ABSTRACT

THE EFFECT OF A COMPUTERIZED, COGNITIVE INTERVENTION ON THE WORKING MEMORY AND MATHEMATICAL SKILL PERFORMANCE OF INNER-CITY CHILDREN

by Christen Rose Davis

This study examines the effectiveness of a computerized, cognitive intervention on the working memory capacity and mathematical performance of elementary students from an urban school. Working memory and mathematics performance were measured using two subtests from the Wechsler Intelligence Scale for Children-Fourth Edition (Wechsler, 2003), the Calculation subtest from the Woodcock-Johnson Psychoeducational Battery – Third Edition (Woodcock, McGrew & Mather, 2001), and the Math Concepts and Applications (MCAP) and Math Calculation (MCBM) assessments from AIMSweb®. Results were analyzed using a paired samples t-tests to evaluate if working memory and mathematics performance scores significantly increased after the cognitive intervention. Results reflected significant differences in working memory capacity and mathematical performance after the intervention. Implications of these results, future research directions, and tips for using cognitive interventions within an RTI framework are discussed.
THE EFFECT OF A COMPUTERIZED, COGNITIVE INTERVENTION ON THE WORKING MEMORY AND MATHEMATICAL SKILL PERFORMANCE OF INNER-CITY CHILDREN

A Thesis

Submitted to the
Faculty of Miami University
in partial fulfillment of
the requirements for the degree of
Educational Specialist
Department of Educational Psychology

by
Christen Rose Davis
Miami University
Oxford, OH
2012

Advisor: _______________________
Dr. Michael Woodin

Reader: _______________________
Dr. Raymond Witte

Reader: _______________________
Dr. Iris Johnson

Reader: _______________________
Dr. Jane Bogan
## Table of Contents

- Chapter 1: Introduction ........................................ Page 1  
- Chapter 2: Review of Literature .......................... Page 3  
- Chapter 3: Method ............................................. Page 12  
- Chapter 4: Results ............................................. Page 14  
- Chapter 5: Discussion ........................................ Page 18  
- References ....................................................... Page 21  
- Appendices ...................................................... Page 25
List of Tables

Table 1: General Frequency Statistics  
Table 2: Paired Samples’ Statistics  
Table 3: Paired Samples t-tests
List of Figures

Figure 1 Page 3
Chapter 1
Introduction

Working memory is a cognitive process that provides temporary storage and manipulation of information while simultaneously engaging and integrating other cognitive activities (Baddeley, 2002). In 1974, Baddeley and Hitch proposed an influential model of working memory. Today, their model has been expanded and is composed of four components. The coordinating element is known as the central executive system and is responsible for a range of cognitive activities, such as processing, storage, retrieval, and scheduling of multiple, concurrent information (Baddeley, 1986). The other three parts are more specialized: the phonological loop retains acoustic and verbal material, the visuo-spatial sketchpad stores and manipulates visual and spatial information, and the episodic buffer assembles information from working memory to long-term memory (Baddeley, 2002).

Recent studies on working memory have shown that this specific cortical process plays a crucial role in high-level cognitive abilities, like maintaining focused behavior and academic learning. For instance, most children with Attention Deficit Hyperactivity Disorder (ADHD) have a working memory deficit (Stevens, Quittner, Zuckerman, & Moore, 2002). Gathercole and Pickering (2001) found that learning difficulties, sufficient enough to warrant special education support, appear to be closely linked with very poor working memory capacities, as well. In addition, extensive studies of the relationship between working memory and reading (Alloway, 2006; Gathercole, Pickering, Knight, & Stegmann, 2004; Swanson & Howell, 2003), and science achievement (Gathercole et al., 2004; Yuan, Steeple, Shavelson, Alonzo, & Oppezzo, 2006) have been established.

In addition to reading and science, mathematics is another academic area that is highly associated with the cognitive process of working memory. Many children with mathematical learning difficulties perform poorly on mathematical tasks due to impairments of their working memory (Gathercole & Alloway, 2008; Gathercole et al., 2004; Gathercole & Pickering, 2000; Geary, Hoard, Byrd-Craven, Nugent, & Numtee, 2007; Mabbot & Bisanz, 2008, McLean & Hitch, 1999; Passolunghi & Siegel, 2004; Swanson & Sachse-Lee, 2001; Wilson & Swanson, 2001). Because working memory is such a significant factor in academic achievement, research directed toward exploring strategies and training programs to develop this cognitive process is ongoing.

In 2001, a computerized, training program was designed to increase working memory performance (Cogmed Working Memory Training™, 2006). This program, developed by Cogmed Working Memory Training™, has participants completing tasks that require the storage and manipulation of verbal and visuospatial information on a daily basis for five weeks. One of the first studies to employ the Cogmed Working Memory Training™ focused on attention, a working memory component. In a randomized, controlled trial, researchers trained 53 children, ages 7- to 12-years-old, who were identified with ADHD (Klingberg et al., 2005). This experiment shows that working memory is plastic and can be improved through intensive training in children with ADHD.

Encouraged by evidence that working memory can be trained, experimenters Holmes, Gathercole, and Dunning (2009a), from the University of York, decided to examine the educational significance of the Cogmed Working Memory Training™ program in children without ADHD and determine whether improvement of working memory function was of sufficient degree to overcome learning difficulties associated with poor working memory.
performance. In a 6-week study, 22 English children completed the adaptive, working memory training and improved their working memory scores to age-appropriate levels. This study also provides the first demonstration that academic deficits and learning difficulties can be improved, and possibly overcome, through intensive working memory training. More specifically, at the 6-month follow-up, the students showed a significant gain in their ability to follow spoken directions and in their mathematical reasoning scores (Holmes et al., 2009a). Thus far, the studies that have been conducted have investigated the positive impact of the Cogmed Working Memory Training™ as an evidence-based intervention with children from Europe.
Chapter 2
Review of Literature

Working Memory

Working memory is a cognitive process which allows a person to multitask, or simultaneously think about and hold information at the same time he or she is completing other tasks. According to Berch and Mazzocco (2007), working memory allows one the ability to temporarily hold a mental representation of information in the mind while concurrently engaging in other mental processes. It is a system responsible for temporarily storing and manipulating information (Alloway, 2006). This is different from short-term memory, which is more a passive storage of the information (Baddeley & Hitch, 1974), and involves only retention and repetition of information without any manipulation, distraction, or demand for simultaneous performance (Klingberg, 2009). Working memory is also one of the major executive functions associated with the frontal lobes of the brain (Stuss & Alexander, 2000). To date, there exists a variety of models describing working memory’s structure and function.

