *Jungle Memory*® can improve working memory for intermediate grade students. Hence, the quasi-experimental research study to discern if working memory could be improved was undertaken as an opportunity to raise awareness of working memory for both educators and parents. This chapter will discuss the results from Chapter IV as related to the previously published research on working memory. The discussion will focus on answering the research questions introduced in Chapter I.

Research Question 1. Can the brain-training program *Jungle Memory*® improve working memory?

Research Question 2. Accepting the use of the social construct of intelligence, can ability scores as indicated on the NNAT-2 increase by the use of the brain-training program *Jungle Memory*®?

Research Question 3. Is there a relationship between general ability (*g*) and working memory?

A pragmatic and interpretivist approach to the research questions was taken to focus on working memory as a neuroscience construct that has individualized meaning for school-aged children (Merriam, 2009). The research study followed the multicomponent system view of working memory as defined by Baddeley and Hitch (1974). The areas of the brain responsible for working memory can be developed for improvement. However, parents, teachers, and school districts should be discerning in accepting claims that any brain-based or brain-training program will benefit students. This chapter will answer the research questions and include additional findings, limitations of the study, and implications for educators. The chapter will also conclude with future research suggestions.

RESEARCH QUESTION 1

The first research question asked could the brain-training program *Jungle Memory®* improve working memory? According to Alloway (2011c), working memory can be assessed as individual components; therefore, the first research question divided working memory into the verbal working memory and visuo-spatial working memory. The use of the AWMA-2 as the assessment allowed for both a pretest and posttest scores on the individual working memory components and scored according the participant's age.

Null Hypotheses Relating to Question 1

Reject Null Hypothesis 1**:** There will be no difference in pretests and posttests of working memory for students who complete the *Jungle Memory*® brain-training program.

Retain Null Hypothesis 4**:** There will be no difference in pretests and posttests of verbal working memory for students who complete the *Jungle Memory*® brain-training program.

Reject Null Hypothesis 5: There will be no difference in pretests and posttests of visuo-spatial working memory.

Discussion of the Findings

The *Jungle Memory*® intervention did not increase the verbal working memory of the participants. Completing the 8-week intervention program did not enhance the verbal working memory of the students. The participant's mean scores were above average from the start of the study and although the mean increased from the pre to post assessment, the gain in scores was not statistically significant. This finding is counter to the findings of Alloway, Bibile, and Lau (in press) who reported *Jungle Memory*® increased verbal working memory in students who completed the intervention at a high frequency rate over playing the games at least four times a week for eight weeks. The present study did not replicate the finding from Alloway (2012) where students on an IEP increased verbal working memory after utilizing the *Jungle Memory*® program for eight weeks. Verbal working memory is paramount to success in reading, language development, and basic arithmetic. The intervention did not demonstrate near transfer effects that increase the verbal working memory of the participants.

However, participation in the intervention did increase the visuo-spatial working memory ability for the participants. Visuo-spatial working memory is important in school for mathematical skills, concrete representations of numeracy, note taking, organization, and following multi-step directions (Gathercole, Lamont, & Alloway, 2006). The participants increased visuo-spatial working memory at a statistically significant rate. This finding affirms the results of another study utilizing *Jungle Memory*® and increasing the visuo-spatial working memory scores in school-aged students (Alloway et al., in press). Holmes, Gathercole, and Dunning (2009) also reported significant increased visuo-spatial working memory ability following the completion of adaptive working memory training. This quasi-experimental study is, at the current time, the only known independent study utilizing *Jungle Memory®* as an intervention to assist in the improvement of working memory.

Because success in school relies on both verbal and visuo-spatial working memory, increasing and strengthening a student's working memory ability can have long lasting educational implications for children. What is not known from the study is how or why the visuo-spatial working memory improved significantly while the verbal working memory ability improved but not significantly. Observing the participants in the playing of the games in *Jungle Memory*®, I anecdotally believe the game is targeted towards visuo-spatial working memory more than verbal working memory. The code breaking game specifically targets spatial skills with letters and the river crossing game requires the participants to complete simple arithmetic problems in both mostly vertical formats. The games were not demanding enough nor taxing according to the conversations with the sample to challenge many of the participants.

