Effectiveness of
Computerized Working Memory Training
on Math Achievement and Other
Transfer Effects in
Children with ADHD and Math Difficulties.

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Dedication

I would like to dedicate my dissertation work to my family. A special feeling of gratitude goes to my husband, Randy, who pushed me to continue when life became overwhelming and I thought I would never finish. I especially want to thank my beautiful children, Ian and Ava, who have only known me as graduate student since they were born. Your laughter, smiles, and hugs helped me more than you can ever imagine in getting through some very stressful times in this journey. I also want to thank my parents and in-laws who were quick to offer kind words, encouragement and help when I felt stretched too thin. To my mother in particular, thank you for being there during both the highs and lows. I couldn’t have done any of this without you.

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Abstract of Dissertation

Examination of the Effectiveness of Computerized Working Memory Training on Math Achievement and Other Transfer Effects in Children with ADHD and Math Difficulties

Background: Children with learning disabilities and attention deficit hyperactivity disorder struggle daily and are at-risk for poor long-term outcomes. Emerging evidence suggests that WM may improve by adaptive computerized working memory training, but what is unclear is its effectiveness and transference to untrained tasks. **Methods**: Twenty-three (11 females) school-aged children with co-occurring math difficulties and ADHD participated in a quasi-experimental, repeated-measures study in school to investigate transfer effects of working memory training (Cogmed RM[1]) on math achievement, fluid reasoning and memory and learning tasks. As part of a pilot, the Cogmed Progress Indicator (CPI) was used to measure transfer effects on working memory, following directions, and math challenge throughout the training. Standardized instruments were administered at baseline and at 4-weeks and 4-months post-intervention. Teachers and students completed the Conners-3 to assess ADHD. Teachers completed the BRIEF to measure executive functioning. **Results:** Significant improvement on the CPI was found on the following directions tasks. Statistically significant improvement was found on indices measuring verbal memory, visual memory,

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verbal working memory, symbolic working memory, attention/concentration, working memory, general memory, and fluid reasoning 4-weeks post-intervention. Statistically significant differences were also found at the 4-month follow-up period with the exception of verbal working memory index. Math fluency improved significantly 4-weeks after the assessment, but was not maintained at the 4-month post-test. The Applied Problems subtest was found to be significantly different at both post-test assessments. No statistically significant improvement was found on the math calculation subtest; however, the math calculation composite was found to improve statistically by the 4-month post-test. Working memory, inhibit, organization, and the Behavior Rating Index scales of the BRIEF were found to be statistically significant at the 4-month post-test. No statistically significant improvement was found on the Conners-3. The results on the DSM-IV-TR checklists on ADHD did show significant improvement at the 4-month post-test.

Conclusion: Although the results of this study are promising, additional research is recommended to address the limitations of this study.

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CHAPTER 1: INTRODUCTION

Overview

With the emerging research supporting the idea that specific cognitive functions can be improved, there is significant potential in the field of education to improve both the short and long term outcomes of individuals with neurodevelopmental deficits. One group that could particularly benefit from interventions that target specific cognitive deficits impeding their academic success is children with Attention Deficit Hyperactivity Disorder (ADHD). ADHD is a diagnostic disorder that is described in the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition, Text Revision (DSM-IV-TR) (APA, 2000) as a "persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequently displayed and more severe than is typically observed in individuals at a comparable level of development" (p. 85). At the time that this research project was being proposed and conducted, the DSM-V was still pending publication, thus the assessments and diagnostic criteria used to identify ADHD in this study is based on the DSM-IV-TR (APA, 2000). According to the DSM-IV-TR, there are three subtypes of ADHD identified in the DSM-IV-TR: ADHD, Inattentive subtype; ADHD, Hyperactive subtype; and ADHD, Combined subtype. ADHD has been significantly linked with deficits in executive functioning, an umbrella term referring to the higher order thought processes believed to be central to problem solving, linked with frontal lobes (Barkley, 1997; Brock et al., 2009: Willcutt et al., 2001). ADHD has been associated with various impairments in inhibitory behavior (Barkley, 1997; Willcutt, Pennington, Olson, Chhabildas, & Hulslander, 2005) and Working Memory (Castellanos, Sonuga-Barke, Milham & Tannock, 2006; Holmes et al., 2010; Martinussen & Tannock, 2006), particularly in the area of visual-spatial memory (Barnett, Maruff, Vance, Luk, Costin, Wood et al., 2001; Martinussen et al., 2005). Due to the relatively recent introduction of computerized interventions, there are a limited number of studies that have been conducted on their effectiveness with children. There are even fewer conducted on children living in the United States who are receiving such services in the school and as part of their special education programming. One promising computerized intervention that has been researched on working memory and attention in young people was initially developed at the Karolinska Institute in Stockholm Sweden by Klingberg and colleagues (2002). Influenced by animal research on training induced neuro-plasticity (Buonoman & Merzenich, 1998), these researchers from the Department of Neuropediatrics collaborated with professional game developers to create an intensive and adaptive training designed to improve working memory. Studies of computerized training programs have been found to be promising in addressing the attentional and working memory deficits linked with ADHD. Cogmed[2] , a computerized program that facilitates systematic practice of working memory, is one of these programs (Klingberg et al., 2002).

[2] Cogmed and Cogmed Working Memory Training are trademarks, in the U.S. and/or other countries, of Pearson Education, Inc. or its affiliate(s).

Because Cogmed was acquired in June of 2010 by Pearson Clinical Assessment group, a publishing company of clinical assessment products, there has been growing interest within the public school system to explore the programs' effectiveness in addressing the needs of individuals from a variety of educational, environmental and ethnic backgrounds. This study specifically examined the impact that the Cogmed working memory training had on the outcomes of students with ADHD who were experiencing math difficulties. This study served as a pilot study to examine a new tool to measure training improvements called the Cogmed Progress Indicator (CPI), which is designed to complement the training index currently incorporated with the training program. The purpose of the CPI aligned with an objective of this study, which was to illustrate the impact of training by requiring participants to perform non-trained tasks in the areas of working memory, by following directions, and by math. The CPI is reported to provide of measure of WM transfer and cognitive change. Through a set of tasks performed five times throughout the training, the outcome was referred to as progress, as measured against the baseline. The coach and end user were able to track the progress and receive a clear report of the training effects at the end of the training period.

In reviewing the cognitive factors of math disabilities, there is emerging evidence that the underlying executive functioning deficits linked with ADHD also play a significant role in math learning. For example, functional imaging studies in adults have demonstrated the significance of the prefrontal cortex in math performance, the area of the brain attributed to executive functioning (Fullbright et al., 2000; Zago et al, 2001).

Impairment in arithmetic calculation in children has also been found to be related to activity in the frontal region (Ansari et al., 2011; Levin, et al., 1996). Because the field of education is only beginning to examine the neuropsychological processes of the co-morbidity of math difficulties and ADHD, it is not surprising that there is a gap in the research on empirically supported interventions designed to address their unique and complex needs (Auerbach et al., 2008). This study contributed to closing this gap by examining the effectiveness of Cogmed (Klingberg et al., 2002; 2005) on children with ADHD and math difficulties.

Statement of the Problem

According to Barkley (2007), ADHD occurs in approximately 3-7 percent of the childhood population and approximately 2-5 percent of the adult population. Of major concern to researchers and practitioners is the poor long-term outcome of children with ADHD (Merrell & Tymms, 2001; Preston et al., 2009). Children with ADHD have been found to be at increased risk of academic underachievement when compared with IQ-matched peers of the same age (Deshazo, Lyman, & Klinger, 2002; Frazier et al., 2007; Kamphaus & Frick, 1996; Wilson & Marcotte, 1996). Specifically, they are likely to have performances that are lower than their classmates by as much as 10 to 30 standard score points on various standardized achievement tests of reading, spelling, math, and reading comprehension (Barkley, DuPaul, & McMurray, 1990; Biederman et al., 1991; Brock & Knapp, 1996; Casey, Rourke, & Del Dotto, 1996). From a statistical survey measuring trends from 2004 to 2006 results of the survey published in 2008 by the Center for Disease Control and Prevention (CDC, 2010) reported that 28% of the children diagnosed either with learning disability or with ADHD had reported having been diagnosed with both conditions (CDC, 2010). In the report, it was suggested that the co-occurrence of ADHD and learning disability reflects shared genetic and environmental factors associated with the development and diagnosis of both of these disorders. Research that has rigorously applied the definition of learning disabilities have estimated approximately 8 to 40% of children with ADHD possess a type of reading disability (Del Homme et al., 2007; Maughan & Carroll, 2006); 12 to 30% have a math disability (Butterworth et al., 2005; Capano et al., 2008; Faraone et al., 1993; Monuteaux et al., 2005), and 12 to 27% have a spelling disorder (Barkley, 2006; Frick & Lahey, 1991). In a clinical sample of 8-16 year-old children, Mayes, Calhoun, and Crowell (2000) found that a learning disability was present in 70% of the children with ADHD. One survey indicated that 27% of children receiving special education services are reported by their parents as having ADHD (U. S. Department of Education, 2003; Wagner & Blackorby, 2004). Research on the co-morbidity of math disabilities and ADHD in particular, found that math disabilities occur more frequently in children with ADHD than those observed in the general population (Butterworth et al., 2005; Capano et al., 2008; Faraone et al., 1993).

Although one of the greatest concerns associated with children diagnosed with ADHD is academic underachievement (Barkley, 2006), there continues to be minimal research conducted on the effectiveness of academic interventions to address their specific learning needs. The majority of research that has been conducted on children with ADHD has focused primarily on behavioral modification techniques and pharmacological treatment in reducing disruptive behavior (Barkley, 2006; MTA Cooperative Group, 1999; 2004). There is a need for more research to be conducted on interventions that can address and improve the academic outcomes of children with ADHD.

One factor that contributes to the lack of research on academic and cognitive interventions to address ADHD is that the disorder typically has been viewed by the symptoms of behaviors. In other words, educational research has generally focused on interventions and strategies that specifically target behaviors believed to impede learning instead of examining the specific cognitive deficits contributing to behaviors, such as issues in inhibition, selecting/sustaining attention, and shifting attention. The recent advancement in neuroscience technology has helped improve the understanding of the related brain functioning that contributes to the manifestation of symptoms. There is strong support that ADHD is related to core deficits in executive functioning, a term referring to the higher order thought processes believed to be central to problem solving (Barkley, 1997; Brock et al., 2009: Willcutt et al., 2001). Although there are differences in how the executive functions of ADHD are conceptualized, there is agreement that executive functioning deficits are central to difficulties in learning (Barkley, 2006). In exploring the heterogeneity of ADHD, there has been a growing body of research supporting the idea that inattentive behaviors, not the hyperactivity and impulsivity symptoms, are generally responsible for poor academic achievement (Daley, 2006; Todd et al., 2002; Rabiner & Coie, 2000). Additionally, findings have found that verbal memory and spatial working memory are among the cognitive deficits influencing achievement outcomes in students with ADHD (Semurd-Clinkeman, Pliszka, & Liotti, 2008). In understanding how to improve specific neuropsychological deficits that are linked to learning, educators will be better prepared to design and implement appropriate interventions for students with ADHD instead of randomly applying frequently used strategies.

Purpose and Research Questions

Purpose of Study

The purpose of this study was to examine school-based interventions that go beyond curriculum instruction and teaching memory strategies; rather, it sought to examine computer based interventions that directly train cognitive processes. Specifically, this study examined the impact of a computerized working memory program on students receiving special education services that were found to have a diagnosis of ADHD, or that demonstrated clinically significant behaviors on behavioral/emotional checklists, and experienced math difficulties. Participants were involved in several pre-test sessions and 4-week and 4 month post-test sessions to assess treatment effects on various processes of memory and learning, fluid reasoning, and academic achievement in math.

Research questions

Questions that were examined using quantitative research methodology include the following:

1. Do the participants show significant improvement on the trained tasks over the intervention training period when implemented in the school day, as measured by index improvement scores collected by the training software program?
2. Do the participants show significant improvement over the intervention period on untrained tasks when implemented in the school day, as measured by the Cogmed Processing Index (CPI) collected by the training software program?
3. Does the training result in near-transfer and far-transfer effects on different tasks of memory and learning, as measured by the WRAML2 at 4 weeks and 4 months following the conclusion of the training?
4. Does the training improve far-transfer effects in the area of fluid intelligence, as measured by standardized assessments at 4 weeks and 4 months after the completion of the training?

5. Does the training result in far-transfer effects in the area of math, as measured by standardized achievement test at 4 weeks and 4 months after the conclusion of the training?

6. Does the program improve executive functioning skills as measured by the BRIEF rating scale, as measured at 4 weeks and at 4 months after the completion of the training?

7. Does the program reduce the frequency of inattention and hyperactivity symptoms in the classroom and home as rated by teachers and parents, as measured at 4 weeks and at 4 months using standardized tools after the completion of the intervention?

Hypotheses

The following hypotheses were generated for this study.

1. Participants will make gains on the trained tasks from the computerized training program administered during the school day, as measured by index improvement scores calculated by the training software program.

2. Participants will demonstrate gains on non-trained tasks, as measured by the Cogmed Process Indicator as piloted in this study.

3. Participants will make near transfer and far transfer gains in memory performance, as measured by the WRAML-2 when assessed at 4 weeks and 4 months after the completion of the training.

4. Participants will demonstrate far-transfer effects, as measured by significant improvement on fluid reasoning tasks when comparing pre-test assessments with post-test conducted 4-weeks and 4 months after the completion of the training.

5. School-aged students ranging from the ages of 9 to 18 years with ADHD and math difficulties (25th percentile rank on individually administered achievement tests prior to intervention) and/or performance below grade level on local/statement assessments who are participating in the computerized training program will show significant growth in their math performance, as measured by individually administered pre and post achievement tests and benchmark assessments.

6. Participants will demonstrate significant improvement on executive functioning skills when comparing pre-test assessments with post-test assessments conducted at 4 week and 4-months after the completion of the training.

7. Teachers' ratings of inattention and hyperactivity will be rated significantly lower at 4 weeks and 4 months after the completion of the training, when compared with the ratings gathered at baseline.