In 1974, Baddeley and Hitch pioneered the most widely accepted and influential model of working memory. Today, their model has been expanded and is composed of four components (See Figure 1). The central executive system is an attention-driven control center for information and is responsible for performing a series of high-order functions, such as ignoring irrelevant information, switching between different retrieval strategies, and temporary activation of long-term memory information (Baddeley, 1986). It processes, stores, retrieves, and organizes multiple cognitive activities simultaneously, and coordinates the functions of the other three systems of working memory: the phonological loop, the visuospatial sketch pad, and the episodic buffer (Baddeley, 1986; Baddeley, 2002). The phonological loop retains acoustic and verbal material, while the visuospatial sketchpad stores and manipulates visual and spatial information, such as shapes, locations, or movements. Both are domain specific. The episodic buffer, introduced as a critical part of the working memory model by Baddeley in 2000, is a limited-capacity system that integrates information from a variety of sources, including both temporary, working memory and long-term memory (Baddeley, 2000).

Figure 1. A schematic adaptation of the Baddeley and Hitch model of working memory

Working memory has gained much interest in the world of research. Accordingly, there have been many measures developed to assess an individual’s working memory capacity and ability. These tests generally require those taking them to process and store increasing amounts of information until the point at which recall errors are made (Alloway, 2006). One of these
measurements is a memory span task, where participants are presented with a series of letters or digits and are asked to recall those stimuli in the same or reverse order as presented. There are also dual-tasks which consist of both a processing and memory task. Many academic tasks, such as mathematical calculation, are dual-tasks.

There is often a large degree of individual variation on these tasks, as well as a substantial degree of variability in working memory capacity at each developmental age (Alloway, 2006). Working memory capacity grows as a person develops from childhood to adolescence, and its ability does not seem to favor one gender over the other (Gathercole, 2008). This growth allows for greater amounts of information to be simultaneously processed and stored (Montague & Jitendra, 2006). Still, despite this growth, its capacity is limited and stored information is easily lost through distraction or overload (Alloway, 2006; Gathercole, 2008). According to Alloway (2006) “carrying out such mental activity is a process that is effortful and error-prone”. Therefore, those with poor capacities or abilities will struggle to meet the heavy working memory demands of many situations (Gathercole, 2008).

Working Memory and Academic Learning

Working memory has been found to be important in many areas of high-level cognitive functioning, such as reasoning, problem-solving, and learning. As of today, evidence linking working memory to academics is extensive. Recent studies on working memory have shown that this specific cortical process plays a crucial role in high-level cognitive abilities, like maintaining focused behavior in school children. For instance, most children with ADHD have a working memory deficit (Stevens et al., 2002) and are unable to focus their attention on learning (Gathercole, 2008).

Working memory has also been related to performance in specific academic areas. A child with poor working memory capacity will often fail in classroom learning activities, disrupting and delaying learning (Alloway, 2006). Teachers may assign lack of attention or decreased motivation to children who cannot meet the working memory demands of the classroom. As a result, these children may make poor academic progress (Alloway, 2006). What we know is that working memory plays a crucial role in key learning areas for children at the beginning of formal education (Alloway et al., 2005). In fact, the connection is so strong that working memory measures, such as digit span, appear to be valid and reliable indicators of later academic attainment (Gathercole, Brown, & Pickering, 2003; Gersten, Jordan, & Flojo, 2005). For children whose working memory ability falls below the 10th percentile, 80 percent have substantial problems in reading or mathematics or both (Gathercole & Alloway, 2008). Recent work has established close associations between children’s capacity to store and manipulate material over short periods of time and their scholastic progress in the domains of language, mathematics, and science across both the primary and secondary school years (Gathercole & Alloway, 2008; Gathercole et al., 2004; Gathercole & Pickering, 2001).

Gathercole and Pickering (2000) found that children who fall below expected levels on standardized national achievement tests show considerable deficits in working memory. In 2001, they also discovered that 6- and 7-year-old children with learning difficulties in language, literacy, and mathematics, sufficient enough to warrant special education support, performed very poorly on many measures of working memory. These results were duplicated by Alloway et al. in 2005. Swanson, Cochran, and Ewers (1990) also found that children with learning disabilities showed impaired performance in working memory tests. In another study, Gathercole et al. (2003) examined the relationship between working memory skills and
performance on national curriculum assessments in English, mathematics, and science for children ages 7 and 14. Results showed that there were close associations between children’s scores on working memory measures and their scores on national curriculum assessments. Achievement in English, mathematics, and science were significantly correlated with working memory scores at age 7, and the strong links persisted at age 14 between complex working memory test scores and attainment levels in mathematics and science. Acquisition of literacy was also linked to working memory capacity (Gathercole et al., 2003).

In summary, there have been extensive studies of working memory’s relationship with ADHD (Stevens et al., 2002), reading (Alloway, 2006; Gathercole & Alloway, 2008; Gathercole et al., 2004; Gathercole & Pickering, 2000; Swanson & Howell, 2003; Swanson & Sachse-Lee, 2001), science (Gathercole & Alloway, 2008; Gathercole et al., 2004; Gathercole & Pickering, 2000; Yuan et al., 2006), standardized national achievement test scores (Gathercole et al., 2003; Gathercole & Pickering, 2000), and learning disabilities (Gathercole & Pickering, 2001).

**Working Memory and Mathematical Difficulties**

One other significant academic area that is highly associated with the cognitive process of working memory is mathematics. Mathematics has a natural connection to working memory, which is why many working memory measures are digit-based. Mathematical problem solving is also greatly linked to working memory. The effortful, multistep process of mental arithmetic is an everyday activity that uses this cognitive process. For example, when adding 2 numbers, without pencil and paper, a person must store these numbers in working memory, systematically apply addition rules found in one’s long-term memory, and temporarily store the intermediate sums that are generated through the stages of calculation (Alloway, 2006). In a more recent study, Meyer, Salimpoor, Wu, Geary, and Menon (2010) found that specific components of working memory seem to be connected to the development of certain mathematical skills depending on a child’s age. In their study, the central executive and phonological loop were observed to facilitate mathematical reasoning performance at an early elementary age, whereas the visuo-spatial sketchpad was shown to play a more significant role in both mathematical reasoning and numerical operations during the late elementary school years. This natural relationship between working memory and mathematics makes for particularly interesting studies of mathematical education.