This study did not discern how the *Jungle Memory*® program trained the areas of the brain related to working memory and attention. Klingberg (2012) reported that targeting the prefrontal cortex and intraparietal regions of the brain through computerized games such as *Jungle Memory*® will translate to the improvement of daily life activities and school activities. Moreover, many researchers say that the training increases self-awareness and assists with strategies to overcome weaknesses in the area of working memory and in and of itself that is enough (Holmes et al., 2009a; Holmes & Gathercole, 2010). I agree with the researchers in that improvement of working memory, self-awareness, and self-advocacy is the ultimate goal for the student.

RESEARCH QUESTION 2

Accepting the presence of the social construct of intelligence, the second research question asked whether ability scores as indicated on the NNAT-2 could increase by the use of the brain-training program *Jungle Memory*®. A series of research articles postulated that working memory training increases fluid intelligence (*Gf*) as well as working memory ability; therefore, participants were assessed on general ability (*g*) as well as working memory (Chooi, 2011; Jaeggi et al., 2008; Jaeggi et al., 2011).

Null Hypotheses Relating to Question 2

Retain Null Hypothesis 2: there will be no difference in pretests and posttests of ability scores for students who complete the *Jungle Memory*® brain-training program.

Discussion of the Findings

The *Jungle Memory*® brain-training program did not increase the general ability of the participants. The participants began the study with average ability scores as assessed by the NNAT-2 and maintained very similar ability scores at the completion of the intervention (Naglieri, 2011). The adaptive working memory intervention did not have a significant impact on the intelligence scores of the participants.

These findings are similar to studies utilizing adaptive working memory training and general intelligence testing (Holmes et al., 2009a). However, it should be noted that different types of testing were completed. In the studies that demonstrated increased intelligence, fluid intelligence measures were utilized rather than general measures like the NNAT-2 (Chooi, 2011; Jaeggi et al., 2008; Jaeggi et al., 2011). Intelligence testing remains controversial among cognitive psychologists who argue the use of intelligence data is necessary at a conceptual level for research purposes rather than a purely data and psychometric level to disaggregate people into categories (Hunt, 2011). Hunt (2011) said that *Gf* is important as a model to assist in solving new problems using general skills while *g* is the general reasoning ability.

The use of any intelligence or ability tests has been controversial since the inception of such assessments. Many believe such tests are discriminatory based on both race and class (Piirto, 2007). However, schools and society have both accepted the cultural norms that surround the use of IQ tests and therefore, the data are available and have societal norms that surround them. As an educator, I do not reject the use of ability tests or the importance of them. I do, however, believe the use of any standardized assessment is only one data point in many that can and should be used to assist teachers in a school environment.

The use of the NNAT-2 provided a foundation for measuring the ability level of the participants as a guide for measuring what students were able to learn regardless of the topic being taught (Naglieri et al., 2008). The use of a general ability test as a measurement in the quasi-experimental study set the basis for answering the third research question.

RESEARCH QUESTION 3

The third research question asked is there a relationship between general ability (*g*) and working memory.

Null Hypotheses Relating to Question 3

Reject Null Hypothesis 3: there is no relationship between general ability (g*)* and working memory.

Discussion of the Findings

The pre-assessments of general ability positively correlated with both verbal working memory and visuo-spatial working memory. A large positive correlation existed between the post-assessments for visuo-spatial working memory and general ability. This substantiates what has been reported by a multitude of researchers who claimed a positive correlation between intelligence and working memory (Alloway, 2009b; Alloway & Elsworth, in press; Gathercole et al., 2006; Jaeggi et al., 2008; Raghubar et al., 2010). Moreover, it is important to note that working memory and intelligence are correlated but not the same. The two constructs share cognitive processes but have distinct measurements (Conway et al., 2013).

The findings of the study reported a medium positive correlation between verbal working memory and general ability on the pretests, neither of which increased because of the *Jungle Memory*® brain-training program. The posttests do not indicate a correlation between the two assessments. However, there is a strong positive correlation between the visuo-spatial working memory and general ability and only the visuo-spatial working memory scores increased because of the training program. Hence, the correlation remained as visuo-spatial working memory increased while the ability score remained consistent.