Statement of Potential Significance

Many school personnel across the nation are struggling as they attempt to better understand the needs of children with ADHD and math disabilities to improve their academic outcomes. Linking needs with appropriate interventions is particularly important because districts are in the process of developing Response to Intervention (RTI) programs as part of the pre referral process to special education identification and are attempting to assist their students in improving their academic outcomes in order to make adequate yearly progress as required by the No Child Left Behind Act of 2001 (Pub.L. 107–110, 115 Stat. 1425, enacted January 8, 2002). Due to the complex nature of the neurocognitive deficits and the role these have in all aspects of their lives, school personnel are also challenged by the need to maintain and generalize intervention effects (Pfinner, Barkley, & DuPaul, 2006).

The consequences of not appropriately meeting the needs of children with ADHD are isolated not only to the school system, but also to those influences that concern almost every aspect of their lives including their transitions and successes as adults. In addition to their academic struggles, children with ADHD have also been found to have high rates of school drop-out and suspensions during adolescence (Merrell & Tymms, 2001; Preston et al., 2009). Research has further supported the idea that their poor academic achievement contribute to delinquency and anti-social behaviors in young people with ADHD (Hinshaw, 2002; Wilson & Marcotte, 1996; Barkley, Fischer, Edelbrock, & Smallish, 1990). They have been found to be more likely involved in car accidents and receive traffic citations (Barkley, Guevremont, Anastopolous, DuPaul, & Shelton, 1993). Additionally, they are also more vulnerable for substance use and abuse (Biederman, Farone, et al., 1997; Barkley, 2006). Adults with significant clinical features of ADHD are at greater risk than the general population in areas of poor employment functioning, social relations, and economic and educational attainment (Barkley, 2006). In examining such risks, it is evident that the consequences of not addressing the academic and behavioral needs of children with ADHD will expand to affect the legal, mental health, drug or alcohol use, and the economic health of the nation.

Conceptual Frameworks

Executive Functioning and ADHD

Research on ADHD has generally regarded this disorder as one related to core deficits in executive functioning, a term referring to the higher order thought processes believed to be central to problem solving (Barkley, 1997; Brock et al., 2009; Jensen, 2015; Willcutt et al., 2001). Executive functions generally include the ability to plan, organize information, self-monitor, change or modify behavior, and manipulate information to solve a problem (Semurd-Clinkeman, Pliszka, & Liotti, 2008). There is considerable controversy regarding the cognitive constructs associated with executive functioning because the definitions can be quite cumbersome to describe in its entirety (Brock et al., 2009; Epsy et al., 2006). Although there are differences in how the executive functions of ADHD are conceptualized, there is agreement that these deficits are central to difficulties in learning.

In recent years, executive functioning skill models have formed the foundation of additional research investigating the role that these cognitive processes have on learning. This body of research includes large studies examining executive functioning in children with learning disabilities, autism, behavioral problems, and language and comprehension problems. Generally, these studies have found that executive functions serve as a good predictor of performance (Bull & Scerif, 2001). Working memory has been linked as playing a particularly significant role in academic performance, although the intricacies of its involvement are unclear and fairly complex (Berg, 2007). Working memory has been found to be one of the key executive functioning deficits linked with the struggles experienced by children and adolescents diagnosed with ADHD, as well as by those children and adolescents with learning disabilities (Kofler et al., 2008).

Baddeley's model of working memory. Because of the significance that working memory has in learning, increased research has been conducted on Baddeley's and Hitch's (1974) multi- component model of working memory. Since the original conceptualization, the model has been modified and is now recognized as Baddelely's model of working memory (Baddeley, 2002; Baddeley, 2007; Semurd-Clinkeman,Pliszka,& Liotti, 2008; Swanson & Beebe-Frankenberger, 2004). Baddeley's (1986, 2007) model describes working memory as a limited capacity executive system that interacts with the slave systems including the speech-based phonological loop and the visual-spatial sketchpad. These passive systems are used for temporary storage of verbal information and visual-spatial information. The central executive is a flexible system responsible for the control and regulation of various cognitive processes. It is believed to bind information from a number of sources into coherent episodes through its coordination with the slave systems. The central executive is theorized to shift between tasks or retrieval strategies and is involved in the processes of selective attention and inhibition. It also serves to coordinate the slave systems (Baddeley & Logie, 1999; Baddeley, 2002; Baddeley, 2007; Swanson & Beebe-Frankenberger, 2004).

The episodic buffer has been added to the model as a slave system responsible for linking information across domains. This includes integrating units of visual, spatial, and verbal information into a particular time sequence, such as the memory of a story. This component of working memory is also believed to have links to long term memory (LTM) and semantic memory (Baddeley, 2000, 2007; Swanson, Jerman, & Zheng, 2008). Further research needs to be conducted on the episodic buffer, in particular, because many of its functions still appear to be unclear. It is unknown, for example, whether other constructs such as the various domains of attention are part of the system or whether they are performed by separate cognitive systems (Bull & Scerif, 2001). A figure of Baddeley's Model of Working Memory is shown below.

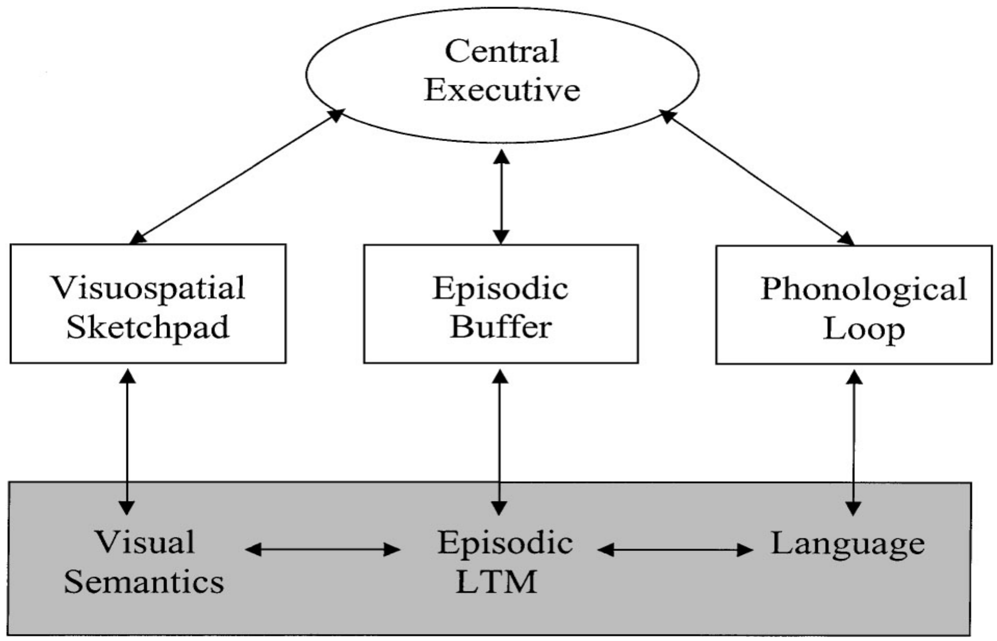

Figure 1.1 Baddeley's Model of Working Memory (Baddeley, 2007)

Functional working memory model of ADHD. The primary framework for this study was the Functional Working Memory Model of ADHD (Kofler et al., 2008), which is based on Baddeley's Model of Working Memory (2007). Within this model, Kofler, Rapport, Bolden, and Altro (2008) view working memory as a core, causal cognitive process responsible for ADHD; behavioral inhibition deficits are considered by-products of working memory deficits. Kofler and colleagues (2008) describe inhibition as a by-product because it is dependent on the individual's ability to register environment stimuli.

In other words, information has to be activated in working memory before a decision can be made to register the information (Rapport, Chung, Shore, & Isaacs, 2001). Additionally, deficits in working memory are presumed to account for secondary features such as hyperactivity, inattention, and impulsivity (Kofler et al., 2008). Associated features and outcomes include impairment in the following areas: cognitive test performance, academic achievement, social skills, organizational skills, classroom deportment, and delay aversion (Kofler et al., 2008). These features include those concerns frequently reported by parents and teachers when describing children with ADHD; they include issues with disorganization, inattention, poor social skills, delay aversion, hyperactivity, and impulsivity. These specific deficits affect children with ADHD to varying degrees across various domains. Performance on cognitive tests is directly impacted by working memory processes and academic achievement reflects the cumulative effects of poor working memory.

Because ADHD has been viewed primarily as a disorder related to behavior, professionals from a variety of disciplines have failed to recognize the importance of examining deficits in psychological processes to understand how such constructs impede learning. By building a bridge between the fields of neuroscience and education, it is hoped that there are increased opportunities to design interventions that will address more directly the neuropsychological processes overlapping in these disorder in order to improve their educational outcomes.

Summary of the Methodology

This study utilized a quantitative, quasi-experimental design without a control group to evaluate whether or not the implementation of a computerized cognitive training program had a significant effect on achievement, various cognitive processes, and observed behaviors on a purposive sample of individuals identified with a disability. Specifically, the results collected from the sample were used to assess the effectiveness of the computerized cognitive training on children identified with math difficulties and ADHD. Students who may not have been previously diagnosed with ADHD, but have presented with clinical symptoms of ADHD, were also included in the sample.

Participants

There were twenty-three participants in the study, ranging in age from 11 to 18, enrolled in a rural school district located in South Central PA. Four additional students who completed 17 to 19 of the sessions within the allocated time were not included in the data analysis because the subjects were required to participate in 20 sessions, at the minimum. The total school district enrollment was appropriately 3,200. The district has three elementary schools, one middle school, and one high school. The purposive sample included students from the 5th grade to the 12th grade. The purposive sample used in this study included individuals who had been identified as having a disability, based on IDEA and state guidelines. The targeted sample was specifically aimed at those with math difficulties and was identified with one of the subtypes of ADHD or had displayed clinically significant behaviors linked with ADHD. Because of the demographics of the school, the participants in this group were Caucasian and consisted of 14 males. It is also important to note that there is a probability that several of the individuals would likely meet the criterion to be considered economically disadvantaged because approximately 30% of the entire student population receives free or reduced lunch. Because of procedures required in the district to protect the privacy of families, an inquiry regarding socioeconomic status was not made when collecting demographic information about the participants in the study. Additional details regarding the inclusion and exclusion criteria of the participants selected for this study is listed under procedures.

Approval to initiate this research was received by the IRB of George Washington University and the school board of the school district. Consent was obtained from the parents/guardian and children with appropriate opportunities for withdrawal.

Procedures

Participants were administered a series of pre-test and post-test intervention assessments within two weeks prior to the start date of the training program, 4 weeks after the completion of the training, and 4 months following the treatment. The BRIEF (Gioia et al., 2000), Conners 3 (Conners, 2009), and the DSM-IV checklist (Cogmed America, 2007) were administered as a pre-test assessment and at the 4 week and 4 month post-test assessment periods. The participants met with the researcher to complete the Conners 3 Self-Report (Conners, 2009) during the first session of each assessment phase. The Woodcock Johnson Third Edition, Normative Update (WJ-III NU) Tests of Achievement (McGrew et al., 2007) was used to assess achievement in math during the second session of each of these three assessment periods. To alleviate the impact of practice effects on the measurements, three different forms of the assessment were used: Form A, Form B, and Form C. The fluid reasoning subtests of the Woodcock Johnson-Third Edition, Normative Update III Tests of Cognitive Abilities (WJ-III NU Cog) (McGrew et al., 2007) was also administered during the second session of the pretest, 4 week, and 4 month post-test phases. The Wide Range Assessment of Memory and Learning 2nd Edition (WRAML2) (Sheslow & Adams, 2003) was administered during the third session of each assessment phase. The examiner was aware of concerns regarding practice effects on the results of the WRAML2 (Sheslow & Adams, 2003) and WJ-III, NU Test of Cognitive Abilities (McGrew et al., 2007); these are discussed in further detail in the discussion. Each subtest was administered as it was standardized. The WRAML-2 (Sheslow & Adams, 2003) battery was administered in the order as it was standardized. Benchmark assessments were reviewed; however, due to discontinuing some of the universal screeners and piloting another assessment for some of the grade levels, three sets of data from the same assessment tool were not able to be obtained for the majority of participants; thus this data was not able to be analyzed.

Delimitations and Limitations

There were several limitations that need to be considered in this study; these are based on utilizing a quasi-experimental approach with a purposive sample and without a control group. Because the study was designed to address a particular subgroup of individuals with specific learning needs, it was not possible to randomize the sample and use a control group due to the small population of participants who met the criteria of the study. The ability to generalize the findings of this study to other similar populations must be interpreted with caution because of these factors.

Another risk in using quasi-experimental design is that the study was susceptible to the internal validity threat of selection (Trochim, 2001). One concern is that the participants selected for the study differed in various unexplained ways. Incorporating pre-tests have helped address some of these issues at the beginning of the study. Another concern raised is maturation from the time the study began to the conclusion of the study, which spanned a period of almost 6 months. Although all students were assessed across the same time periods, the issue could be raised that subjects within the pre-adolescent and adolescent time frame matured at different developmental rates. Another risk with multiple measures, particularly when considering the length of time of this study, there was also the risk that some of the subjects would not be available or not be interested in participating in the final stages of testing. Each of the twenty-three students who finished the minimum of 20 sessions was available for all three periods of assessments.

An additional, notable concern is that the researcher being involved in the selection of the purposive sample and in the assessment of the participants, there was the risk of experimental bias. To assist in alleviating the effects of researcher bias, a standardized protocol established by the designers of the Cogmed (Klingberg et al., 2002) was implemented. Additionally, special education teachers served as the coaches and thus were responsible for overseeing the program and collecting and reviewing the data directly generated from the intervention. The information gathered from the WRAML2 (Sheslow & Adams, 2003), and the WJ III- NU Tests of Achievement and Cognitive Abilities (McGrew et al., 2007) were not provided to the Cogmed coaches to assist in avoiding bias. Subtests of each battery were administered as standardized. Additionally, protocols and the data that were collected were coded to assist in addressing concerns regarding bias. Data were entered into the data base with the identifying code but without referring to the initial list assigning the individuals with the specific codes.