Mathematical learning is an essential component in education and mathematical difficulty can strongly impair functioning in school environments and everyday life (Passolunghi, Vercelloni, & Schadee, 2007). There are many children in school who experience difficulty in mathematics. These children are those who perform in the low-average to deficit range, which is at or below the 35th percentile, on tests of mathematical achievement (Hanich, Jordan, Kaplan, & Dick, 2001). Many labels exist for children who fall into this range. Under the *Individual with Disabilities Education Improvement Act* (IDEIA 2004), a student can be classified as having a Specific Learning Disability (SLD) in mathematics and offered educational services outside the general education curriculum. According to the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, Text Revision* (DSM-IV-TR; American Psychiatric Association, 2000), a child with substantially low arithmetic ability is diagnosed as having a Mathematics Disorder. Also, Dyscalculia is sometimes used to describe mathematical impairment (Berninger, O’Donnell, & Holdnack, 2008). For the purposes of this paper, Mathematical Learning Disability (MLD), a specified learning disorder in which a child shows severe lack of performance on mathematical skills (Berch & Mazzocco, 2007), will be the label used.
Much research of MLD has focused on three sources of mathematical disability: difficulty in accurately and automatically retrieving basic arithmetic facts from long-term memory (Gersten et al., 2005; Swanson, 1993), use of developmentally immature calculation procedures (Barrouillet, Fayol, & Lathuliere, 1997), and have issues with visuospatial representation of numerical information (Geary, 1993). Due to an inability to retrieve facts from memory, students with MLD often commit more errors and have a slower reaction time (mastery and fluency) when solving arithmetic facts in comparison to their peers (Barrouillet et al., 1997). They also struggle with counting and number sense (Gersten et al., 2005).

Approximately five to eight percent of students have a MLD (Geary, 2004; Gross-Tsur, Manor, & Shalev, 1996), which is just as common as a reading disability. In fact, many children who present with mathematical difficulties also have comorbid difficulties in reading and attention (Gross-Tsur et al., 1996). However, unlike reading and attention difficulties, research on learning difficulties in mathematics has progressed more slowly (Geary, Hamson, & Hoard, 2000; Gersten et al., 2005). Still, many students are being identified with MLD.

MLD can be determined through use of the discrepancy model, which defines mathematical disability as involving a significant discrepancy between IQ and achievement, or through the response-to-intervention (RTI) model. RTI is a multi-tiered, intervention approach schools use to help struggling students in general education. Student progress is monitored closely at each tier and research-based instruction is implemented based on formative evaluation and data-based decision making. Employing this model, students would be classified as MLD only after attempts at group and individual interventions have been exhausted. The use of the RTI model to evaluate specific learning disorders is currently gaining favor in schools (Fuchs et al., 2005). More specific to MLD, this model is increasingly being applied in elementary and middle schools to promote high-quality math instruction, to identify students who are struggling with mathematics, and to execute early, evidence-based interventions to improve their mathematical ability (Gersten et al., 2009).

Many cognitive deficits have been associated with MLD and mathematical difficulties in children. “The use of experimental and neuropsychological measures suggest that the five to eight percent of elementary school students have some form of specific cognitive deficit that interferes with learning and understanding numerical and arithmetical concepts, procedures or facts” (Geary, 2004). In a study conducted by Geary et al. (2000), memory retrieval deficits of children with mathematical difficulties was not a result of a lack of exposure to mathematical instruction, poor motivation, low confidence, or low IQ, but was reflective of a cognitive deficiency.

More recent studies have sought to determine which cognitive function is responsible for mathematical performance. In a study of cognitive processes and mathematical problem solving, Passolunghi and Siegel (2001) found that poor problem solvers showed a general impairment on working memory tests, but not in typical tests of short-term memory. Similarly, Berg (2008) found that among 90 child participants, grades three through six, the cortical functions of processing speed and short-term memory did not eliminate the contribution of working memory to arithmetic calculation. Swanson, Jerman, and Zheng (2008) also discovered that working memory contributed to mathematical problem solving beyond the cortical functions related to processing speed, phonological knowledge, reading skill, or calculation ability. This means that the majority of students with mathematical difficulties have a cognitive deficit solely in working memory that interferes with their ability to perform mathematical skills (Berch & Mazzocco, 2007; Geary, 2004; Geary et al., 2000; Montague & Jitendra, 2006).
Recently, there has been much debate as to if mathematical difficulties are due to domain-general or domain-specific working memory deficit, or which of the various components of working memory affect mathematical ability. Several studies suggest that children with arithmetic difficulties have a generalized deficit in working memory (Passolunghi & Siegel, 2001; Swanson, 1993; Swanson & Sachse-Lee, 2001). For instance, Passolunghi and Siegel (2001) found that children with a mathematical disability performed poorly on both numerical and verbal working memory tasks. Many of the mathematical tasks mentioned earlier, including addition, multiplication, word problem solving, are partially or fully mediated by working memory, and all four components of Baddeley’s working memory model (2000) contribute to mathematical performance these tasks. This is known as domain-general processing (Swanson, 1993; Swanson & Sachse-Lee, 2001). On the other hand, there is domain-specific processing.

In an assessment in which nine-year-old children with mathematical difficulties were compared to age-matched and ability-matched control groups, children with poor working memory and their ability-matched peers had deficits in executive and spatial aspects of working memory, but normal phonological working memory relative to age-matched peers (McLean & Hitch, 1999). These deficits in executive and spatial aspects of working memory seem likely to be important factors in poor arithmetical attainment. Similarly, Berg (2008) found that both verbal and visuospatial each contribute to arithmetic calculation. One likely conclusion is that mathematical difficulties are mediated by both a domain-general and domain-specific working memory system (Wilson & Swanson, 2001). Today, many working memory interventions are specifically tailored to address these difficulties by enhancing both domain-general and domain-specific aspects of working memory (Cogmed Working Memory Training™, 2006).

Having a cognitive deficit in working memory, be it either domain-general or domain-specific, means that students will perform poorly on mathematical tasks in which they must manipulate or transform material while remembering information and disregarding irrelevant information (Passolunghi & Siegel, 2001). A number of studies have been conducted to determine just how many mathematical tasks are hampered by poor working memory capacity and ability.