An interesting finding is that verbal working memory and visuo-spatial working memory are not correlated to one another in either the pretests or posttests. This substantiates the Baddeley and Hitch (1974) theory of distinct and separate components of working memory as the phonological loop as measured by verbal working memory assessments and the visuo-spatial sketchpad measured by visuo-spatial working memory assessments (Alloway, 2011c). An individual can have strength in one area of working memory and have an average or below average score in the other area. Of course, an individual can have strengths or weaknesses in both areas, but the components are not correlated to one another.

Each participant was tested in an individual setting using the online Beta version of AWMA-2. Although the study did not collect data on the subject comments, it was obvious that many students had a discrepancy in the verbal and visuo-spatial working memory areas based on the assessments. Visuo-spatial working memory was tested in an activity using red and blue balls being held by computer figures. Many participants grumbled and complained at the end of both the pretests and posttests that they did not like the activity. School relies heavily on the use of verbal working memory and many of the participants who did not score well on the visuo-spatial working memory assessments perform extremely well in school as they rely on the use of verbal working memory.

Verbal working memory and general ability only had a medium correlation and this too is evident in school. Many teachers assume students with average to above average verbal working memory are more intelligent and often better prepared for school. Although this could be true, it could also be that the stronger verbal working memory allows the student to follow directions better, retain more verbal direction, and comprehend more from reading. All areas that a student with a weak verbal working memory would struggle regardless of ability score.

Because verbal working memory and visuo-spatial working memory are not correlated, many teachers may assume a student with a strong visual-spatial working memory is being inattentive or underperforming when teachers rely on verbal directions and lessons. These students may confuse teachers who are not aware of the importance of working memory or teachers who rely on single data points for decisions about students' ability.

ADDITIONAL FINDINGS

Summary of the Findings

Additional analysis of the data did not reveal any significant differences in pretest and posttest results based on gender. The research sample was split into categories based on the pretest NNAT-2 scores to discern if the *Jungle Memory*® brain-training program yielded different results for the different categories of students. The participating students in the below average category did not make any gains in visuo-spatial working memory ability, whereas the average and above average groups did make significant gains.

Three parents of female participants reported that their daughters had dyslexia. Although the sample was too small for further analysis, these three students failed to make progress from the pretests to the posttests. The parents also report that the *Jungle Memory*® brain-training program was very difficult and the girls did not want to continue in the study if the games would continue to get more difficult. They specifically reported the code breaking game was a challenge and struggle. This makes sense as the code breaking game relied on spatial skills and letter rotation, an area that is commonly reported difficult for students diagnosed with dyslexia.

Discussion of the Findings

An unexpected result of the study was that the students who started the *Jungle Memory*® brain-training program with above average visuo-spatial working memory ability increased their scores significantly, while the students whose scores were below average for the sample did not have any significant increases as a result of the intervention. Klingberg (2012) proclaimed that working memory does not have a fixed capacity and therefore can be increased; however, the sample for this study substantiates this claim only for the participants who had strength in visuo-spatial working memory from the beginning. It is not known if other studies that demonstrated an increase in visuo-spatial working memory after participating in adaptive training disaggregated for the ability level of participants (Alloway, 2012; Holmes, Gathercole, & Dunning, 2009b; Holmes & Gathercole, 2010; Morrison & Chein, 2011). This result is disappointing, as the students who could benefit the most from a program that proclaimed to increase working memory ability did not receive significant benefits from the completion of the training. Poor working memory skills are known to constitute high risk factors for underachievement, poor grades, and gaps in educational achievement (Alloway et al., 2009a). This result perpetuates the Matthew effect that the academically rich get richer, while the poor get poorer. Hence, it is even more critical to find interventions, strategies, and educational accommodations for the students who have working memory deficits.

The sample of the students on IEPs was too small to disaggregate the data for significance, but the scores either remained the same or increased only slightly for most of the IEP students. This was a disappointing result of the study. One IEP student, however, increased his scores by over 30 points in the working memory assessments and increased *g*.