One other limitation that needs to be considered in interpreting the results of this study are related to practice effects of the instruments being used at pre-test and post-test sessions. This was of particular concern with the Wide Range Assessment of Memory and Learning-2nd Edition (WRAML-2) (Sheslow & Adams, 2003) battery and the Fluid Reasoning subtests of the Woodcock Johnson-Third Edition, Normative Update (WJ-III NU) Tests of Cognitive ability (Woodcock et al., 2001) because only one form was developed for each of the subtests. To alleviate the risk of practice effects on the measures of achievement, three different forms of the WJ-III NU Tests of Achievement were administered (Form A, Form B, and Form C) (Woodcock et al., 2001).

Because of concerns with scheduling the intervention sessions during the school day, the sample size was small, with 23 participants from one elementary school, the middle school, and the high school. One of the assumptions of this study was that the students were available to participate in the training program as prescribed and that they would put forth their best efforts, particularly with the incorporation of the coaching component and external incentives. Issues did arise at times because of problems with school cancellations due to inclement weather and issues related to absences of two students who had medical issues. In such cases, it is important to consider that the intervention was implemented with fidelity, because the intervention was administered in a comparable manner to all participants over time (Smith, Daunic, & Taylor, 2007). Because there were three different coaches, based on building level, and several teaching aides overseeing the working memory intervention, there may be questions raised regarding the consistency in the quality of the coaching sessions. Each coach was trained by the Cogmed staff and followed the prescribed protocol to help ensure consistency. Factors such as the relationship between the coach and the participants were not investigated in the study, but should be considered as possible factors that may have influenced motivation.

Another assumption is that the data instruments used throughout the study are valid and reliable tools based on previous use and research. Information on these tools is discussed further when reviewing the particular assessments used in this study.

Definitions of Key Terms

Attention Deficit Hyperactivity Disorder **(ADHD)** is described as a "persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequently displayed and more severe than is typically observed in individuals at a comparable level of development" (p. 85). *Diagnostic and Statistical Manual of Mental Disorders Fourth Edition, Text Revision (DSM-IV-TR)* (APA, 2000).

Attention Deficit Hyperactivity Disorder Subtypes as defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR); American Psychiatric Association, 2000)

ADHD -- Inattentive type is defined by an individual experiencing at least six of the following characteristics:

1. Fails to give close attention to details or makes careless mistakes
2. Has difficulty sustaining attention
3. Does not appear to listen
4. Struggles to follow through on instructions
5. Has difficulty with organization

6. Avoids or dislikes requiring sustained mental effort
7. Often loses things necessary for tasks
8. Is easily distracted
9. Is forgetful in daily activities

ADHD -- Hyperactive/Impulsive type is defined by an individual experiencing six of the following characteristics:

1. Fidgets with hands or feet or squirms in seat
2. Has difficulty remaining seated
3. Runs about or climbs excessively (in adults may be limited to subjective feelings of restlessness)
4. Has difficulty engaging in activities quietly
5. Talks excessively
6. Blurts out answers before question have been completed
7. Has difficulty waiting in turn taking situations
8. Interrupts or intrudes upon others

ADHD -- Combined type is defined by an individual meeting both sets of attention and hyperactive/impulsive criteria.

Baddeley's Model of Working Memory (2007): This model proposed a three-part working memory system that contains a central executive control system that regulates two subordinate systems: the visuospatial sketchpad and the phonological loop (Baddeley, 2007; Dehn, 2008; Miller, 2007).

Central Executive: A component of Baddeley's Model of Working Memory that is described as a flexible system responsible for the control and regulation of various cognitive processes. It is believed to bind information from a number of sources into coherent episodes through its coordination with the slave systems (Baddeley & Logie, 1999; Baddeley, 2002; Baddeley, 2007; Swanson & Beebe-Frankenberger, 2004).

Computerized training: The basic premise of computerized training is that participants participate in a variety of computer activities designed to improve various cognitive skills or academic performances (Mezzacappa & Buckner ,2010)

Episodic Buffer: A component of Baddeley's model of working memory that is described as a slave system responsible for linking information across domains. This includes integrating units of visual, spatial, and verbal information into a particular time sequence, such as the memory of a story. This component of working memory is also believed to have links to long term memory and semantic memory (Baddeley, 2000; Swanson, Jerman, & Zheng, 2008).

Executive Functions (EF): Executive Functions are "directive capacities that are responsible for a person's ability to engage in purposeful, organized, strategic, self-regulated, goal-directed processing of perceptions, emotions, thoughts, and actions." (McCloskey, Perkins, & Van Divner, 2009; p. 15).

Math Learning Disability (MLD) (Dyscalculia): A Math Learning Disability is a disability in which individuals have markedly poor skills at learning and deploying basic computational processes used to solve equations (Haskell, 2000). A profile of someone with a math learning disability can include having difficulties in the following areas: being slower in basic numeric processing tasks, making comparison between magnitude of numbers, counting forward and backward, strategy use, and visualization of numbers (Geary, 2011: Rasanen, et al., 2009).

Phonological Loop: The phonological loop, originally referred to as the articulatory loop, is conceptualized as the component of WM that is responsible for holding verbal information in the mind (Baddeley, 1986, 2003, 2007; Baddeley, Gathercole, & Papagno, 1998; Dehn, 2008).

Working Memory: A limited capacity store for retaining information for a brief period while performing mental operations on that information (Dehn, 2008; Miller, 2007).

Visuospatial sketchpad: A component of the Baddeley's Model of Working Memory held to be responsible for the short-term storage of visual and spatial information (Baddeley, 2007; Dehn, 2008).

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter provides an overview regarding the current concerns linked with underachievement in children with ADHD and with the failure to provide interventions to address their academic needs, particularly with students also struggling in math. In order to provide appropriate interventions it is important to understand the neuropsychological processes underlying ADHD and math disabilities and to examine the link between the two disorders. This will include looking specifically at models of executive functioning, attention, and working memory. Interventions that have been supported in improving executive functioning, attention, and working memory are particularly important because of the relationships these processes have on learning and behavior. Part of this chapter will also review the research on computerized cognitive training programs purported to improve neuropsychological processes that have been linked with ADHD and math achievement.

Systematic Literature Review

Method of Systematic Literature Review

The literature review occurred in various phases in order to understand the neuropsychological processes underlying math difficulties and ADHD and in order to examine the pool of research on interventions to address related cognitive weaknesses.

The first phase of the literature review consisted of an overview of the current research on math disabilities. After reviewing a variety of these articles, additional searches were conducted to limit the topic to meet the particular research interest in the neuropsychological constructs underlying math difficulties. From this ongoing research, there followed an investigation of the literature examining math difficulties in children with ADHD. Due to the limited number of studies examining the neuropsychological overlap of ADHD and math learning disabilities, specific emphasis was placed in this literature review in identifying variables that have been found to cross studies on both ADHD and math learning disabilities. Literature selected for this review included those examining executive functioning, attention, and working memory. Researchers primarily used behavioral surveys and group and individually administered cognitive, achievement, and neuropsychological assessments to assess results. Sample sizes within these studies ranged from 33 to 4,148 students with children from pre-school programs to elementary aged students. Eight studies were conducted in various regions around the United States. A few studies from other countries such as Canada and England were included. The subjects showed minimal variety in socio-economic status, with the majority of students described as middle class; there were a few studies that included students from Title 1 schools. The majority of articles selected were those conducted after 2000 in order to ensure that the data collected most accurately represent current academic practices and programming in the public education setting.

The next phase of research specifically examined interventions to address cognitive or academic interventions in children with ADHD. The initial research utilized a computer search on ERIC (education), PsychINFO, and Academic Search Primer. The first phase of this literature review consisted of an overview of the current research being conducted on ADHD, attention, interventions, working memory, and math. The number of articles found on each of these databases ranged from 2 to 5, with overlapping articles. To expand the search, several combinations of key terms were used. When linking Working Memory with interventions a range of articles were found, from 19 at the initiation of this literature review to 53 as the literature review progressed. Throughout the year and half process in reviewing the research, the number of articles increased to 276. These articles covered a variety of research studies, many of them linking assessments with interventions in specific areas such as language, math, and reading. Searches on Working Memory, ADHD, and computerized training yielded 5 studies. Revisits to these search engines throughout the proposal process revealed the emergence of additional research, with a few articles being published; within the past year a search recently yielded 13 articles. Additional studies on computerized working memory training and attention were found through a review of the research; there were also individual searches on Academic Search Primer, Dissertations/Thesis Online, and ERIC. Because the field of computerized training is relatively new, the literature search primarily contained articles conducted since 2000, with a few studies on attention training published in the late 90s. Studies were excluded if they addressed adults in rehabilitation settings. Due to the limited number of studies examining computerized training in young children, additional searches on these data bases were conducted on computerized interventions addressing executive functioning, attention, and/or working memory. Within the year in which the research was being conducted, a few additional articles were published which did examine the use of computerized working memory intervention in the school setting and with children with co-occurring learning disabilities and ADHD.

Introduction to ADHD and Achievement

ADHD and achievement. With the emerging research that supports the idea that specific cognitive functions can be improved with training, there is growing interest in the field of education to introduce interventions to improve both the short and long term outcomes of individuals with neuro-developmental deficits. One particular group of students that are particularly in need of interventions that target specific cognitive deficits in order to reduce their risk of academic failure are those identified with Attention Deficit Hyperactivity Disorder (ADHD). ADHD is a chronic and impairing disorder that has been estimated to occur in approximately 7.8% of children and 2% to 5% of the adult population (Angold, Erkanli, Egger, & Costello, 2000; Barkley, 2007; Demaray, Schaefer, & Delong, 2003; Jensen et al., 1999). Numerous studies have suggested that the long-term outcomes of children with ADHD are generally poor (Merrell & Tymms, 2001; Preston et al., 2009). Children with ADHD have consistently been found to be at increased risk of academic underachievement and grade retention, when compared with IQ-matched peers of the same age (Barry, Lyman, & Klinger, 2002; Kamphaus & Frick, 1996; Wilson & Marcotte, 1996). Specifically, research has found that they are likely to have performances that are lower than their classmates by as much as 10 to 30 standard score points on various standardized achievement tests of reading, spelling, and math (Barkley, DuPaul, & McMurray, 1990; Brock & Knapp, 1996; Casey, Rourke, & Del Dotto, 1996). Research that has rigorously applied the definition of learning disabilities have estimated a range of 8 to 40% of children with ADHD possess a type of reading disability (Del Homme et al., 2007; Maughan & Carroll, 2006); 12 to 30% have a math disability (Butterworth et al., 2005; Capano et al., 2008; Faraone et al., 1993; Monuteaux et al., 2005), and 12 to 27% have a spelling disorder (Barkley, 2006; Frick & Lahey, 1991).

In a clinical sample of 8-16 year-old children, Mayes, Calhoun, and Crowell (2000) found that a learning disability was present in 70% of the children with ADHD. One survey indicated that 27% of children receiving special education services are reported by their parents as having ADHD (U. S. Department of Education, 2003; Wagner & Blackorby, 2004). In a review of 17 studies (2001 to 2011) examining the co-morbidity of ADHD and learning disabilities, DuPaul et al. (2013) revealed a high mean comorbidity rate of 45.1%. They proposed that this higher mean than had previously been reported in other studies may be the result of including writing disorders with reading and math.

In addition to their academic struggles, children with ADHD have also been found to have higher rates of school drop-out and suspensions during adolescence (Merrell & Tymms, 2001; Preston et al., 2009). Pisecco, Wristers, and Swank (2001) also found a predictive relationship between poor academic-self concept in children with ADHD and antisocial behaviors when they enter early adolescence. It was suggested by these researchers that academic difficulties, or at least the perception of academic failure, had a causal relationship to antisocial behaviors and poor academic outcomes (Pisecco, Wristers, and Swank, 2001; Preston et al, 2009).

Although one of the greatest concerns associated with children diagnosed with ADHD is academic underachievement (Barkley, 2006), there continues to be minimal research conducted on the effectiveness of interventions to address their specific learning needs. Most of the research that has been conducted on children with ADHD has focused primarily on behavioral modification techniques and pharmacological treatment in reducing disruptive behavior rather than on examining the specific cognitive deficits that may be directly influencing their ability to learn. (Barkley, 2006; MTA Cooperative Group, 1999; 2004). With the recent advancement in neuroscience technology, educators have gained increased understanding in the manifestation of symptoms in students with ADHD. Before further exploring the theories of ADHD to help understand the link between ADHD and learning difficulties, it is valuable to review the differences among the subtypes of ADHD and the current issues surrounding the diagnosis of ADHD.

ADHD diagnosis and subtypes. This research was conducted prior to the release of the *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (DSM-V, 2013), in which there were changes in the criteria used in diagnosing ADHD. Because the assessment tools in this study were designed and standardized, based on the criteria established in the *DSM- Fourth Edition-Third Revision (DSM-IV-TR)*, this study will examine the definition in the *DSM-IV-TR* (APA, 2000). A summary of the differences that can be found between the two versions of the DSM includes the facts that symptoms can now occur by the age of 12 rather than by age 6; several symptoms need to occur in more than one setting rather than only some impairment in more than one setting, and new descriptions were included to show what symptoms may look like in older ages, and for individuals over the age of 17, only 5 symptoms need to be present versus 6 as required for younger individual (CDC,2013; APA,2013). The following information contains the diagnosis of ADHD used in guiding the selection of participants and the interpretation of tools used to measure ADHD symptomology.

In the Diagnostic and Statistical Manual of Mental Disorders Fourth Edition, Text Revision (DSM-IV-TR) (APA, 2000), ADHD is described as a "persistent pattern of inattention and/or hyperactivity-impulsivity that is more frequently displayed and more severe than is typically observed in individuals at a comparable level of development" (p. 85). There are currently three subtypes of ADHD identified in the DSM-IV-TR: ADHD, Inattentive subtype; ADHD, Hyperactive subtype; and ADHD, Combined subtype.

According to the DSM-IV-TR, the individual must meet six of the following nine attention-related characteristics to be diagnosed with ADHD, Inattentive type:

1. Is easily distracted by extraneous stimuli
2. Often fails to give close attention to details or makes careless mistakes in schoolwork, work, or other activities
3. Often does not seem to listen to what is being said to him or her
4. Often has difficulty organizing tasks and activities
5. Often loses things necessary for tasks or activities (e.g. school assignments, pencils, books, tools, or toys)
6. Often has difficulty sustaining attention in tasks and play activities
7. Often does not follow through on instructions and fails to finish schoolwork, chores, or duties in the workplace (not due to oppositional behavior or failure to understand instructions)
8. Often avoids or strongly dislikes tasks (such as schoolwork or homework) that require mental effort
9. Often forgetful in daily activities

Children identified with the combined subtype of ADHD, must demonstrate six of the symptoms of the inattentive type of ADHD and six items from the list of hyperactivity/impulsivity listed: (APA, 2000).