An experiment by Passolunghi and Siegel (2004) examined the relationship between working memory, mathematical ability, and the cognitive impairment of children with difficulties in mathematics. For this study, a group of children presenting with mathematical difficulties was compared to a group of children with normal achievement. A total of 59 participants, matched on age, gender, and vocabulary, performed tasks in working memory and short-term memory. They found that children with mathematical disabilities were impaired in simple and basic arithmetic skills, as well as higher order processes, like the ability to identify the correct operation in a word problem. The results also showed that the children with mathematical difficulties had a persistent deficit in working memory, specifically in the central executive component and primarily in the ability to inhibit irrelevant information. Similarly, Geary et al. (2004, 2007) found that children with MLD and poor working memory skills showed deficits across math cognition tasks, including counting, number representation, and addition.

Research aimed at exploring the working memory functions in children with low arithmetical achievement and normal reading ability was conducted by D’Amico and Guarnera (2005). In their study, 50 children, with an average age of nine, completed a series of working memory tasks involving the central executive functions, the phonological loop, and the visuospatial sketchpad. Results show that poor arithmeticians performed worse on all the central
executive and visuospatial sketchpad tasks, and unachieved with the digit span forward portion of the phonological loop task. This could explain why students with mathematical difficulties have issues with mental and written calculations that require them to simultaneously retain information while transforming new incoming items (D’Amico & Guarnera, 2005).

In another study by Geary et al. (2007), three groups of kindergarten children from 12 different elementary schools participated in a longitudinal study. These three groups were classified as math disabled (MLD), low achieving, and typically achieving students, and were administered a battery of mathematical cognition, working memory, and speed of processing measures. The children with MLD showed substantial deficits across all math cognition tasks when compared to the typical achieving students. Many of these deficits were partially or fully mediated by working memory or speed of processing. The children with MLD also had significantly lower scores on measures of the phonological loop, visuospatial sketch pad, and central executive measures relative to the two other groups. In comparison of the typical achieving and low achieving students, there were no significant differences on the three working memory measures.

Mabbot and Bisanz (2008) led a study that investigated knowledge and skill in multiplication for late elementary-grade students with MLD. These students were compared to low-achieving, typically-achieving, and ability-matched peers. All groups were examined through measures of computational skill, working memory, and conceptual knowledge. They found that children with MLD used a greater number of procedures, used retrieval less frequently, were less accurate overall, were slower to solve simple multiplication problems, and had smaller operation and digit spans relative to average-achieving peers. They also had lower multiplication fact mastery, calculation fluency, and working memory than their typical-achieving peers, and were slower in executing backup procedures. Their performance was similar to low-achieving age-matched students, except that children with MLD appeared to display poorer general working memory skills. Their multiplication knowledge and skill most resembled that of the ability-matched younger children. Therefore, MLD may be due to difficulties in computational skill and working memory.

Working memory plays a crucial role in solving arithmetic word problems (Geary et al., 2000). Poor working memory was found to predict word problem solving solution accuracy (Passolunghi & Siegel, 2001; Swanson et al., 2008; Swanson & Sachse-Lee, 2001). Only one study found a weak relation between working memory and math problem solution accuracy (Swanson, Cooney, & Brock, 1993). An investigation to explore the relationship between working memory and mathematical problem solving in children with learning disabilities (LD) was conducted by researchers Swanson and Sachse-Lee in 2001. They compared children with LD to age-matched and achievement-matched peers on measures of general working memory, verbal and visuospatial working memory, phonological processing speed, components of problem-solving, and word-problem solution accuracy. Results showed that children with LD were inferior on all components except for visuospatial working memory when compared to age-matched children, and similarly compared to the younger ability-matched children on most all the components except general working memory and visuospatial working memory. They also found that the measures of the domain-specific working memory (verbal and visuospatial) contributed significantly to variance in solution accuracy.

In a longitudinal study conducted by Swanson et al. (2008), 353 elementary school children, who were at risk and not at risk for serious math difficulties, were examined to see if their working memory ability influenced their mathematical problem solving solution accuracy.
The children identified as at risk showed less growth rate of working memory and lower levels of performance on cognitive measures than did children not at risk. Also, the assessed components of working memory seemed to predict future word problem solving solution accuracy, with at-risk students performing worse on both tasks in comparison to their not at risk peers. Their data supports the notion that the capacity to store and process materials in working memory constrains a child’s ability to problem solve during the elementary school years.

Working memory is also a reliable indicator of mathematical disabilities in the first year of formal school (Gersten et al., 2005). In a study with 170 primary school students, Italian researchers, Passolunghi et al. (2007) determined that the working memory assessments given to the students were the most distinct and significant predictor of mathematics learning at the beginning of primary school and of children’s overall mathematical abilities.

Although the relation between working memory and difficulties in completing mathematical problems is not yet fully understood, it is clear that working memory is a central deficit in children with mathematical difficulties (Gathercole & Alloway, 2008; Gathercole et al., 2004; Gathercole & Pickering, 2000; Geary, 2004; Geary et al., 2007; Mabbott & Bisanz, 2008, McLean & Hitch, 1999; Passolunghi & Siegel, 2004; Swanson, 1993; Swanson & Sachse-Lee, 2001; Wilson & Swanson, 2001). Students who present with mathematical difficulties and a working memory deficit will typically need adaptations and accommodations in mathematics classes if they are going to succeed in the general curriculum (Montague & Jitendra, 2006). In this time, when schools and federal law are embracing the RTI model, evidence-based interventions are also being applied to tackle these issues.

**Working Memory Treatment for Mathematical Difficulties**

Until recently, many did not believe that low working memory ability could be remedied. However, recent studies have suggested its plasticity, meaning working memory can be improved. Because working memory is such a considerable factor in behavior and academic achievement and the use of evidence-based interventions is highly important in today’s educational climate, researchers are currently exploring strategies and direct instructional programs that focus on improving cognitive function, in particular working memory. And, because mathematical difficulties are so hindering, various working memory interventions have been implemented for the purpose of improving mathematical ability.

Turley-Ames and Whitfield (2003) performed three experiments examining how certain types of strategy training influenced working memory performance. In a pretest-posttest design, all participants completed two versions of a working memory span measure, with half of the participants received strategy instructions prior to the posttest. They found that participants with low working memory spans benefited the most from rehearsal strategy instruction versus semantic or imagery strategies. Gathercole (2008) also suggests encouraging students to use memory aids to strategies to support memory. Another method shown to effectively help students’ learning and poor working memory capacity is to decrease the cognitive load processed by the students by redesigning academic presentation methods and learning materials (Gathercole, 2008; Sweller, van Merrienboer, & Paas, 1998). Teachers can be trained on how to recognize task failures due to working memory overload, monitor their students for these failures, and reduce or re-present the information when necessary (Alloway, 2006; Gathercole, 2008).