Many of the participants reported that the games in *Jungle Memory*® brain-training program were “boring.” In the informal conversations with the participants and parents, the games did not engage the students nor foster a desire to play. Based on other video games that students play and educational games that are used, the games were stagnant with limited graphics, sound effects, or badges earned. The games could also be completed very quickly. The games adapted to the level of the players, but since the sample was above average to begin with, I suspect the adaptability of the game may not have resulted in sufficient stretch to demand more from the students.

LIMITATIONS AND DELIMITATIONS OF THE STUDY

Delimitations of the Study

True experimental design is the gold standard in research and utilizes both a control and experimental group (Creswell, 2008; Salkind, 2012). It was determined that this study would utilize a quasi-experimental double pretest and posttest design. Recent critiques of research studies that claim to be able to increase working memory ability are critical of approaches that lack control groups in the research design (Melby-Lervåg & Hulme, 2012; Morrison & Chein, 2011; Shipstead et al., 2012). An additional delimitation was the use of students from a single school district in central Ohio. The use of the Baddeley and Hitch (1974) theoretical perspective is an additional delimitation as the theoretical framework utilizes a European view of working memory that included the importance of the prefrontal cortex as the attentional control necessary for working memory (Baddeley, 2000).

Limitations of the study

The use of a purposeful convenience sample of intermediate grade students in Ohio is a limitation of the study, as it did not allow for random selection. The self-selection by the parents and participants was a threat to the internal validity of the study. Attrition was a limitation and three students did not complete the intervention with fidelity; therefore, their results were not reported or utilized in the overall data analysis. These limitations affected the sample size, strength, and generalizability of the results of the study.

IMPLICATIONS

Implications for Research

The implication for research is that working memory does not have a fixed ability and therefore can improve. Future research should continue to investigate how working memory improves and the impact that can have in far transfer situations to assist students who have working memory deficits. Researchers should investigate what changes in the brains of participants who complete interventions and how what is occurring to allow for increases in working memory ability. This study only demonstrated significant changes in visuo-spatial working memory, but applying the concept that increases can occur may allow future researchers to target strategies that can improve verbal working memory as well.

An important component of increasing working memory is the idea that far transfer should also occur. If a student can increase his or her working memory then academic increases in subjects such as reading and math should be enhanced. Students being able to hold more content in the mind while manipulating the content for other uses can enhance the reading comprehension and mathematical problem solving for many students.

Researchers can also investigate the use of the NNAT-2 as a general ability assessment and further investigate the positive correlation between the NNAT-2 scores and visuo-spatial working memory. In addition, do all nonverbal ability tests positively correlate with visuo-spatial working memory? If so, future researchers may posit the acceptable use of such assessments for certain educational settings.

Implications for Educators

The implications of this study for educators, students, and parents are important. When all groups become aware of working memory and its significance in academic success, all can recognize the importance of additional training and understanding in order to improve the educational system. Working memory is not a widely understood concept in American schools and therefore many children with working memory deficits are falling through the cracks in the classrooms (Dehn, 2011). Teachers who recognize a working memory deficit can implement strategies in classrooms to remediate the deficits before a child falls too far behind.

Verbal working memory is critical in learning speech sounds, identifying words, and reading comprehension (Gathercole et al., 2006). A child struggling in reading at the early grade level can receive working memory assessments, as well as language screenings, to discern if working memory is a reason why the child is having difficulty in reading. Verbal working memory is also important in learning the basic arithmetic facts and computation such as carrying digits in multi digit problem solving. Teachers can utilize strategies to help children with verbal deficits by arranging math problem in a vertical manner rather than horizontal to rely less on verbal working memory and more in visuo-spatial working memory. However, if the teacher is not aware of the importance of working memory, these accommodations will be underutilized.

Visuo-spatial working memory is utilized when students represent knowledge like place value, counting, representing size, attending to multiple step instructions, and note taking. If classroom educators do not recognize deficits in these important educational tasks, a student may not progress at his or her potential and be at risk for underachievement (Alloway et al., 2009a). Educators and parents alike should be aware of the importance of working memory and that interventions can be undertaken that may enhance the working memory ability of the child. Early diagnosis and interventions are vital for the continued success for children who may have deficits that can be remediated.