Hyperactivity

1. Often fidgets with hands or feet or squirms in seat
2. Often leaves seat in classroom or in other situations in which remaining seated is expected

3. Often runs about or climbs excessively in situations in which it is inappropriate (in adolescents or adults, may be limited to subjective feelings of restlessness)
4. Often has difficulty playing or engaging in leisure activities quietly
5. If often “on the go” or often acts as if “driven by a motor”
6. Often talks excessively

Impulsivity

1. Often blurts out answers before questions have been completed
2. Often has difficulty awaiting turn
3. Often interrupts or intrudes on others (e.g., butts into conversations or games).

In considering whether or not a child can be diagnosed with ADHD, other factors that need to be considered include the following: demonstrating symptoms that caused impairment were present before the age of 7; some impairment from the symptoms is present in two or more settings (e.g., school and work); clear evidence of clinically significant impairment in social, academic, or occupational functioning, including the fact that they do not occur exclusively during the course of a Pervasive Developmental Disorder, Schizophrenia, or other Psychotic Disorder and are not better accounted for by another mental disorder (e.g., Mood Disorder, Anxiety Disorder, Dissociative Disorder, or a Personality Disorder) (APA, 2000, pp. 92-93).

In exploring the heterogeneity of ADHD, there has been a growing body of research that has supported the conclusion that inattentive behaviors, not the hyperactivity and impulsivity symptoms, are generally responsible for poor academic achievement (Daley, 2006; Todd et al., 2002; Rabiner & Coie, 2000). This finding is significant when considering the number of people identified with Inattentive or Combined subtypes of ADHD. It has been found that when students identified with ADHD-I (ADHD, Inattentive Type) are included in the group identified with ADHD-C (ADHD combined type), the total group represents over 75% of the population of children identified with ADHD (Gathercole & Pickering, 2002; Wilens, Biderman, & Spencer, 2002; Zentall, 2005).

As efforts have been made to look more closely at the similarities and differences among individuals identified with the various subtypes of ADHD, there has been growing interest in a qualitatively new subtype of ADHD knows as sluggish cognitive tempo (SCT), which is believed to account for 30 to 50% of children diagnosed as having Predominantly Inattentive Type of ADHD (ADHD-PI) (Barkley, 2006). SCT is characterized as having cognitive sluggishness and social passivity. These children also tend to be rated by parents and teachers as hypoactive, day dreamy, slow moving, staring, confused, and "in a fog", when compared with children who have ADHD-Combined type

(Barkley, 2006; Milich et al., 2001). Children with SCT have also been found to have more internalizing symptoms of unhappiness, anxiety, depression, and social withdrawal, as well as having more information-processing defects than children with ADHD-Combined type (Barkley, 2006; Carlson, Mann, & Alexander, 2000; Milich et al., 2001).

When considering the emerging research on ADHD subtypes, it has been suggested that clinicians recognize that there are likely two distinct dimensions of inattention. One type is the well-known inattentive type already identified in the *DSM-IV-TR* (APA, 2000) and listed in child behavior rating scales used to assess for ADHD (Barkley, 2006). SCT has been receiving increased interest as another possible subtype because it appears to reflect a distinct disorder of attention. It is not commonly referenced in assessing for ADHD, especially because it has not been described as a separate category in the majority of broad and narrow band behavioral/emotional assessments. Additional research is needed to understand the heterogeneity of ADHD and the implications it holds when providing interventions to students (Barkley, 2006).

As revisions of the *DSM-V* were being discussed in the final stages of its publication, the *DSM-V* ADHD work group released a list of proposed revisions in 2010 (http://www.dsm5.org). Although the *DSM-V* has been published, it is beneficial to examine the proposed revisions to understand the continual debates in the field about the diagnosis of ADHD. One of the proposals was to return to the term Attention Deficit Disorder. Three particular options were being proposed on how to address individuals who portray significant impairment in the area of inattention, but do not show related symptoms of hyperactivity or impulsivity. In the June 2010 publication of *The ADHD Report*, Adams et al. (2010) summarized the options presented by the workgroup and offered their perspective on the changes.

Option One: The work group suggested that there would be a separate code for ADHD-Primary Inattentive type, but no change in diagnostic criteria. Adams et al. (2010) reported that this is the least appropriate option, given the research findings. One of the criticisms is based on the framework which assumes that the symptom criteria are specific and reliable enough to differentiate between individuals with ADHD-C and ADHD-PI. For example, it was proposed under Option One that an individual with six Hyperactivity-Inattention symptoms would be diagnosed with ADHD-C, but that an individual with five Hyperactivity-Inattentive symptoms would be diagnosed with ADHD-PI. The argument has been raised regarding the continual practice of including ADHD-PI in the same category as disruptive behavior disorders when research has supported the idea that individuals with ADHD-PI demonstrate very few behaviors that are typically linked with impulsivity and hyperactivity. Among the criticisms, Option One had been described as lacking heuristic value and that by continuing to use a cut point of symptoms between the ADHD-C and the ADHD-PI subtypes, there is risk for continual contamination in the research by facilitating heterogeneity among the subtypes (Adams et al., 2010).

Option Two proposed creating a new ADHD subtype, "restrictive predominantly inattentive" (RPI). Restrictive Predominantly Inattentive type is a term suggested for individuals who meet the criteria in the area of inattention, but have no more than two hyperactive/impulsive systems currently and also no past history. Similar to Option One, there continues to be some concern raised regarding the continual presence of impairment related to hyperactivity and impulsivity. Another limitation is that RPI would continue to be considered a subtype of ADHD, which could contribute to further difficulty in large scale research attempting to track the use of the diagnosis and differentiating subtypes. One noted advantage described by the work group is that it places a category in the *DSM* for those who are "purely inattentive"; these may previously have been lumped with ADHD-C. Similar to the concerns presented earlier, Adams et al. (2010) described this category as inappropriate when considering that these individuals typically are rated low on scales of exhibiting disruptive behaviors, but would still be placed under the category of exhibiting disruptive disorders (Milich et al., 2001).

Option Three suggested giving Attention Deficit Hyperactivity Disorder its own diagnostic code that would be characterized by impairment solely in inattention. Advocates of this option reported that it provides a more accurate and appropriate term to describe the symptom profile in comparison with the awkwardness of the current term, particularly when attempting to describe the reason why a child with issues of inattention is being diagnosed with a disruptive behavior disorder. Similar to Option Two, there is increased opportunity to conduct research that specifically examines individuals diagnosed with inattention issues without hyperactivity. An advantage of Option Three over Option Two is that it encourages researchers to examine the needs of the child with inattention impairment outside of prior ADHD research. This option was believed by the workgroup as facilitating the understanding of ADHD as a unique disorder. One of the issues that was considered in adding this diagnosis would be in the reconsideration of exclusionary diagnoses (Adams et al., 2010). For example, symptoms of impulsivity and hyperactivity would need to be excluded in order to preserve the uniqueness of this disorder category. Another consideration is that there is still much that needs to be learned regarding the pathological underpinnings of this disorder. It was noted in the ADHD Report (Adams et al., 2010) that this factor should not preclude the classification and that it may, in fact, bring researchers closer to understanding the discrete factors and mechanism that contribute to inattention without hyperactivity. Another noted concern by the work group was the need to revise and recalibrate diagnostic tools used to assess the severity scales of ADD and ADHD (Adams et al., 2010).

In considering that the one reason there is so much attention given to the diagnosis of ADHD relates to the media portrayal of it as being an over-identified disorder, there has been research further examining the impact that age may play in inappropriately diagnosing the disorder. Specifically, a recent study out of North Carolina State University found significant differences in diagnoses of ADHD depending on their ages when entering kindergarten (Evans et al., 2010). Children entering school shortly after-the cutoff date, who were considered relatively old for the grade, were significantly less likely to be diagnosed with ADHD and receive treatment ,when compared with those relatively young for the grade with birthdates occurring right before the cutoff date. Because ADHD is an underlying neurological problem, the researchers noted that incident rates should not significantly differ from one birth date to the next (Evans et al., 2010). This finding raises questions about the process in which individuals are diagnosed with ADHD, particularly when age relative to classmates is not being considered. Critics have cautioned that the study has some limitations such as whether or not older children are being under diagnosed because they possibly look more mature than their peers (Szabo, 2010). It has been suggested by the researchers that as a result of this study, professionals involved in the diagnosis of ADHD will be encouraged to look more specifically at whether children are just young or if they do meet the diagnostic criteria of the disorder (Evans et al., 2010).

As the debate continues relative to establishing the diagnostic criteria for ADHD and subtypes, educators are simply struggling to understand how to address the needs of their students in the classroom. Because there is lack of understanding among many parents and educators about the neuropsychological underpinnings of ADHD, they may resist in accepting the fact that the behaviors and academic difficulties displayed by these young people may truly be difficult for them to manage. In order to minimize the myths and negative connotations that often deleteriously influence people's patience and willingness to address the challenging behaviors linked with ADHD and to increase the willingness to engage in interventions that target cognitive processes linked with the disorder, it is valuable for educators and families to understand the etiology and neurophysiology of the disorder as summarized in the following section.

Research on the Neurophysiology and Etiology of ADHD

Various studies have been conducted to examine potential etiologies of ADHD. At this time there has not been one specific factor identified as causing ADHD. The general consensus is that ADHD results from a complex interplay of genetic, environmental, and neurobiological factors (Brock, Jimerson, & Hansen, 2009; Kieling, Goncalves, Tannock, & Castellanos, 2008; Mick & Faraon, 2008; Shastry, 2004; Spencer, Biederman, Wilense, & Farone, 2002). Within this section, a summary of the research on the neurophysiology and etiology of ADHD will be presented.

Neurophysiology. Advances in functional imagining technology have allowed researchers to examine more thoroughly the differences in brain development among individuals with and without ADHD (Brock et al., 2009). One of the differences found is in overall brain size. When comparing age- and gender-matched peers, individuals with ADHD were found to have about a 3 – 8% smaller brain volume when compared with individuals without ADHD (Kieling et al., 2008). Recent results generated from brain imagery technology have suggested that the brains of children with ADHD are developmentally delayed by three years, thus generally appearing behaviorally different from their same aged peers (Shaw et al., 2010). Research utilizing behavior rating scales and neuropsychological tests found that individuals with more severe symptoms of

ADHD also had smaller brain volumes (Bush, Valera, & Seidman, 2005). These differences have consistently been found throughout childhood and adolescence and do not appear to be influenced by medication status (Castellanos et al., 2002). The prefrontal cortex, the area of the brain linked with attention, behavioral inhibition, and executive functioning has also been found to be significantly smaller in children with ADHD, when compared with controls (Brock et al., 2009; Seidman, Valera, & Makris, 2005). The reduction of the dorsolateral prefrontal cortex, a region in the frontal lobes of the brain heavily interconnected with a variety of other cortical brain regions, has been particularly implicated in the pathophysiology of ADHD (Brock et al., 2009; Kieling et al., 2008; Krain & Castellanos, 2006; Seidman et al., 2005).

Research that has examined cerebral blood flow found patterns of underactivity in the prefrontal areas of the central nervous system (CNS) and their connections to the limbic system via the stratium (Barkley, 2006). Earlier studies hypothesized that deficiencies in specific neurotransmitters, namely dopamine and norepinephrine, may explain these patterns of underactivity because this is the region in which these neurotransmitters are most prolific (Shaywitz, Shaywitz, Cohen, & Young, 1983; Zametkin & Rapport, 1986). In a landmark study conducted in 1990, Alan Zametkin and colleagues at the National Institute of Mental Health (NIMH) (Zametkin et al., 1990) evaluated the brain metabolic activity in 25 adults with ADHD who had a childhood history of ADHD and who also had children with the disorder. Through the use of positron emission tomography (PET), reduced brain metabolic activity was found in the adults with ADHD, when compared with controls, particularly in the frontral and stratial areas. These results were consistent in many of the earlier studies, demonstrating similar patterns of blood flow in children with ADHD (Barkley, 2006; Lou et al., 1984, 1989). Additional research was also being conducted by NIMH utilizing magnetic resonance imaging (MRI) to evaluate the brain structure of children identified with ADHD (Hynd et al., 1990). Hynd et al. (1990) focused on total brain volume as well as on the specific regions in the anterior and posterior sections of the brain. It was found that children with ADHD had abnormally smaller anterior cortical regions. This was especially apparent on the right side. Additionally, they lacked typical normal right-left frontal asymmetry (Barkley, 2006; Hynd et al., 1990). This team also revealed subsequent findings that both the anterior and posterior regions of the corpus collosium were smaller in children with ADHD (Hynd et al., 1990; Semrud-Clikeman et al., 1994).

Since this research, a smaller left caudate region in children with ADHD was found by Hynd et al. (1993). Giedd et al. (1994) also reported finding smaller anterior regions of the corpus collosium (Rostrum and rostral body). The degree of blood flow in the right frontal region has been associated with the behavioral severity of the disorder, and reduced flow in the posterior regions and the cerebellum has been correlated with motor impairment (Gustafsson et al., 2000). Additional research has found that blood flow appears to be affected by the stimulant methylphenidate, which is used to treat ADHD (Barkley, 2006; Langleben et al., 2001).

Studies examining larger samples of children with ADHD and utilizing MRI technology have also found significantly smaller right prefrontal cortex and striatal regions within this group (Castellanos et al., 1994; 1996; Filipek et al., 1997). In Castellanos and colleagues research (Castellanos et al., 1996), regions in the basal ganglia (particularly the striatum), and the cerebellum were also found to be smaller on the right-side of these structures. In contrast, Filipek et al. (1997) found the left striatal region to be smaller. Although differences exist in these studies, the research is fairly consistent that the prefrontal-striatal network is smaller in children with ADHD and the right prefrontal region is smaller than the left (Barkley, 2006). Many theorists have used this evidence to purport that ADHD does involve impaired brain development and that it likely originated in embryological development (Barkely, 2006; Castellanos et al., 1996).