However, the practicality of these approaches is limited, and they do not allow for generalization across different academic domains (Yuan et al., 2006). Also, working memory
gains from strategy training often do not extend to varied learning situations that children experience daily (Holmes et al., 2009). This concern has also been noted by Turley-Ames and Whitfield (2003): “While the ideal solution would be to remediate these memory impairments directly, there is little evidence that training working memory in children with low working memory skills leads to substantial gains in academic attainments.” While these researchers are correct in their statement, new evidence-based interventions designed to directly target working memory capacity and skill have now been developed.

The Cogmed Working Memory Training™, a highly researched, computerized program, is an intensive working memory intervention developed to increase working memory function through a sustained period of practice on activities that tax working memory (Cogmed Working Memory Training™, 2006). The Cogmed Working Memory Training™ program, RoboMemo®, is composed of ten exercises, which include verbal, visuospatial, and numerical tasks. A robot guides program users through all tasks and reads letters or digits during the exercises. Participants respond to the program by clicking on the computer screen, and the program automatically adjusts the difficulty level to match the working memory ability of each individual. According to the Cogmed Working Memory Training™ (2006), increased working memory performance is seen in eighty percent of individuals who complete the training.

One of the first studies to employ the Cogmed Working Memory Training™ focused on attention, a working memory component. In a randomized, controlled trial, researchers from Sweden used the Cogmed Working Memory Training™ to train 53 children, aged 7 to 12, who were identified with ADHD but were not using stimulant medication (Klingberg, et al., 2005). Participants were randomly assigned to either the treatment, computer program for working memory, or a comparison program, and their working memory ability was measured through a visuospatial span-board task. Results showed a significant improvement in working memory, response inhibition, and complex reasoning for the children who were exposed to the training program. Parental ratings of inattention and hyperactivity/impulsivity also showed a significant reduction. The experiment proves that working memory is plastic and can be improved through intensive training in children with ADHD.

In a more recent study by Holmes et al. (2009b) investigated the extent to which the working memory deficits associated with ADHD can be ameliorated by two different forms of treatment: psychostimulant medication and the Cogmed Working Memory Training™. Twenty-five children, ages 8 to 11, with an ADHD diagnosis were trained in working memory skills for a minimum of 20 days. While medication significantly improved visuospatial working memory performance, working memory training led to substantial gains in all components of working memory (verbal and visuospatial) that were maintained six months after training.

Encouraged by evidence that working memory deficits can be alleviated, experimenters Holmes et al. (2009a) decided to examine the educational significance of the Cogmed Working Memory Training™ program in children without ADHD. They also wanted to determine whether improvement of working memory function was of sufficient degree to overcome learning difficulties associated with poor working memory performance. In a 6-week study, 22 English children completed the adaptive, working memory training and improved their working memory scores to age-appropriate levels. This study also provides the first demonstration that academic deficits and learning difficulties can be improved, and possibly overcome, through intensive working memory training. More specifically, at the six-month follow-up, the students showed a significant gain in their ability to follow spoken directions and in their mathematical reasoning scores (Holmes et al., 2009a).
The Present Study

The present study seeks to complement and extend the research completed by Holmes et al. (2009a) by reexamining the effects of the Cogmed Working Memory Training™ on working memory performance and mathematical skill ability. It hopes to determine if the Cogmed Working Memory Training™ computerized, evidence-based program, equipped with a progress monitoring component, can improve the working memory performance, and consequently the mathematical achievement, of urban school students, within a school environment that emphasizes an RTI framework by employing curriculum-based measurement (CBM) tools for benchmarking and progress monitoring, as well as a tiered-model of intervention and service delivery to students. Findings from this study will help to determine the efficacy of computerized, cognitive training as a working memory and mathematical processing intervention. It is anticipated that this training may not only improve the students’ current working memory ability, but also increase and enhance their mathematical achievement and problem-solving ability.
Chapter 3
Method

Participants
This study’s participants included 16 third, fourth, fifth, and sixth grade grade elementary students from an urban school in a Midwest state. The students ranged in age from seven to eleven years old, and all participated in a summer enrichment program offered by the school. All students that participated in summer school program were invited for participation. Informed consent was signed and collected by all participating children’s parents or legal guardians before beginning the study. Child assent was also obtained from the students.

Materials and Measures
For this study, the researcher employed the use of the Cogmed Working Memory Training™ RoboMemo® (2006), a computerized, multimedia training program (equipped for Windows) designed to improve working memory in school-aged children, ages seven and up. This program, which includes verbal and visuospatial working memory tasks, guides the student through multiple rotating exercises each day. The software was provided by Cogmed Working Memory Training™ and installed on the school computers. In the computer lab, each student was assigned a computer at which to work and save their training data. Researchers were trained as Cogmed Working Memory Training™ coaches, and learned how to load, manage, and provide technical assistance if any implementation issues arose. They then supervised the students’ training for approximately 45 minutes daily for five weeks.

A variety of selected measurement tools were used to assess the students. Various demographic information was collected from each participant, including age, gender, and year in school. This information was used to examine developmental differences in several areas of working memory and mathematics. The students also received tests of working memory and mathematical performance.

For this study, working memory was defined as the capacity and ability to simultaneously process and store information. The Cogmed Working Memory Training™ programs provided an initial assessment of a user’s working memory capabilities, and it monitored students’ progress with weekly measurements of working memory. In addition to the working memory assessment tools provided by Cogmed Working Memory Training™, the researcher and other trained graduate students administered the Digit Span and Letter-Number Sequencing subtests of the Wechsler Intelligence Scale for Children – Fourth Edition (WISC-IV; Wechsler, 2003). These are measures used to assess working memory in children ages six to sixteen. In Digit Span Forward, the child repeats numbers in the same order that the presenter reads them aloud. In Digit Span Backward, the child says the numbers backwards from what the presenter reads aloud. With Letter-Number Sequencing, the child is read a sequence of numbers and letters and then has to flexibly rearrange and recall the numbers first, in ascending order, and then the letters in alphabetical order. For these two subtests, one point is given for each correct sequence and zero points are given for each incorrect sequence. The subtests are discontinued after the student obtains all zeros within a number-letter set. Digit Span and Letter-Number Sequencing, have high test-retest reliability, .81, .75, and .75 respectively (Williams, Weiss, & Rolffhus, 2003). The scores attained for each of these two subtests are combined and provide a Working Memory Index (WMI) score for each child.