Children with poor working memory have characteristics that mimic attentional deficits, self-regulatory deficits, and executive dysfunction. Without an understanding of the basics of working memory, many teachers may assume these children are not behaving appropriately by choice and confuse an academic concern with a disciplinary issue. Teachers should have the resources available to assist in the identification of working memory deficits and professional development to learn how to accommodate teaching to allow these children to be successful.

RECOMMENDATION FOR FUTURE RESEARCH

Reiterating the literature and meta analysis on improving working memory is essential in American education. Future research should focus on the far transfer effects of the working memory intervention programs. Research that asks and answers questions about the role of working memory and reading comprehension should be conducted.

Alternatively, research that studies the relationship between the completion of a working memory intervention program and the impact on math fluency skills can be performed. These questions are important next steps in the understanding of working memory in schools.

The controversy over the programs that claim to improve working memory and the financial incentives for the use of such program is a fine academic debate; yet, to receive funding for additional research in American schools, the research must include the far transfer effects in the core subjects of reading and math. Schools in the United States are spending millions of dollars each year on interventions for struggling students and the absence of working memory interventions is downheartening. Research and educational funding will only come when awareness can be raised at the policy level. Educating schools, administrators, teachers, and parents can occur when research that demonstrates far transfer are available and provided at the local school level. Future research has to have an educational mission to begin the dialogue that focuses on the core subjects that are of concern in most educational communities.

Another area for future research is an understanding of working memory and the identification of giftedness. There is not one single definition of giftedness in the United States; rather, each state sets the criteria for identification based on standardized test scores or checklists (Piirto, 2007). Is it possible that students identified as academically gifted or superior cognitive ability have higher working memory ability? Alloway and Elsworth (in press) asked a poignant research question in a study in Great Britain that could be a direction of future research in the United States: Do high ability students have an increased working memory ability or do they use better memory strategies than the average student? Advances in understanding how to educate gifted students is important as educational funding is being cut, and many gifted programs are being phased out of schools that need to conserve money. Promoting research that answers questions about both the identification of gifted children and educating more teachers about working memory is worthwhile as a contribution to the body of knowledge on both giftedness and working memory.

A final recommendation is a longitudinal study that follows a child or children with a working memory deficit on his or her educational journey. The voice of the child and parent is missing in the research on working memory. A phenomenological study or case study is missing from the literature to put the human face on the problem of working memory. In order to acquire research dollars or money in schools to provide interventions for children with working memory deficits, the story of the child and his or her educational struggles must be told. Similar to the path many researchers have taken to redefine dyslexia in the American school, the same should be done for working memory. Crossing the bridge from education and neuroscience to understand the brain and how it works will benefit many children and educators. Putting the personal story with the neuroscience expertise will allow for a better understanding of this important concept in education.

CONCLUSION

Working memory is paramount for academic success. Understanding the significant role working memory has in teaching and learning should be a component of all educational programs and professional development provided to teachers. Educating the professionals who teach children about the importance and significance of working memory is a valid endeavor to increasing academic achievement in all schools. Schools are striving to improve and find intervention programs to assist children with learning difficulties.

Integrating neuroscience and teaching can revolutionize education if done in a responsible manner. Research that integrates education, cognitive science, and neuroscience should continue as a means to find solutions that assist children but not as expensive silver bullets that are advertised to cure or replace professional educators. Evidenced based programs and interventions should be investigated and implemented only if the research can substantiate the claims that the programs are successful for the targeted audience.

The results of this research study do not indicate that the *Jungle Memory*® brain-training program can fulfill the evidenced based requirement outlined. It did not improve the working memory ability of the students who needed it the most, therefore from a research perspective I would not recommend a school district invest in the program alone as an intervention for students who have working memory deficits. I remain, however optimistic that ultimately, through research and reflection, we can find the programs that help the neediest of students.

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APPENDIX A

HUMAN SUBJECTS REVIEW BOARD APPROVAL

APPENDIX A

HUMAN SUBJECTS REVIEW BOARD APPROVAL

ASHLAND
UNIVERSITY

TO:	Misty Swanger
FROM:	Brent Mattingly, HSRB Acting Chair
DATE:	February 15, 2013
SUBJECT:	Human Subjects Review Board Approval
PROJECT TITLE:	Working Memory and Education
HSRB APPROVAL CODE:	02-08-13-#090

The Human Subjects Review Board has approved the research proposal you submitted. You may proceed with the project.