Because of significant growth in medical technology, further evidence continues to emerge in helping to understand brain activity and related development. Studies involving functional MRI (fMRI), which has greater sensitivity for the localization of activity, have found different patterns of activation when subjects are asked to perform tasks requiring attention and inhibition. Collaborating with other research, the differences can be observed in the basal ganglia (striatum, globus pallid, and putamen) and the cerebellum (Rubia et al., 1999; Teicher et al., 2000; Vaidya et al., 1998; Yeo et al., 2003). Many reviewers of the literature in the past few decades support the belief that abnormalities in the frontal-striatal-cerebellar structures of the brain have been determined as an underlying factor contributing to the development of ADHD in children

(Arnsten, Steere, & Hunt, 1996; Barkley, 2006; Benton, 1991; Hendren et al., 2000; Mercugliano, 1995; Tannock, 1998). In reviewing this research, it is important to consider that the prefrontal cortex and the networks linked with the cerebellum and basal ganglia are also believed to mediate executive functions (Barkley, 2006).

Genetics. Research generated from family, twin, adoption, genome, and candidate gene search studies have supported the idea that genetics play a powerful role in the inheritability of ADHD (Biederman, 2005; Brock et al., 2009; Daley, 2006; Mick & Farone, 2008; National Institute of Mental Health [NIMH], 2006). Genetics have been found to be such a significant factor in explaining the etiology of ADHD that Spencer and colleagues (2002) wrote, "It is more attributional to genetic factors than are depression, generalized anxiety disorder, breast cancer, and asthma" (p. 6). In a literature review conducted by Biederman (2005), it was found that parents and siblings of children with ADHD have a two- to eight-fold increased risk for the disorder. When examining the specific incident rate of parents and siblings of children also diagnosed with ADHD, it was reported to be 25 to 26% percent, respectively (Biederman, Faraone, Keenan, Knee, & Tsuang, 1990; Brock et al., 2009; Welner, Welner, Steward, Palkes, & Wish, 1977). Another statistic indicated that the occurrence of ADHD among children of parents with ADHD is 55% (Biederman et al., 1995; Brock et al., 2009). In a review of twin studies, Tharpar, Harrington, Ross, and McGuffin (2000) indicated that the heritability of ADHD may range from 64 to 91%. Barkley (2006) has suggested that the average rate of heritability to be 80 to 90%. Additional research on 20 twin studies found a mean heritability estimate of 76% (Brock et al., 2009; Faraone et al., 2005). When examining the research on fraternal twins, the risk of both twins having ADHD is not any greater than non-twin siblings (29%), regardless of the fact that they share the same maternal environment during pregnancy (Brock et al., 2009; Gilger, Pennington, & DeFries, 1992).

In order to investigate further the role of environment and genetics as contributing to the causation of ADHD, studies involving children who have been adopted have been invaluable. Sprich, Biederman, Crawford, Mundy, and Faraone (2000) found that the adopted relatives of children with ADHD were less likely to have ADHD than their biological relatives. Although these results provide support of genetic factors to explain the etiology of ADHD, additional consideration of candidate gene studies is also important in order to understand more clearly the specific chromosome regions and specific genes that are linked with ADHD.

Candidate gene studies. Clinical and empirical evidence on ADHD has supported the notion that the candidate genes likely linked to ADHD are those involving the regulation of brain chemicals (i.e.. dopamine), found primarily within the frontal-subcortical network or region (Brock et al., 2009). Dopmaine, one of the transmitters linked with ADHD, is believed to be responsible for reward-driven learning. Serotonin, another neurotransmitter linked with psychiatric concerns, is a chemical that has been found to assist in managing moods (Brock et al., 2009; Mick & Farone, 2008). Research gathered by Mick and Farone (2008) have further researched these neurotransmitters and have identified five genes that have been implicated in the etiology of ADHD.

1. *Dopamine D4 Receptor* (DRD4, located in frontal-subcortical networks and associated with the personality trait of novelty seeking)

2. *Dopamine D5 Receptor* (DRD5, abnormalities are believed to underlie ADHD*),*

3. *Dopamine,SLC6A3 Transporter* (regulates dopamine and is affected by stimulant medication)

4. *Synaptosomal-Associated Protein of 25kD* (SNAP-25, which effects dopamine and serotonin levels and might cause hyperactivity)

5. *Serotonin HTR1B Receptor* (believed to underlie the impulsive symptoms in ADHD)

(Cited from Brock et al., 2009, p. 12)

In reviewing this research, it has been cautioned that association of these genes with ADHD is small, however, and that genetic vulnerability may be affected by many genes of small effect (Brock et al., 2009; Mick & Farone, 2008). Psychotropic medications, such as methylphenidate and dextraoamphetamine, are examples of medications that are frequently used to alter the levels of these transmitters to improve behaviors linked with ADHD (Brock et al., 2009; Smith, Pelham, Gnagy, Molina, & Evans, 2000).

Environmental factors. Myths regarding factors contributing to ADHD often entail environmental sources such as television watching, consuming too much sugar, or diet concerns in general. These variables have not received substantial support in the research (Brock et al., 2009). Based on the finding that inheritance does not account for all accounts of ADHD symptoms, other environmental factors may be considered in the development of the disorder (Barkley, 2006; Brock et al., 2009; Das Banergee et al., 2007). Factors that have been considered include alcohol use or smoking during pregnancy as well as low birth rate (Brock et al., 2009). For example, mothers who smoked during pregnancy were three times more likely to develop a child with ADHD than mothers who did not smoke (Milberger, et al., 1997). Although low birth rate has been found to be a common factor in children with ADHD, the exact relationship between these variables is not able to be explained (Brock et al., 2009; Mick, Biederman, Prince, Fisher, & Faraone, 2002).

When examining the etiology of ADHD, there is much more that needs to be learned and more work to be completed to alleviate the misunderstanding about the causes of ADHD. Because there is considerable support that the causes of ADHD are significantly influenced by medical factors versus environmental sources, it is not uncommon in the United States for the use of medications to be the first, if not the only, form of intervention or treatment to manage the symptoms of ADHD. Although medications have been found to be successful in managing ADHD for many children and adults, there is also merit to consider additional forms of interventions that may be valuable to implement in the school setting in order to address the educational, social, and behavioral needs of individuals diagnosed with the disorder (Brock et al., 2009; Barkley, 2007).

Based on the increasing evidence in the field of neuropsychology that helps to explain the cognitive processes implicated in the manifestation of symptoms, primarily those described as Executive Functions, educators are better prepared to identify, design and implement strategies to address the particular learning needs of children with ADHD. This research is to serve in helping make the paradigm shift in recognizing that treating only the behavioral symptoms is not sufficient and more attention needs to be directed towards interventions that also address learning and overall success in the classroom and community.

Research on ADHD Theory

There is strong support that ADHD is related to core deficits in executive functioning (EF), a term referring to the higher order thought processes believed to be central to problem solving (Barkley, 1997; Brock et al., 2009: Willcutt et al., 2001). Although there is agreement that executive functioning processes are linked to ADHD, there are differences in how the models are conceptualized (Barkley, 2006). Because the purpose of this research is specifically to examine cognitive training for children with ADHD, it is beneficial to examine the specific cognitive processes regarded as core EF tasks. Within this section, a summary of the different models and psychological processes linked with ADHD are reviewed.

Executive functioning and related theories. Executive function generally is described as an "umbrella term" (Anderson, 2002, p. 71) used to include the ability to plan, organize information, self-monitor, change or modify behavior, and manipulate information to solve a problem (Semurd-Clinkeman, Pliszka, & Liotti, 2008). Anderson (2002) emphasized that the major elements of EF comprises of anticipation, goal selection, initiative of activity, use of feedback, mental flexibility, self-regulation, and attention. As a result of the significant interest in executive functions, there has been a growing body of research in recent years investigating the role these cognitive processes have on learning. This body of research includes large studies examining executive functioning in children with learning disabilities, autism, behavioral problems, and language and comprehension problems. Generally, these studies have found that executive functions serve as a good predictor of performance (Bull & Scerif, 2001). Based on growing evidence, it has been suggested that Executive Functioning may play a more significant role in learning than any other factor, including IQ, from young childhood into adulthood (Alloway, 2009).

When examining executive functioning processes in all children, it is important to consider that the complex structures and neurochemical processes linked to these skills follow a developmental progression (Brown, 2005; Hale & Fiorello, 2004). In fact, these processes and structures begin to form early in fetal development, but mature slowly, continuing to form and refine throughout childhood and into adolescence and adulthood. Bacon (2001) reported that although most of the neurotransmitter systems are formed at birth, the dopamine and norepinephrine systems take much more time to develop. As described previously, these particular systems are critical in the execution of executive functions and may not fully form until early adulthood (Brown, 2005, Jensen, 2015).

Another developmental process that is important in the refinement of EF skills is "myelination," in which a protective coating forms around the fibers that transmits messages from the brain to the body (Brown, 2005, Jensen, 2015). A significant amount of mylination occurs before the age of two. The more complex areas of the brain, such as the areas in the prefrontal cortex responsible for EF skills, do not become fully mylinated until adulthood (Brown, 2005; Jensen, 2015; Sampaio & Truwit, 2001). Research has found that the foundation of EF skills are developed early for most children; however, full development of specific abilities such as regulating action, modulating emotions, and sustaining attention takes longer (Brown, 2005, Jensen, 2015).

During the early adolescent years, a pattern of rapid increases in brain volume has been observed with a proliferation in the number of neural networks, especially in the cerebellum and frontal lobes (Brown, 2005; Geidd, Blumenthal et al., 1999; Giedd, Snell, et al., 1996). It was also discovered that following this rapid increase in brain cells, rapid pruning of the neural networks also occurs, a process believed to improve overall mental efficiency (Brown, 2005). Benes (1994) reports that during the teenager years, myelination increases by 100 percent, and that executive functions continue to develop into adulthood. This falls within the same range of time in which adolescents are better able to manage their emotions and impulses (Benes, 1994; Brown, 2005). Differences can also be noted among individuals, with some children taking much longer than their peers (Brown, 2005). It is suggested that children with ADHD are able to manufacture dopamine and norepinephrine, but they do not release and reload them effectively in the areas necessary to execute executive functions. This results in messages not consistently being transmitted adequately and in a timely manner (Brown, 2005).

Despite the consensus regarding the development and importance of EF in everyday life functioning, there is considerable debate regarding the cognitive constructs associated with executive functioning because the definitions can be quite cumbersome to describe in their entirety (Brock et al., 2009; Epsy et al., 2006). Throughout the research there are discussions on EF skills and how they impact individual's performance, but conceptual models to explain the relationship among the various processes is limited. In examining the research that has been conducted on EF, McCloskey et al. (2009) noted two key dimensions that are consistent in the research. One is that the related executive functioning capacities involve directing or cueing other mental processes and/or motor processes. Second, these processes have been found to be activated in portions of the frontal lobe region of the cerebral cortex (McCloskey et al., 2009, p. 38). These findings formed the foundation of McCloskey (2004) Model of Executive Functions, in which he conceptualized the interplay of multiple executive functions using five holarchichally organized tiers of executive capacity. The first three tiers of McCloskey's model are directly involved with daily self-control (McCloskey et al., 2009). These tiers are Self-Activation, Self-Regulation, and Self- Realization and Self-Determination (McCloskey et al., 2009). Self-activation refers to an individual's ability to awaken and attend. Self-regulation comprises of 23 self-regulation executive functions that are considered responsible for cueing, as well as directing functioning within the domains of emotion, cognition, sensation and perceptions, cognition, and action (McCloskey et al., 2009, p. 40).

The third tier, self-realization and self-determination, involve processes of self-control that go beyond self-regulation. Self-realization involves self-awareness as well as self-analysis (McCloskey et al., 2009). The final two tiers represent processes that go beyond the needs of day to day functioning, but rather involve the ability to consider the meaning of life and develop a personal philosophy of life. This tier is termed "Self-generation" and is linked with mind-body integration and sense of spirit. The last tier, "Trans-Self-Integration", refers to the ability to transcend and see outside of the notion of 'self' through an experience of "unitary consciousness" (McCloskey et al., 2009, p. 39). Additional information on these tiers and McCloskey's model of Executive Functions can be found in *Assessment and Intervention for Executive Function Difficulties* (McCloskey et al., 2009).

Other models that entail details about the role of executive functioning have also been developed with the emphasis being primarily directed towards individuals with ADHD. These models include examining specific executive functioning deficits in children with ADHD and the impact that the related domains may have in learning and daily functioning (Wilcutt, Doyle, Nigg, & Pennington, 2005). One model designed by Brown (2005) grouped specific cognitive functions into six clusters that clearly outline the various executive functioning impairments linked to individuals with ADHD. The following is a list of categories.

Cluster 1: Activation: Organization, prioritizing, and activating for tasks.

Cluster 2: Focus: Focusing, sustaining, and shifting attention to tasks.

Cluster 3: Effort. Regulating alertness, sustaining effort, and processing speed.

Cluster 4: Emotion. Managing frustration and modulating emotions.

Cluster 5: Memory: Utilizing working memory and accessing recall.

Cluster 6: Action: Monitoring and self-regulating action.

Brown (2005) concludes that these clusters tend to be integrated and clinically related. Based on this understanding, Brown describes ADHD as a syndrome similar to other developmental disorders and indicates that the clinical symptoms improve in conjunction with treatment (Brown, 2005, p. 22). This model holds significant implications for treating ADHD as a syndrome, because addressing both behavioral and neuropsychological processes can have a positive interacting effect in the overall presentation of symptoms.