To gain an accurate measure of each student’s mathematical achievement, the Calculation test of the Woodcock-Johnson Psychoeducational Battery – Third Edition (WJ-III; Woodcock,
McGrew & Mather, 2001) was administered, before and after the Cogmed Working Memory Training™ intervention. This norm-referenced and individually administered subtest is suitable for people ages two and up and has a reliability of .86 (Schrank, McGrew, & Woodcock, 2001). It requires the student to independently solve representative paper-and-pencil, math computation problems with no assistance from the examiner. Within an RTI environment, traditional norm-referenced measures, such as the Calculation subtest, are often supplemented or replaced by the use of CBMs that can be used for benchmarking and progress monitoring purposes. As such, two CBMs designed for the area of mathematics were also given for this study. These include the AIMSweb® Math Concepts and Applications (MCAP) as well as the Math Calculation (MCBM; AIMSweb®, 2008) probes. These probes are standardized and the results are analyzed according to a large national aggregate norming sample. The MCAP measure has reliabilities between .80 and .86 for second through sixth grade level probes, and the MCBM measure has a reliability of .93 (AIMSweb®, 2008).

**Design and Procedure**

This study was intended as seminal pilot research and, as such, employed a descriptive pretest-posttest design. After receiving the principal’s approval to execute the Cogmed Working Memory Training™ program as part of the summer enrichment program, the parents and/or legal guardians of the elementary students were presented with a letter describing the study and a request for permission for their son or daughter to participate in the assessments and intervention program (see Appendix A). After parental consent was obtained, and child assent was acquired (see Appendix B), the researcher and trained graduate students began administering pretest measures (selected subtests from WISC-IV, WJ-III, and AIMSweb®, mentioned above). All measures were labeled with identification numbers to protect students’ confidentiality. The testing session lasted approximately 45 minutes for each child, and students were assured there would be no penalty for wrong answers or blank, unfinished work. The AIMSweb® math probes were administered by school staff during the spring and fall benchmarks.

The cognitive intervention occurred over a five week period in the school computer lab. The students used the Cogmed Working Memory Training™ tool for 30-45 minutes a day, Monday through Friday. Sessions were monitored by the researcher, who was trained as a Cogmed Working Memory Training™ coach, to assist students with technical difficulties and to monitor the progress of the training sessions. Weekly progress monitoring meetings were held for each individual student, too. The researcher was able to discuss individual progress with each student, using the Cogmed Working Memory Training™ program to visually display his or her performance. These meetings provided also an opportunity for researcher to offer encouragement and reward the student for his or her efforts. Tangible treats, such as bouncy balls, lip gloss, and pencils, were given to those students who completed all their training sessions for the week. The examiner also completed a standard treatment checklist to ensure treatment fidelity.

The post-intervention measurements took place after the 5-week training session was complete. At that time, the experimenter and fellow graduate students reassessed the students on levels of working memory (WISC-IV) and mathematics performance (WJ-III). AIMSweb® data was collected in the fall by the school staff. The pretest and posttest assessment scores were used for data analysis.
Chapter 4
Results and Analysis

The present research study attempted to answer the following hypothesis: Participation in the computerized, evidence-based, Cogmed Working Memory Training™ would improve the working memory performance, and consequently, the mathematical achievement, of urban school students.

Paired samples t-tests were used to evaluate the difference between eight measures of working memory and mathematical achievement before the intervention (PRE_) and after the intervention (POST_). Students showed significant gains in five out of these eight measures. General frequency statistics were also calculated for the demographic information (see Table 1).

Table 1: General Frequency Statistics

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th></th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
<td>Valid Percent</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>11</td>
<td>68.8</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>5</td>
<td>31.3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Age</th>
<th></th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
<td>Valid Percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12.5</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>7.00</td>
<td>2</td>
<td>12.5</td>
</tr>
<tr>
<td></td>
<td>8.00</td>
<td>3</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>9.00</td>
<td>3</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>10.00</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>11.00</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16</td>
<td>100.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Grade</th>
<th></th>
<th>Cumulative</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Frequency</td>
<td>Percent</td>
<td>Valid Percent</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25.0</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>3.00</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>4.00</td>
<td>4</td>
<td>25.0</td>
</tr>
<tr>
<td></td>
<td>5.00</td>
<td>5</td>
<td>31.3</td>
</tr>
<tr>
<td></td>
<td>6.00</td>
<td>3</td>
<td>18.8</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>16</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Results from the Working Memory Index paired samples t-test indicate that mean student WMI score after the intervention (M=103.19) was significantly higher than the mean student WMI score before the intervention (M=90.13), t(15) = -4.936, p<.05. All three Digit Span measures, which make up a component of the WMI, were also found to be significantly different pre- and post-test, with greater mean scores on these measures after the intervention. The Digit Span Forward (DSF) mean scores after the intervention (M=100.9375) was significantly higher.
than the mean DSF score before the intervention (M=95.0000), t(15) = -2.643, p<.05, the Digit Span Backward (DSB) mean score after the intervention (M=108.4615) was significantly higher than the DSB mean score before the intervention (M=92.3077), t(12) = -4.246, p<.05, and Digit Span Total (DST) mean score before the intervention (M=105.3846) was significantly higher than the DST mean score before the intervention (M=93.8462), t(12) = -5.035, p<.05. Finally, a significant increase was found between the pre-test WJ-III Calculation (CALC) measure (M=102.44) and the post-test scores of the same measure (M=127.31), t(15) = -6.066, p<.05.