The primary function of the HSRB is to ensure protection of human research subjects. As a result of this mandate, we ask that you pay close attention to the fundamental ethical principles of autonomy, justice, and beneficence when establishing your research proposal. These ethical principles pertain specifically to the issues of informed consent, fair selection of subjects, and risk/benefit considerations.

If you have any questions, please contact me.

Sincerely,

[redacted]

Phone: 419-289-5342
E-mail: bmatting@ashland.edu

Graduate School | 401 College Avenue | Ashland, Ohio 44805 | 419.289.5750

APPENDIX B

PARENT CONSENT FORM

APPENDIX B

PARENT CONSENT FORM

Working Memory in Education

A. PURPOSE AND BACKGROUND

Misty Swanger in Ashland University's Leadership Studies Program is conducting a quasi-experimental research study on working memory in education. Your child is being asked to participate in this study.

B. PROCEDURES

If you agree for your child to be in the study, the following will occur:

1. ______________________ (child's name) will complete a pre-assessment on both working memory and cognitive ability. The working memory assessment will be completed on a computer and the cognitive ability test will be completed in a small group setting.
2. _______________ (child's name) will be given a user name and password to complete an online brain-training program. This program will be in a game format and will be completed three times a week for 30 minutes each session.
3. _______________ (child's name) will complete a post assessment on both working memory and cognitive ability. The working memory assessment will be completed on a computer and the cognitive ability test will be completed in a small group setting.
4. Pseudonyms will be used on data and additionally, all identifying information will be removed or changed to maintain the confidentiality of all subjects.
5. Parents may submit a written request for access to their child's scores at the end of the intervention and testing, in June 2013.

C. RISKS/DISCOMFORTS

1. Some of the questions might be difficult to answer, however it is important for your child to answer all of them honestly and to the best of his or her ability.
2. Participation in this research will involve no loss of privacy and your child' records will be handled confidentially.

D. BENEFITS AND USES OF DATA

This study provides an opportunity for schools to learn about a training program that may or may not be able to enhance student learning. Misty Swanger will use the information for her doctoral dissertation at Ashland University. No publication or presentation of the study's results will contain any identification of students who participated in the study.

E. COSTS/PAYMENT

There will be no costs to your student as a result of taking part in this study. You will receive no payment for your participation in this study and you will not lose anything if you do not participate in this study.

F. QUESTIONS

You have the opportunity to ask Misty Swanger any questions about this study. Please contact Misty Swanger via email at mswanger@ashland.edu You may also contact the chair of this dissertation: Dr. Carla Edlefson at cedlefso@ashland.edu

The Ashland University Human Subjects Review Board regulates research ethics at Ashland University. If you have concerns, contact Dr. Brent Mattingly, Chair, phone: (419) 289-5342, or e-mail: bmatting@ashland.edu

G. CONSENT

You will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. Your child is free to decline to be in this study, or to withdraw from it at any point. Your and your child's decision as to whether or not to participate in this study will have no influence on the present or future status of your child.

If you agree to participate, you should sign below.

___________________________ ____

Date Signature of Parent/Guardian of Participant

APPENDIX C

STUDENT CONSENT FORM

APPENDIX C

STUDENT CONSENT FORM

Working Memory in Education

A. PURPOSE AND BACKGROUND

I understand that my parents/guardian have/has given permission for me to participate in a study concerning working memory under the direction of Ms. Swanger.

B. PROCEDURES

I understand I will be given pre and post test during this project. I understand I will play a computer game three times a week for up to 30 minutes.

C. RISKS/DISCOMFORTS

I understand I may not know all the answers to the test questions, but will do my best to answer all questions.

D. BENEFITS

I understand this project may benefit schools and students in the future.

E. QUESTIONS

I understand I can ask Ms. Swanger any question I have about this project

F. CONSENT

My participation in this project is voluntary. I am taking part because I want to. I have been told that I can stop at anytime I want to, and nothing will happen to me if I want to stop.