In examining the various models of ADHD, there is some debate regarding the primary mechanisms responsible for the manifestation of symptoms in children with ADHD. Barkley (1997; 2006) suggests that students with ADHD experience a core deficit in behavioral inhibition, the ability to filter out competing stimuli and delay prepotent responses (Raggi & Chronis, 2006). According to Barkley's model (2006), behavioral inhibition affects numerous executive functioning processes including non-verbal working memory, delayed internalization of speech (verbal working memory), immature self-regulation of affect/motivation/arousal, impaired reconstitution (i.e. analysis and synthesis of behavior; verbal fluency, goal directed behavior, syntax of behavior, and behavioral simulations), and reduced motor control/fluency/syntax (Barkley, 1997, p. 73). Poor behavioral inhibition has also been hypothesized to be a cognitive process that subserves behavioral regulation as well as executive functions (Barkley, 2006; Alderson et al., 2010). These deficits have direct implications in students' abilities to learn in the regular education classroom. It is believed, for example, that inhibitory processes of children with ADHD are unable to prevent extraneous information from entering the working memory system effectively, resulting in an inability to maintain task goals without interference (Brock et al., 2009). Deficits in working memory, for example, contribute to symptoms of forgetfulness, difficulty in organizing and failure to start items, due to poor time management, and limited foresight (Mash & Barkley, 2003; Raggi & Chronis, 2006). The difficulties associated with poor motor coordination include difficulties in planning and following through with complex, lengthy, and novel steps towards reaching a goal (Mash & Barkley, 2003; Raggi & Chronis, 2006). Slow perceptual speed and motor response have also been linked to deficits in academic performance (Barkley at al., 1992; Plomin and Foch, 1981; Raggi & Chronis, 2006). Immature self-regulation of affect and motivation may lead to poor emotional and behavioral control in the classroom (Raggi & Chronis, 2006).

There are implications that the behavioral aspects of executive functioning deficits affect ADHD children's learning in the classroom; these include inability to attend to class, frequent displays of off-task behaviors, failing to listen to the teacher, forgetting to complete and turn in assignments, increased activity level, tendency to make frequent errors, difficulty returning to activities when distracted, and paying less attention to task rules (Raggi & Chronis, 2006). Children with hyperactivity and high motor activity also may have difficulty staying in their seats, playing without interrupting others, and frequently demonstrating a tendency to touch objects (Marsh & Barkley, 2003; Raggi & Chronis, 2006). Additionally, impulsivity is a significant academic risk factor because these students may have trouble withholding active responses and thus tend to answer questions inaccurately due to difficulty in waiting for correct alternative information (Raggi & Chronis, 2006; Zentall, 1993).

In contrast to the Disinhibition model proposed by Barkley, research by Kofler et al. (2008) indicate that working memory is the core, causal cognitive process responsible for ADHD in their model called the Functional Working Memory Model of ADHD. Behavioral inhibition deficits and other executive functions are considered byproducts of working memory deficits. Kofler and collegues (2008) describe inhibition as a byproduct because it is dependent on the individual’s ability to register environmental stimuli. In other words, information has to be activated in working memory before a decision can be made to register the information (Rapport, Chung, Shore, & Isaacs, 2001). Within this model, working memory (WM) is specifically defined as processes that construct, maintain, and manipulate information. WM serves as the mechanism that allows for organized, future-oriented behavior or problem solving skills. Deficits in working memory are presumed to account for secondary features such as hyperactivity, inattention, and impulsivity. Associated features and outcomes include impairment in the following areas: cognitive test performance, academic achievement, social skills, organizational skills, classroom deportment, and delay aversion (Rapport et al., 2001; Kofler et al., 2008). These features include those concerns frequently reported by parents and teachers when describing children with ADHD.

It is also believed that the breakdown in WM leads children to demonstrate stimulus seeking behavior. The specific behaviors of hyperactivity and impulsivity replace the rapidly fading traces of working memory. Children with ADHD seek rapid input from stimuli in order to fill the voids that occur when they can no longer recall the previous activity. In regard to attention, it is believed always to be a conscious activity. Students with ADHD tend to avoid tasks with high demands on WM by engaging in escape behaviors (Rapport et al, 2001). When examining WM deficiencies in children with ADHD, it is also important to consider the cumulative effects of poor working memory, particularly when students are faced with high-stake assessments that rely on their abilities to learn and retain information (Rapport et al., 2001).

Another model of ADHD is based on motivational variables in which the individuals with the disorder demonstrate an abnormal sensitivity to reinforcement (Douglas, 1999; Sagvolden & Sergeant, 1998; Sagvolden et al., 2005). It has been found that reinforcement contingencies, such as reward/punishment/response costs and (accuracy) feedback, as well as combinations, have a positive impact on children with ADHD as well as on controls (Prins et al., 2011). Luman et al. (2005) found that high intensity reinforcement and immediate versus delayed reward as more noticeably effective in children with ADHD. It was further described that children with ADHD need added external incentives for potentially boring tasks to optimize their motivational state, and that without these external reinforcement, their attention span is limited.

Performance deficits in children with ADHD are partially attributed to low effort and intrinsic motivation (Luman et al., 2005; Shanahan et al., 2008).

In explaining the abnormal sensitivity to reinforcement found in children with ADHD, Sergeant et al. (1999) hypothesized that these individuals suffer from a nonoptimal energetic state, based on the assumption that the processing of information is affected by process and state factors such as effort, arousal, and activation (Prins et al., 2011). It is suggested that reinforcement plays a role in inducing the energetic state (Luman et al, 2005). Computer assisted instruction (CAI) has been described as a method that has been found to improve interest and motivation in children with ADHD because of its emphasis on external incentives (Pfinner, Barkley, & DuPaul, 2006; Prins et al., 2011). They appear to be attracted to the game-like format and clear goals and objectives established within CAI (Prins et al., 2011). In examining the design of the computerized training program being proposed by this researcher, several elements of the prescribed protocol present with motivational variables that likely contribute to students' willingness to continue with the training program.

Summary reflections on conceptualizations of ADHD. Although there are differences in how the executive functions of ADHD are conceptualized, there is agreement that these deficits are central to difficulties in learning. In examining the neuropsychological research conducted on the specific cognitive domains, however, the results are inconclusive. For example, verbal memory and spatial working memory have been suggested as pervasive difficulties in students with ADHD (Semurd-Clinkeman, Pliszka, & Liotti, 2008). Impairment in spatial working memory has been well-established in the research within this population, whereas verbal working memory has not been empirically supported to the same degree (Matinussen et al., 2005; Pennington & Ozonoff, 1996; Semurd-Clinkeman, Pliszka, & Liotti, 2008; Wilcutt et al., 2001). Additionally, there have been some conflicting results regarding consistent weaknesses in response inhibition, reaction time, and visuo-spatial ability in children with ADHD (Chelune, Ferguson, Koon, & Dickey, 1986; Gorenstein, Mammato, & Sandy, 1989; Grodzinsky & Diamond, 1992; Semurd-Clinkeman, Pliszka, & Liotti, 2008). One of the issues raised in the research is that subtypes of ADHD are often lumped together; this raises the question about whether or not the confounding results may be due to differences in the cognitive constructs underlying the three subtypes of ADHD described previously (American Psychiatric Association, 1994, 2000; Nigg, 2001; Semurd-Clinkeman, Pliszka, & Liotti, 2008).

Studies completed by Sonuga-Barke (2003; 2005) have suggested that children with ADHD are likely a heterogeneous group with multiple causal pathways involved in the manifestations of ADHD symptoms. Support of this belief was found through a Meta-Analytic review of 83 studies that administered EF measures to groups with ADHD (N = 3734) and without ADHD (N=3734) (Willcutt et al., 2005). It was found that groups with ADHD did exhibit significant impairment in all EF tasks (Willcutt et al., 2005). Although EF weaknesses were found to be significantly correlated with ADHD, moderate effect sizes and lack of universality of EF deficits among individuals with ADHD suggested that EF deficits are not the single and sufficient cause of ADHD in all individuals with the disorder. Willcutt and colleagues (2005) reported that ADHD should be further investigated as a *multiple-deficit disorder* to assist in accounting for the neuropsychologic heterogeneity of ADHD (Castellanos & Tannock, 2002; Nigg et al., 2005; Sergeant, 2005; Sonuga-Barke, 2005: Wilcutt et al., 2005). The strongest and most consistent effect sizes were obtained on measures of response inhibition, vigilance, working memory, and planning (Wilcutt et al., 2005).

In summary, ADHD has been widely recognized as a disorder related to core deficits in EF. There is some debate on the core mechanisms that may be responsible for the specific manifestation of symptoms in children with ADHD. Two primary models that have emerged are the behavioral inhibition model and functional working memory model of ADHD. It has also been described as a cluster of symptoms that are integrated and clearly related, as suggested by Brown (2005). The manifestation of ADHD symptoms has also been explained as being influenced by motivational variables affected by process and state factors such as effort, arousal, and activation (Prins et al., 2011). Recent research has questioned whether or not ADHD subtypes may have unique, heterogeneous pathways to explain the different presentation of symptoms. Because one of the purposes of this research is to implement interventions specifically to address the cognitive processes underlying ADHD, it is beneficial to examine the specific cognitive processes regarded as core EF tasks. One particular area that has been viewed as a hallmark symptom of ADHD is inattention. There is growing evidence that attentional processes are also an important cognitive construct requiring consideration when looking at individuals with learning difficulties.

Attention System of the Brain and ADHD

Difficulty with attention is often regarded as the hallmark feature of ADHD. Through extensive exploration in adult neuroimaging studies, a great deal has been learned about the attention system of the brain. Although the models of attention continue to be debated and refined, knowledge of the particular regions of the brain becomes clearer with the advances in medical technology. Attention has been discovered to be a system that is interrelated with other processes or systems of the brain, yet also functions as a unique, distinct system. The cognitive processes linked with attention are not carried out by one particular area of the brain, but rather functions as part of an anatomical network (Posner & Peterson, 1990; Fernandez-Duque & Posner, 2001). Posner (1992) theorized that attention includes anterior, posterior, and vigilance attentional systems. Specifically, attention is involved in orienting to sensory events, detecting signals for processing and maintaining vigilance or maintaining an attentional state (Posner & Peterson, 1990). Fernandez-Duque, & Posner (2001) built on previous attention models as they described three attentional networks: the orienting network; the vigilance network; and the executive network. A recent model revisited by Posner and his colleague, Rothbart, can be found in their book on *Educating the Human Brain* (Posner & Rothbart, 2007), in which the authors describe three distinct networks in the brain that perform various functions ; these include the alert network (alert state); orienting network (orienting to sensory events); and the executive network (maintaining continuity of behavior when presented with conflicting responses).

Within Posner's and Rothbart's model (2007), the alert system is reported to be involved in assisting and maintaining an alert state, which varies as people transition from a sleep to alert state. It is a system that has been found to arise in an area of the midbrain called the locus coeruleus, which is also the source of the modulator, norepinephrine (Posner & Rothbart, 2007). When individuals must be involved in sustained vigilance for significant periods of time (tonic alertness), the right cerebral hemisphere is also involved (see Posner & Peterson, 1990 for a review).

The orienting network involves the individual's ability to orient to sensory events through such processes as shifting the eyes or moving the head to bring the event to the fovea, the part of the eye responsible for sharp central vision, and align the sensory processes (Posner & Rothbart, 2007). This system can also serve to convert shifts of spatial attention to increase sensory perception and activation, but in the absence of covert head or eye movements (Posner & Rothbart, 2007). Research has found that the orienting network processes occur in two separate regions of the parietal lobe that are closely related to eye movements (Corbetta & Shulman, 2002; Posner & Rothbart, 2007).

Providing the basis for voluntary behavior is the third network, the executive network (Posner & Rothbart, 2007). This system is activated when an individual is in conflict with two possible responses to an event. One example from neuropsychology research occurs when a subject is presented with a Stroop task; this is a situation in which a word is presented in an ink color that is either the same or different from the word name. The difficult task requires the individual to activate regions for voluntary control and inhibit responses to read the word and not the color (Posner & Rothbart, 2007). Areas of the brain found to be linked with this network includes the anterior cingulate, lateral prefrontal, and basal ganglia (Posner & Rothbart, 2007).

One of the aspects that has been discovered when examining the executive attention network is that it involves the same brain areas linked with emotion (Bush, Luu, & Posner, 2000; Posner & Rothbart, 2007). Studies utilizing pediatric neuroimaging have been able to trace the development of this network in toddlers and young children (Posner & Rothbart, 2007). Executive attention has also been linked with a particular form of memory called *explicit learning,* which involves a child's ability to recall previously presented information (Posner & Rothbart, 2007). Posner and Rothbart (2007) noted that attention is needed in order for this memory to be put into a form to be reinstated later. They also noted that executive attention is central to children's ability to regulate both their emotions and cognition; thus, it is of great importance in their success in learning specific skills in the school setting. Weaknesses in executive attention can influence the explicit learning necessary for higher level skill acquisition in reading, math, and abstraction (Posner & Rothbart, 2007). Effortful control, or the measure of an individual's ability to inhibit a dominant response in order to complete a non-dominant response, is an area that improves with maturation of the brain (Posner & Rothbart, 2007).

When examining the research on attention, it is important to consider that several theoretical models exist, although several terms or definitions among these may overlap. Another theoretical model on attention was developed by Mirsky et al., (1991). After examining more than 600 individuals with clinical disorders of attention, they developed the following taxonomy of attention: *focus/execute, sustain and stabilize, shift*, and *encode*. In applying these terms to the application of learning, *focus/execute, sustain*, and *shift* are significant processes that play an important role in learning because it involves individuals' abilities to attend initially to the stimuli, maintain attention, and shift attention when necessary (Miller, 2007). S*tability* has been a term that has been connected with the reaction time measured by Continuous Performance Tests (Conners, 1994) and e*ncode* has emerged as synonymous with working memory (Miller, 2007, p. 133). Being aware of the terminology of the different models, such as Mirsky's et al. (1991), is beneficial when examining the neuropsychological processes described in the research, with the understanding it may be measuring a similar process but described by a different term. In reviewing the literature, it can be summarized that, overall, the role of attention has increasingly been viewed not only as a significant issue behaviorally, but also as critical to learning. It has been particularly recognized as an important process in working memory.

In summary, difficulty with attention is viewed as one of the primary complaints presented by educators when discussing the challenges they face in teaching and managing the behaviors of children with ADHD. Although most educators understand that attention affects behaviors, they may minimize the impact that attention has on all aspects of learning, including the various types of cognitive processes involved. This is particularly salient when considering that children with attention difficulties without hyperactivity may be easily missed in the classroom. One of the significant factors that requires consideration when targeting interventions for children with inattention difficulties is the role such deficits have on memory, particularly working memory. Additional information will be presented in the following section on working memory in children with ADHD, which will also include the relationship it has with attention. Reviewing this information will serve in validating the importance of investing in interventions that more specifically target the cognitive weaknesses found in individuals with inattention difficulties and learning disabilities.