There were no significant difference between the pre-test (M=93.1250) and post-test (M=100.3125) means of Letter-Number Sequencing (LNS), t(15) = -1.984, p>.05, which is the other component of the WMI. AIMSweb®’s MCAP and MCBM, the curriculum-based mathematic measures, were also found to be insignificant. The MCAP mean score after the intervention (M=95.0000) was not significantly higher than the mean score before the intervention (M=93.5000), t(15) = -.507, p>.05, and the MCBM mean score after the intervention (M=101.4375) was not significant compare to the mean score before the intervention (M=103.4375), t(15) = .503, p>.05. All scores were reported in standard score format. See Table 2 and Table 3.
Table 2: Paired Samples’ Statistics for Pretest-Posttest Measures of Working Memory and Mathematics Performance

<table>
<thead>
<tr>
<th>Pair</th>
<th>Measure</th>
<th>Mean</th>
<th>N</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PREWMI</td>
<td>90.1250</td>
<td>16</td>
<td>11.91008</td>
<td>2.97752</td>
</tr>
<tr>
<td></td>
<td>POSTWMI</td>
<td>103.1875</td>
<td>16</td>
<td>14.88274</td>
<td>3.72068</td>
</tr>
<tr>
<td>2</td>
<td>PREDSF</td>
<td>95.0000</td>
<td>16</td>
<td>11.54701</td>
<td>2.88675</td>
</tr>
<tr>
<td></td>
<td>POSTDSF</td>
<td>100.9375</td>
<td>16</td>
<td>12.54575</td>
<td>3.13644</td>
</tr>
<tr>
<td>3</td>
<td>PREDSB</td>
<td>92.3077</td>
<td>13</td>
<td>12.68454</td>
<td>3.51806</td>
</tr>
<tr>
<td></td>
<td>POSTDSB</td>
<td>108.4615</td>
<td>13</td>
<td>16.75617</td>
<td>4.64733</td>
</tr>
<tr>
<td>4</td>
<td>PREDST</td>
<td>93.8462</td>
<td>13</td>
<td>12.10266</td>
<td>3.35667</td>
</tr>
<tr>
<td></td>
<td>POSTDST</td>
<td>105.3846</td>
<td>13</td>
<td>14.78478</td>
<td>4.10056</td>
</tr>
<tr>
<td>5</td>
<td>PRELNS</td>
<td>93.1250</td>
<td>16</td>
<td>15.37043</td>
<td>3.84261</td>
</tr>
<tr>
<td></td>
<td>POSTLNS</td>
<td>100.3125</td>
<td>16</td>
<td>14.65933</td>
<td>3.66483</td>
</tr>
<tr>
<td>6</td>
<td>PRECALC</td>
<td>102.4375</td>
<td>16</td>
<td>13.15025</td>
<td>3.28756</td>
</tr>
<tr>
<td></td>
<td>POSTCALC</td>
<td>127.3125</td>
<td>16</td>
<td>21.27195</td>
<td>5.31799</td>
</tr>
<tr>
<td>7</td>
<td>PREMCAP</td>
<td>93.5000</td>
<td>16</td>
<td>13.94752</td>
<td>3.48688</td>
</tr>
<tr>
<td></td>
<td>POSTMCAP</td>
<td>95.0000</td>
<td>16</td>
<td>16.75311</td>
<td>4.18828</td>
</tr>
<tr>
<td>8</td>
<td>PREMCBM</td>
<td>103.4375</td>
<td>16</td>
<td>16.94685</td>
<td>4.23671</td>
</tr>
<tr>
<td></td>
<td>POSTMCBM</td>
<td>101.4375</td>
<td>16</td>
<td>10.75775</td>
<td>2.68944</td>
</tr>
</tbody>
</table>
Table 3: Paired Samples t-tests for Pretest-Posttest Measures of Working Memory and Mathematics Performance

<table>
<thead>
<tr>
<th>Paired Samples Test</th>
<th>Paired Differences</th>
<th>95% Confidence Interval of the Difference</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>Lower</th>
<th>Upper</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair 2 PREDSD - POSTDS</td>
<td>-5.93750</td>
<td>8.98494</td>
<td>2.24624</td>
<td>-10.72524</td>
<td>-1.14976</td>
<td>-2.643</td>
<td>15</td>
<td>.018</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 4 PREDST - POSTDST</td>
<td>-11.53846</td>
<td>8.26252</td>
<td>2.29161</td>
<td>-16.53145</td>
<td>-1.14976</td>
<td>-2.643</td>
<td>15</td>
<td>.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 5 PRELNS - POSTLNS</td>
<td>-7.18750</td>
<td>14.48778</td>
<td>3.62195</td>
<td>-14.90749</td>
<td>.53249</td>
<td>-1.984</td>
<td>15</td>
<td>.066</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 7 PREMCAP - POSTMCAP</td>
<td>-1.0625</td>
<td>.83893</td>
<td>.20973</td>
<td>-.55329</td>
<td>.34079</td>
<td>-507</td>
<td>15</td>
<td>.620</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pair 8 PREMCBM - POSTMCBM</td>
<td>.13875</td>
<td>1.10240</td>
<td>.27560</td>
<td>-.44868</td>
<td>.72618</td>
<td>.503</td>
<td>15</td>
<td>.622</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5
Discussion

The results of this study indicate that the students’ working memory, as measured by the WISC-IV Working Memory Index (WMI) and Digit Span subtests, significantly improved after completing five weeks of the Cogmed Working Memory Training™ program. Moreover, although not found to be statistically significant, the scores the students attained on the WISC-IV Letter-Number Sequencing (LNS) subtest did trend toward significance. Therefore, this study contributes to the evidence supporting Cogmed Working Memory Training™ as an effective intervention for increasing participants’ working memory performance.

As referred to above, the results attained were largely favorable regarding working memory improvement as the findings were either all statistically significant or approached significance. However, the findings attained regarding improvement of mathematical performance were more variable. To be sure, the data attained provided only mixed results for this sample of students regarding their mathematical achievement. A highly positive finding involved the area of math calculation skills as the mean WJ-III Calculation (CALC) scores significantly improved over the course of the five-week, working memory intervention. This indicates the possibility of a positive relationship between increased working memory capacity and increased mathematical performance using norm-referenced, standardized instruments. Even so, the results of the paired-sample t-test for the math curriculum-based measurements (CBMs) did not indicate significant pre-post test improvements between the students’ performance on spring and fall benchmark assessments for either math calculation (MCBM) or math problem-solving (MCAP) skills. One reason for the discrepancy may be how the tests were administered. The WJ-III Calculation subtest was given individually in an untimed format, while the CBMs were administered in a group setting under timed conditions. As such, this study provides a positive initial indication of the impact of the Cogmed Working Memory Training™ as a working memory intervention that may improve children’s achievement in the area of math calculation skills. On the other hand, the results attained also point to the need for further study about the impact of this working memory intervention upon the timed areas of math calculation and problem-solving is warranted, as no gains were found in these areas as measured by the CBM probes. Also, the CBMs are timed, while the WJ-III Calculation subtest is not.