______________________________ ________________________

Participant Signature Date

APPENDIX D

SCHOOL DISTRICT SUPPORT LETTERS

APPENDIX D

SCHOOL DISTRICT SUPPORT LETTERS

[redacted]

[redacted]

[redacted]

To Dr. Carla Edlefson:

Please accept this letter as confirmation of my support for doctoral student, Misty M. Swanger, to complete her dissertation research at [redacted] Intermediate School. I understand that Misty will recruit student participants for the project and all participants and parents will complete a consent form in order to participate in the research study. Each participant will be free to withdraw from the study at any time.

Although as an employee of the district, I understand the data collected by Ms. Swanger is confidential and will not be shared with the school district. Misty will have access to student computer labs and classroom space in order to carry out the assessments and interventions as outlined in the research proposal.

Misty has shared her research methodology and intervention protocol with me. I support the use of this intervention with the students who choose to participate. I understand Misty will have approval from Ashland University's Human Subjects Review Board before proceeding with the dissertation project.

Please do not hesitate to contact me if you have any questions regarding my support of Misty Swanger's dissertation and the use of students from [redacted].

[redacted]

[redacted]
Superintendent of Schools

[redacted]

[redacted]

[redacted]

[redacted]

To Dr. Carla Edlefson:

Please accept this letter as conformation of my support for doctoral student, Misty M. Swanger, to complete her dissertation research at [redacted] Intermediate School. I understand that Misty will recruit student participants for the project and all participants and parents will complete a consent form in order to participate in the research study. Each participant will be free to withdraw from the study at any time.

Although an employee of the district, I understand the data collected by Ms. Swanger is confidential and will not be shared with the school district. Misty will have access to student computer labs and classroom space in order to carry out the assessments and interventions as outlined in the research proposal.

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Please do not hesitate to contact me if you have any questions regarding my support of Misty Swanger' s dissertation and the use of students from [redacted] Intermediate School.

Sincerely

[redacted]

[redacted]

APPENDIX E

SAMPLE PARENT REPORT

APPENDIX E

SAMPLE PARENT REPORT

A[redacted]

11.20

Naglieri Nonverbal Ability Test (NNAT-2)
Reported as Index Score with 100 as average

Pretest score: 103

Posttest score: 108

Automated Working Memory Assessment (AWMA-2)
Reported as percentile score with 50 as average

Verbal Working Memory Pretest: 70

Verbal Working Memory Posttest: 75

Visuo-Spatial Working Memory Pretest: 68

Visuo-Spatial Working Memory Posttest: 97

The AWMA-2 measures working memory. Verbal working memory refers to the capacity to hold in mind and manipulate verbal information over a brief period. This includes material that is expressed in spoken language, such as words, numbers, and sentences. Visuo-spatial working memory refers to the ability to hold in mind and manipulate visuo-spatial information for a brief period. Visuo-spatial memory includes images, pictures, information about location, and physical characteristics. Both verbal and visuo-spatial working memory abilities are closely associated with a wide range of measures of academic ability, including literacy and mathematics (Alloway, 2011).

The NNAT-2 measures general ability (*g*), which is the foundation, that allows for learning regardless of what is being taught. G is utilized in the solving of problems including but not limited to verbal, quantitative reasoning, memory, sequencing, patterning, verbal skills, math skills, connecting ideas across content, making insights and connections, drawing inferences, and analyzing simple and complex ideas (Naglieri, Brulles, & Lansdowne, 2008).

Examples of classroom behaviors for children with low working memory:

- Incomplete recall (forgetting some of the words in a sentence)
- Failure to follow instructions and/or frequently asks for help
- Place keeping errors (repeat or skip items when reading or writing)
- Raise hand to answer a question and frequently forgets what he or she intended to say
- Abandon tasks
- Lack of academic progress or growth especially in literacy and math
- Appear to be easily distracted or have short attention span (but not usually disruptive to others)
- Difficulty with sequences
- Difficulty transcribing notes from board or book to paper
- Require regular repetition of instructions
- Carries out some of the steps, but not all steps in an activity or from instructions