Research on Working Memory and ADHD

As previously reported, another construct of executive functioning that has been considered a potentially significant mechanism of ADHD and linked with attention is working memory (Beck et al., 2010; Castellano & Tannock, 2002; Semurd-Clinkeman, Pliszka, & Liotti, 2008). Working memory is described as a key executive function that has been linked with many cognitive tasks and achievement (Berg et al., 2010; Nigg, 2006). There is still much that is unknown about working memory because of the difficulty in isolating working memory as a single construct. It has generally been regarded as a task that is difficult to assess due to the interconnections between executive functioning processes. An increasing number of studies, however, have investigated and found that working memory is a primary deficit in children with ADHD. Brown, Reichel, and Quinlan (2007), for example, found that over 74% of ADHD individuals in the sample had significant working memory deficits. After Martinussen, Hayden, Hogg-Johnson, and Tannock (2005) conducted a meta-analysis of 26 studies on children with ADHD, they found a significant portion of students had deficits in multiple components of working memory. They also further concluded that children identified with ADHD tended to struggle academically; this due to their working memory deficits rather than being a direct result of inattention.

In examining the link between ADHD and working memory, it has also been suggested that an assessment in various constructs of memory can assist in diagnosing and determining ADHD subtypes (Dehn, 2008; Quinlan & Brown, 2003). Brown (2005) found that tests of short-term auditory memory were particularly helpful in the diagnosis of ADHD (Quinlan & Brown, 2003). They found that 66% of adults with ADHD had a significant discrepancy of at least one standard deviation between their verbal IQ and story memory. Only 16% from the general public demonstrate such variability. A study on children by Brown (2001) yielded similar results. Using a story memory test, 57 to 73 percent of the children with ADHD showed significant differences with story recall; only 25 to 33% of children in the general population demonstrated difficulties.

Martinussen and Tannock (2006) are among a group of researchers who have found that young people with ADHD, combined type, tend to perform worse than normal students on all measurements of short-term and working memory components. In contrast, individuals with primarily inattentive subtype were deficient in visuo-spatial and executive working memory and the primarily hyperactive-impulsive subtype tended to have deficits primarily in the executive domain of working memory. Another study based on Baddeley's model of WM found that children with ADHD had impairment in all three components of working memory, specifically the central executive, visuospatial sketchpad and phonological loop (Rapport et al., 2008). Adding to this research, they found larger effect sizes for impairment in the central executive area than in the two storage areas. More specifically, converging evidence suggest that the largest deficit is found in the domain general central executive system (CE), followed by visuospatial storage/rehearsal (VS) and the phonological storage rehearsal systems (PH) (i.e. deficits in CE> VS>PH; Martinussen et al, 2005; Rapport et al., 2008). It has been suggested that the central executive component of WM is also related to the hyperactivity of ADHD (Rapport et al., 2009). Verbal working memory and executive working memory deficits have also been proposed as the common neuropsychological construct that links the co-occurrence of inattentive ADHD and learning disabilities (Martinussen & Tannock, 2006; Dehn, 2008).

In viewing this research, the results appear to be mixed in terms of delineating the specific memory deficits that children with ADHD may experience; this could be attributed to the flaws in research on working memory to be discussed later in this chapter. Although the results regarding the relationship between the systems of working memory and ADHD subtypes are not clear, this body of research holds significant implications when considering that working memory may be a primary underlying factor affecting the academic progress of children identified with ADHD (Dehn, 2008). These findings are particularly important when considering that investing in interventions that target working memory may prove to be beneficial in meeting the learning needs of those children who have to struggle continually, despite educators best effort to address their needs, such as those children targeted for this study.

Research on Attention and Working Memory

As described previously in the review on attention, a relationship does appear to exist between attention and working memory. Being able to share the research on the relationship between working memory and attention with educators is important to help guide educators in finding peak opportunities to engage children struggling with their symptoms of ADHD. For example, research has found that children who are presented with information that exceeds their working memory capacity are more likely to “zone out” or abandon particular tasks (Gathercole & Alloway, 2008). A study by Kane et al. (2007) found that individuals with low working memory abilities were significantly more likely to report unrelated tasks and inattention. This study, in which the participants were located in a novel and naturalistic setting, found increases in inattention when completing more challenging and difficult tasks. From the perspective of Baddeley's model (2001) and the Functional Model of Working Memory (Kofler et al., 2010), it is suggested that inattentive behavior observed in children with ADHD during academic tasks may be a result of exceeding the capacity either of the phonological or of the visualspatial storage/rehearsal components (Kofler et al., 2010).

Another component of Baddeley's (2007) working memory model to explain inattentive behavior is the significant role that the domain general central executive component has in controlling and focusing attention (Baddeley, 2007; Koefler et al., 2010; Rapport et al., 2008). A study by Kofler et al. (2010) investigated whether or not ADHD is functionally related to domain-general central executive and/or subsidiary story/rehearsal components of working memory. Through objective observations of children's attention behavior when completing counterbalanced tasks that differentially manipulated central executive, phonological storage/rehearsal and visual spatial storage/rehearsal demand, two conditions were found that accounted for attentive behavior deficits. These conditions are: a) placing demands on EF processes, even with low cognitive loads, and b) exceeding storage/rehearsal capacities. The latter was found to occur in children with ADHD and in typically developing children, but occurred at lower cognitive loads for children with ADHD (Kofler et al., 2010).

In reviewing the research and theories regarding the relationship between inattention and working memory, it is evident that separating cognitive processes concisely from each other is difficult. With this in mind, it is important for educators to consider the neuropsychological research on attention and working memory in order to apply interventions that specifically addresses the cognitive needs of children with ADHD. Although educators are seeking additional interventions to address the needs of these students, it must be acknowledged that the field of education is only at the beginning of examining the neuropsychological processes of the co-morbidity of math difficulties and ADHD. It is not surprising, therefore, that there is a gap in the research on empirically supported interventions implemented in the school setting designed to address the unique and complex needs of children with ADHD and learning difficulties (Auerbach et al., 2008). One of the reasons for this limited research is that the needs of individuals with ADHD have been focused primarily on the behavioral symptoms of ADHD; thus, the majority of studies have examined behavioral modification techniques and pharmaceutical treatment in reducing disruptive behavior (DuPaull &Eckert, 1997; Pelham & Fabiano, 2008). Through further investigation of interventions implemented in the school setting that address specific neuropsychological deficits linked with working memory and attention, educators will be able to incorporate appropriate cognitive interventions more efficiently and effectively for students with ADHD instead of randomly and haphazardly applying strategies that typically focus on classroom management and fail to address their academic struggles. Because it is the researcher's goal to assist in narrowing the gap between the fields of neuroscience and education by investigating an intervention that addresses the cognitive constructs that affect learning, the following section will provide a closer examination of the neuropsychological processes linked with math achievement and ADHD.

ADHD and Math Achievement

As described earlier, ADHD has been found to co-occur with specific learning disabilities to a fairly significant degree (Barkley, 2006; Frick & Lahey, 1991). Providing interventions to address the needs of children with ADHD and learning disabilities is a priority when considering the short-term effects and long-term outcomes when their various concerns and needs are not appropriately addressed. When examining the various academic needs of children with ADHD, there is limited empirical research to clearly define the specific psychological processes contributing to the co-morbidity of math disability with ADHD.

One of the issues in examining research on math disabilities, in general, is that there is not a consensus definition of a true math learning disability (Lewis, 2010). A math disability, also called Dyscalculia, typically refers to an individual with markedly poor skills at deploying basic computational processes used to solve equations (Haskell, 2000). A profile of someone with a math learning disability can include having difficulties in the following areas: being slower in basic numeric processing tasks, making comparison between magnitude of numbers, counting forward and backward, strategy use, and visualization of numbers. They also may have difficulty learning basic calculation procedures needed to problem solve (Geary, 2011; Rasanen, et al., 2009).

Researchers have hypothesized that the cognitive constructs associated with math performance are likely discrete and separate processes dependent on the particular task being performed (Fuchs et al., 2006). Cognitive processes that have consistently been found to be involved with math learning include those deficits that are directly linked with ADHD, namely executive functions, attention, and working memory (Bull & Johnston, 1997; Hooper, Swartz, Wakely, deKruf, & Montgomery, 2002; Lyon, Fletcher, & Barnes, 2003). Supporting this research, functional imaging studies in adults have demonstrated the significance of the prefrontal cortex in math performance, the area of the brain attributed to executive functioning and linked with impairment in individuals with ADHD (Fullbright et al., 2000; Zago et al, 2001). Impairment in arithmetic calculation in children has also been found to be related to activity in the frontal region (Ansari et al., 2011; Levin et al., 1996). For example, the prefrontal region has specifically been associated with the detection of errors and the deployment of cognitive control over errors in arithmetic (Ansari et al., 2011). Ansari et al., (2011) recently found through the use of functional Magnetic Resonance Imaging (fMRI) that the main effect of accuracy (incorrect versus correct) was observed in the medial and lateral regions of the prefrontal cortex. This study further indicated that more activation was observed in this region for incorrectly solved trials in individuals with higher levels of math competence versus their peers who struggled more intensely in arithmetic. They concluded that individuals with higher math competence may have greater awareness of errors and then be able to implement greater cognitive control following the commission of errors than individuals who tend to struggle more intensely in arithmetic.

Working memory, as indicated earlier as one of the primary constructs linked with executive functioning, has been found to play a particularly significant role in math learning. Simply stated, working memory has been considered important for math performance because information needs to be stored and manipulated from long-term memory in order to solve math problems (Andersson, 2008). Additionally, working memory deficits can affect the representation and articulation of numbers during the counting process (McClean & Hitch, 1999), which contributes to secondary deficits in numerical processes (Zamarian et al., 2006). Research has specifically focused on visual-spatial and verbal working memory and the relationship these domains have with particular aspects of math performance (Fletcher et al., 2007). It has been suggested that verbal working memory has been linked with numerical computation, depending on whether or not regrouping is necessary, and that visual-spatial working memory is required for numerical operation (Fletcher, Lyon, Fuchs, & Barnes, 2007; Khemani & Barnes, 2005). Both types of working memory have also been found to be related to a student's ability to acquire math strategies for computation (Fletcher, Lyon, Fuchs, & Barnes, 2007; Wilson & Swanson, 2001). Furthermore, visual-spatial working memory has been associated with children's early counting ability (Kyttala, Aunio, Lehto, vanLuit, & Hautamaki, 2003), whereas verbal working memory may become more significantly involved as basic math calculations become more automatic (Siegler, 1996).

When examining the construct of working memory in learning more clearly, there are concerns in interpreting the findings because the term is applied loosely and is not consistently defined. As described previously, one variable that complicates the definition of working memory is the relationship it has with attention. Some researchers indicate that it should be more precisely called working attention because of its role in manipulating information instead of storing information as the name implies (Kaplan, Crawford, Dewey, & Fisher, 2000; Sergeant et al, 2003; Zentall, 2005). Despite the specific challenges in delineating between the various cognitive constructs, attempts are currently being made to meld the fields of neuroscience and education in order to assist educators in designing researched based interventions that more appropriately meet the learning needs of struggling students in the school. In order to help educators become more invested in interventions that are based on the findings from the field of neuroscience, it is important to examine the role that attention, executive functioning skills, and working memory has on math achievement; this will be reviewed within the following section.

Attention and Math Achievement

Research involving 4,148 children from a nationally represented sample of schools in England was conducted by Merrell and Tymms (2001) to investigate the role of attention on achievement by including an examination of the differential diagnosis of the ADHD subtypes based on teacher's ratings of characteristics delineated in the *Diagnostic and Statistical Manual of Mental Disorders- Fourth Edition* (*DSM-IV)* (American Psychiatric Association, 1994). In addition to the behavioral rating scale, they examined the students' levels of academic achievement and the amount of progress in math and reading between the start of their formal schooling (aged 4 to 5 years), a year later, and again at the end of Key Stage 1 (year two, aged 6 to 7 years). Results suggested that students with unusually high teacher ratings on the initial assessment continued to display similar severity of symptoms at the end of the two year period. The researchers also found that children with high scores on the Combined and Predominantly inattention subtypes made significantly less progress in math between the start of the study and at the conclusion of Key Stage, when compared with children with zero scores on the behavioral rating scale. Additionally, it was found that students with the highest rating scales at the beginning of the study also had the lowest level of achievement in math and then made less progress during Key Stage, thus indicating that these students were continuing to fall even further behind than their peers.

In comparing the subtype characteristics of ADHD, the researchers found that students with high scores on the Predominantly Hyperactive/Impulsive subscale of the behavioral rating assessment did not differ as greatly on tests of achievement when compared with students who scored zero. This study supported previous research findings, indicating that hyperactive and impulsive students were not 'academically impaired' and suggested that significant learning differences exist among some of the subtypes of ADHD (Gaub and Carlson, 1997; Merrell & Tymms, 2001). Overall, it was concluded that children with ADHD, particularly in the subtypes with inattention, frequently tend to achieve lower levels of math achievement when compared with peers (Merell & Tymms, 2001).

Another investigation of the role of attention in learning was examined by Fuchs and colleagues (2005). The research team from Vanderbilt University found that teachers' ratings of inattention predicted the development of first-grade math skills, which included math computation and fact retrieval. Specifically, they found that attention, or distractibility, uniquely accounted for 1.7% of the variance on fact fluency, 1.4 to 3.7% on computation (depending on measure), 2.3% on story problems, and 2.8% on concepts/applications. These results corroborated evidence that attention is a determining mechanism in the development of first grade math skills. They hypothesized that attentional skills provide students with an opportunity to persevere with academic tasks, which is especially important when learning items such as math that require serial execution (Luria, 1980, as cited in Fuchs, et al., (2005), p. 510). In the conclusion, Fuchs and colleagues proposed that attention is a critical cognitive component in learning. Basic fact fluency was found to be predicted specifically by performance on attention. On the end-of-the year computation skills, attention was found to be a unique variance with working memory, also contributing to performance on CBM computation. Attention, as well as working memory and nonverbal problem solving, was linked to children's performance when they were required to have a conceptual underpinning of numbers. The authors recommended continual research to broaden the search for cognitive determinants and to examine student variables in order to design effective practices (Fuchs et al., 2005).