Limitations and Suggestions for Future Research

There were a few limitations to this study that need to be mentioned. The first has to do with the relatively small sample size employed for this intervention. The working memory and mathematical performance data were obtained from only 29 students at one urban elementary school in Ohio. This is a small sample size indeed. However, of these initial 29 participants, 13 participants did not complete the 17 days of training required by the researchers (Cogmed Working Memory Training™ recommends a minimum of 20 days) and were thus excluded from the data analyses. As such, due to factors like summer absences, field trips, and technology compliance issues, the eventual sample size of this study was small. Moreover, since the findings were only taken from one urban school, results can only truly reflect functioning at that school itself. Even though the nature of this study is exploratory and seminal, it is essential that further research include a larger sample size and seek to include students from all elementary grades, as well as from a greater number and/or variety of schools and school districts. It is
likely that a randomized, controlled trial or regression discontinuity study should be used to truly provide an indication of the intervention’s effectiveness.

Secondly, it must be indicated that the students’ training conditions were not ideal. Cogmed Working Memory Training™ recommends that training be conducted often individually or one-on-one with a teacher or adult supervising. The company also suggests that a participant train in a quiet learning environment free from distraction. It was intended that the present study be conducted in just such a quiet learning environment. However, research work in schools is often characterized by a need to be flexible and to make changes in design and study expectations. During the time that the study was conducted, a new summer learning program was being instituted at the school with a small staff that did not include technology aides. The training was conducted in the school’s computer lab that did not have readily available headphones, but did have intermittent internet connectivity problems. Therefore, even though the students were split between two sessions in hopes of minimizing sound and increasing supervision, the training environment could be loud and disruptive, at times. Future research should strive to better adhere to the environmental recommendations established by Cogmed Working Memory Training™, but it should also try to understand and incorporate the unique logistics of hosting such a computerized program in a school lab. A compromise of ideal and realistic suggestions may need to be reached in order to make the use of this intervention tool possible in a school setting.

A third limitation that is important to note includes the number of training sessions completed by the students within the sample. In the future, it would be prudent to conduct a study and provide the intervention used without the time-constraint of operating within a six-week summer program. Due to this time constraint, only the minimum 17 sessions were completed by the students within the sample. Allowing for more time in which the students could complete the program’s typical 25, training session requirement might better ensure and represent the true benefits of the program. The findings generated through this study should thus be understood with this in mind, as the students only completed the Cogmed Working Memory Training™ protocol with the minimum number of sessions needed rather than the optimal number recommended by the program’s author.

The final limitation to note is the fact that the Cogmed Working Memory Training™ intervention was not the sole intervention executed as part of the summer enrichment program and therefore, it cannot conclusively be regarded as the only source of improvement or change within the scores attained by the students within the sample. At the time the Cogmed Working Memory Training™ program was being used with the students, this same group was also receiving a series of reading, writing, and math interventions during the summer learning program. These interventions act as a confounding variable and may have contributed to the significant increase in the post-test, WJ-III Calculation mean during data analysis. Therefore, this study’s significantly greater WJ-III Calculation post-test mean, may be the result of a combined effect from both the Cogmed Working Memory Training™ program and the interventions implemented by the teachers during the summer enrichment program.

Still, one could argue that this computerized, cognitive intervention is almost always implemented concurrently with a student’s regularly scheduled education plan. In fact, a combined treatment plan of the two could be considered typical, especially in a school that follows a RTI philosophy. That said, the Cogmed Working Memory Training™ should continue to be employed in conjunction with students’ educational curriculum. Greater working memory
capacity and academic performance could be the consistent result of this juncture, and should be encouraged.

**Conclusion**

Results from this study supported the hypothesis that use of the Cogmed Working Memory Training™ program was able to increase both working memory capacity and math calculation skill. However, results in the area of math were significant only for individually administered, untimed measures and were not significant for group administered, timed assessments or math calculation and problem-solving. These variable results were thought to be due to a number of limitations experienced during the study. These limiting variables included (1) small sample size, (2) suboptimal environmental conditions, (3) the number of training sessions employed, and (4) lack of experimental control over other academic interventions used with these students. Suggestions were given for further research in this area and with the Cogmed Working Memory Training™ intervention. The findings attained do provide information contributing to the body of research investigating the potential benefit of working memory intervention effects on working memory and the relationship between working memory and the academic area of mathematics. The study also provides seminal information about the Cogmed Working Memory Training™ program’s promise as an effective intervention for use with urban, elementary student populations from the United States of America, as this is a demographic group not yet explored by other researchers.

In the educational age of RTI, administrators, teachers, and parents near to be aware of not only evidence-based interventions (EBIs) that are academic in nature, but also the possible benefit and efficacy of cognitive interventions that can impact students’ underlying learning and thinking processes, such as working memory. Future research could explore implementing a variety of working memory interventions and strategies and investigate the effectiveness of each program on improving working memory capacity, academic performance, and classroom behavior.
References


Appendices

A. Parent/Guardian Consent Form

B. Student Consent Form
Appendix A

Parent/Guardian Consent Form

I, ______________________, have an understanding of the purpose, procedures, and my parental rights in regards to the intervention study that will be conducted at Dayton View Academy. I have contacted or will contact the Primary Investigator or Project Director if I have any concerns or questions regarding my son’s or daughter’s participation in the study or the intervention.

☐ I give permission for my child, ______________________, to participate in the intervention study. I understand that I can contact the Primary Investigator regarding my child’s general progress at any time. I also understand participation is completely voluntary and that my child may withdraw from the intervention study at any time without negative consequences.

_______________________________________________            ________________________
Parent/Guardian Signature                           Date

By signing above, I acknowledge that I am 18 years or older.
Appendix B

Student Consent Form

I am conducting a study to see if a computer game can help students better remember information and improve their skills in math. It is my hope that if you choose to be in the study, you will learn these skills and do better in school. If you agree to be in the study, you may have to leave class for some testing and for 30 minutes each day for five weeks. During this time, you will work on the computer game. At the end of the five weeks, there will be a few more tests. All testing is just to see what you know and will not affect your grades. If you have any questions before, during, or after my study, you can ask them. If you decide you do not want to finish the study, you can ask to stop.

If you sign this paper, it means that you have read this and that you want to be in the study. If you don’t want to be in the study, don’t sign this paper. Being in the study is up to you, and no one will be upset if you don’t sign this paper or if you change your mind later.

Your signature: ___________________________________________________________________ Date ________

Your printed name: __________________________________________________________________Date ________