In examining the work that has been conducted in the area of math thus far, researchers have hypothesized that the neuropsychological processes involved in math learning is likely dependent of the specific math construct being performed and is best viewed from a multi-variant approach (Fuchs et al., 2006). To further examine the role that attention and various other cognitive constructs have on specific aspects of math, Fuchs and colleagues (2006) conducted a study with support from a grant from the National Institute of Health and Human Development. As part of their study, they summarized prior work and developed hypothesized paths of specific cognitive constructs believed to mediate the following aspects of math: arithmetic, algorithm computation, and arithmetic word problems. The specific attributes and related math aspects that were hypothesized are listed in Table 2.1.

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Table 2.1

Hypothesized Attributes Found to Mediate Aspects of Math

Aspect of Math	Attributes found to mediate aspects of math
Arithmetic	Working Memory, processing speed, phonological processing, attention, and long-term memory
Algorithmic Computation	Attention, working memory, phonological processing, and long-term memory
Arithmetic Word Problems	Working memory, long-term memory, attentive behavior, nonverbal problem solving, language ability, reading skill, and concept formation

Adapted from Fuchs et al., 2006

In testing the model, Fuchs and colleagues (2006) conducted a series of path analyses to examine the various cognitive processes listed in the previous table. In this study, three hundred and twelve third graders were assessed in a variety of cognitive constructs. Teachers' ratings of inattention were also obtained. The students participating in this research were part of the first wave of a prospective four-year study selected from 30-third grade classrooms in six, Title 1 and one non-Title 1 school (two to six teachers per school) in a southeastern metropolitan school district. The final model found that only inattention predicted all three aspects of math performance (Fuchs et al, 2006).

Fuchs and colleagues noted that their results suggest that aspects of math cognition are distinct, but highlighted the potential importance of attention (Fuchs et al., 2006).

In assessing the link between attention and academic performance, the previously described studies failed to examine the multidimensional conceptualization of cognitive functioning (Fuchs et al, 2006). To build on the research examining the multiple domains of attention and the relationship and the impact these processes may have on have on academic performance, Preston and colleagues (2009) conducted hierarchical regressions performed with selective, sustained, and attentional control/switching domains of the Test of Everyday Attention for Children (TEA-CH). Participants (N =45) in this study were children (ages 7 to 15) diagnosed with ADHD, recruited from a psychology clinic in a large teaching hospital. A total of 22 participants (49%) met the American Psychiatric Association (2000) *DSM-IV-TR* criteria for comorbid psychiatric conditions, including reading disability (n =5), oppositional defiant disorder (n =6), conduct disorder (n =3), adjustment disorder (n=30), and mood or anxiety disorder (n=40). Four had more than one comorbid condition. Children with Verbal, Performance, or Full-Scale IQ scores of less than 70 were excluded. Parents of the participants completed the Conner's Parent Rating Scale-Revised (Long Version) (CPRS-R: L; Conners' Parker, Sitarenios, & Epstein, 1998), in which the Inattention index was used. Assessment scores were also obtained from the Wechsler Individual Achievement Test-Second Edition (WIAT-II, Wechsler, 2001). Intellectual function was assessed using the Wechsler Intelligence Scale for Children-Fourth (WISC-IV) (Wechsler, 2003), Wechsler Intelligence Scale for

Children –Third Edition (WISC-III) (Wechsler, 1991), or the Wechsler Abbreviated Scale of Intelligence (WASI) (Wechsler, 1999).

Results of this study found that academic achievement was predicted significantly by performance on measures of attentional control/switching. It was suggested that academic impairment can be accounted for by the attentional domain that requires more executive control than other domains of attention. Specifically, this includes the skills measured by the TEA-CH subtests, comprising inhibition, working memory, and set shifting, all components associated with executive functioning (Preston et. al, 2009). Sustained attention was found to predict variance in math. These results support the idea that difficulties experienced by children with ADHD are related to executive functioning deficits. It is also suggested that attentional control/switching are particular skills that are integral in order to learn reading, math, and spelling when considered within the context of children with ADHD.

As part of a secondary analysis, an independent t-test was conducted by Preston et al., (2009) with ADHD-combined type and the ADHD-inattention type as the independent variables. The VIQ, the CPRS-R: L, TEA-CH composite scores, and the WIAT-II Word Reading, Numerical Operations, and Spelling, served as the dependent variables. No group differences were found between these two subtypes. The authors' research corroborate other findings demonstrating that students with ADHD and executive functioning deficits are more likely to have academic difficulties than children with ADHD who do not have executive functioning deficits (Preston et al, 2009).

In reviewing the research on the attentional domain being linked with math difficulties, additional questions have been raised by researchers such as Raghubar and colleagues (2009) regarding the specific nature concerning how attention issues can manifest in specific operations of math. Fuchs and colleagues (2005, 2006) are among several researchers who have found that teachers' ratings of inattentive behavior predicted math skills, including math computation and fact retrieval (Fuchs et al., 2006). Little research has specifically examined, however, the relationship between attention and multi-digit computation (Rughubar et al., 2009). It has been suggested that students with math disabilities, as well as individuals with ADHD, are prone to committing certain errors such as adding when subtracting is required on mixed format problems (Jordan & Hanich, 2000) or have difficulty in shifting psychological sets when two or more operations of one kind (i.e. addition) were followed by another kind (i.e. subtraction) (Raghubar et al., 2009). Based on these assumptions, it has been hypothesized that these difficulties are associated with aspects of attention involving inhibitory control and switching. One of the issues examined by Raghubar et al. (2009) is the relationship of teachers' ratings of inattention with errors in multi-digit arithmetic. Additionally, because studies that have been conducted on these specific processes have often failed to examine systematically whether or not switch errors are also prevalent in other disorders, the researchers examined the types of errors made by students, based on their particular academic difficulties, including those with math and reading difficulties, math difficulties, reading difficulties, or no difficulties (Raghubar et al., 2009).

Two-hundred and ninety-one children in the third and fourth grades were recruited from 20 schools within Houston, Texas, and Nashville, Tennessee to investigate these particular issues. All children were required to have an IQ score of 80 or above. Learning difficulty categories were determined by using cutoff scores below the 30th percentile rank on standardized subtests on reading and arithmetic from the Wide-Range Achievement Test-Third Edition (WRAT-3; Wilkinson, 1993). They also conducted a second analysis comparing individuals with severe math disabilities, low average achievement in math, and no learning disabilities. Teachers' ratings of inattention were also correlated with errors in multi-digit arithmetic.

Overall, children with math disabilities (MD) were found to perform worse on multi-digit computation task, when compared with children without MD. In assessing whether or not differences existed between students with MD+ reading disabilities (RD) and MD alone, no significant differences were found. It was found that children with MD+RD and MD alone committed more procedural bugs than children with RD and no learning disability (LD). The types of procedural bugs made among all groups were similar. Differences were noted when comparing students with MLD to Low Average achievement (LA) groups. Specifically, MLD students were found to make more subtraction bug errors than LA children, but not in addition. In summary, the math learning disability group had the most significant deficits in conceptual and procedural knowledge, skills needed for performance on multi-digit subtraction. Regarding the subjects' performances on math fact errors and procedural slips, group differences were not found between the math difficulty group and children without learning disabilities. In contrast to the wide held belief that operation switch-errors are common in students with math difficulties, no significant differences were found. Due to the lack of significance found between attention and procedural slips, the researchers suggested that the errors may be related more directly to a lack of consolidation than to issues directly associated with lapses of attention (Raghubar et al., 2009). Results did support Fuch's et al. (2005) findings that teachers' ratings of attention served as a predictor of mathematical outcome. In this particular study, teachers' ratings were found to correlate with accuracy, math fact errors, and procedural bugs (Raghubar et al., 2009). Regarding these findings, additional questions were raised regarding whether or not the behavioral rating of inattention was tapping into aspects of working memory or inhibitory control (Liu & Tannock, 2007).

Raghubar et al. (2009) indicated that these findings support the hypotheses that students with math difficulties may have inefficient inhibitory processes in working memory (Geary, 2004; as cited in Raghubar et al., 2009). For example, they may retrieve the number 8 for 3+4 because of problems with inhibiting irrelevant associations (Geary, 2004 as cited in Raghubar et al., 2009). It was also suggested that the execution of math procedures can be laborious for people with poor attentional capacities. In other words, considerable cognitive resources are needed to solve multi-digit arithmetic problems and thus it may be necessary to examine further the multi-variant nature of math learning (Imbo et al., 2008).

An important finding of Raghubar et al.'s (2009) study is that it dispelled commonly held educational beliefs that children with MD are prone to visual errors or switching errors. Although this study has contributed significantly to further elucidating the cognitive origins of arithmetic errors, the researchers did not incorporate standardized cognitive measures of working memory and attention (Liu & Tannock, 2007) and switching (Murphy et al, 2007) into their research design to support their hypotheses and to understand more specifically the relationship these constructs have in math learning. Additional research in this area of attention was recommended to help build a model of mathematical processing that may include understanding how these variables work in a multi-variant framework.

In summarizing the research on attention and working memory, several studies have provided evidence that teachers' ratings of attention served as significant predictors of math outcome. Preston et al. (2009) presented a case on the importance in examining the multiple domains of attention, finding that attentional control/switching significantly correlated with low academic performance. Sustained attention was found specifically to have a unique variance in predicting math over other academic areas. In a study examining the relationship between cognitive constructs and math computations, Raghubar and colleagues (2009) found that attention correlated with accuracy, errors, and repeated procedural bugs (errors). Students with higher scores of inattention were also found to be particularly vulnerable to having significantly lower performance on academic tasks, thus supporting a link between ADHD and math learning difficulties. Fuchs and colleagues (2004) did raise the question about whether or not the mismatch between students' academic needs and instruction results in poor attention. An additional issue that was raised regarded whether or not teachers' ratings of attention were influenced by interpretation of the students' academic performance instead of accurately rating the presentation of symptoms. Although the question addressing the teachers' ratings are important, the results of these studies also hold significant implications regarding the role that specific executive functioning and attentional processes may have in striving for math proficiency for struggling students. It was concluded by several of the researchers that it is essential for teachers to be aware of the special needs of children with ADHD and to develop not only behavioral interventions to address their specific needs, but to also incorporate academic interventions into their educational programming in order to improve students' outcomes. It was also recommended to consider the complexity of mathematical proficiency and to consider the contributory roles of other executive functioning processes (Fuchs et al., 2006; Preston, 2009; Raghubar et al., 2009).

Broad Executive Functions and Math Achievement

In addition to the studies which parsed out the specific cognitive constructs of attention associated with academic achievement, researchers have also grouped executive functioning into broad categories in order to assist in examining the differences between behavioral and cognitive aspects associated with executive functioning. Barry et al. (2002) conducted a study with a control group of 33 non-ADHD children (15 males and 18 females) and 33 children in the ADHD group (21 males and 12 females), ranging in age from 8 years 9 month to 14 years 5 months (M= 11 years 2 months) to examine the significance that executive functioning deficits have on achievement and behavior. Children in the ADHD group were recruited from pediatric practices, mental health centers, a university research database on children with ADHD, and local schools. The control participants were recruited from a university research database of non-ADHD participants who had participated in previous research. Executive functioning evaluations used in this study included: a computerized Tower of Hanoi (TOH) (Borys, Spitz, & Dorans, 1982), as a measure of executive functioning; a computerized version of Wisconsin Card Sorting Test (WCST) (Grant & Berg, 1948; Loong, 1990); and the Trail Making Test, Part B (TMT-B), a test in which the subject is instructed to connect a set of dots as fast as possible and to maintain accuracy (Reitan, 1958; Reitan & Wolfson, 1993). Executive functioning data were analyzed by examining seven key variables collected from these three instruments: total moves on the TOH, which involves moving disks into rods, following specific rules; total categories, trials to first category, percent error and perseveration responses on the WCST, and Time and errors on the TMT-B. These variables were selected, based on analyses from previous research (e.g. Grodzinsky & Diamond, 1992; Pennington et al., 1993; Shue & Douglas, 1992). An executive functioning composite score was also calculated, based on item analyses. Additional assessments were administered to assess for cognitive ability, achievement, and behavior. Participants were tested without their stimulant medications and were scheduled within a certain period of the dosage to ensure the subjects were not receiving the benefit of medication (Barry et al., 2002).

Overall, it was found that a group of children of average intelligence with ADHD performed significantly lower than expected in the area of reading, writing and math than the group of non-ADHD children (Barry et al., 2002). Regression analysis conducted in this research found that children who exhibited more severe, pervasive, and frequent ADHD behaviors (as measured by the ADHD severity index) were more likely to achieve below their expected levesl of achievement. Consistent with the research described previously, Barry and colleagues (2002) concluded that the severity and pervasiveness of ADHD symptoms may likely serve as a good predictor of academic achievement. In examining the behaviors of ADHD in comparison with broad EF measures, the authors indicated that more severe ADHD behaviors were associated with more severe behavioral impairment than behaviors in individuals with executive functioning deficits alone. They did find, however, that executive functioning predicted performance in the area of math over and above ADHD behavior (Barry et al., 2002).

An additional study that examined broad executive functioning constructs on academic achievement was conducted by Brock et al. (2009). In this study, Brock et al.

(2009) grouped executive functioning skills into the two broad categories of 'hot' executive functioning (behavioral symptoms) and 'cool' executive functioning (attention, inhibitory control, and working memory). Brock and colleagues (2009) specifically examined the contributions of 'hot' and 'cool' executive functions to children's academic achievement, learning-related behaviors, and engagement in kindergarten students. Participants were 173 students (90 male and 83 female) enrolled in one of 36 kindergarten classrooms in seven elementary schools located in four rural school districts in the southeast. The teachers' ranges of experience were 1 to 37 years with a mean of 18 years. Of the 333 kindergarteners, four to six children were randomly selected from each classroom to be research participants. Research assistants administered executive functioning and achievement tasks in the fall and spring of the students' kindergarten year. Additionally, a cognitive abilities test was administered during a separate session and each was observed approximately five times on three different days throughout the school year for a 10 minute period. Children's Observed Engagement in Learning was completed by research assistants, blind to the aim of the study (Rimm-Kaufman, 2005; as cited in Brock et al., 2009). Teachers were also asked to rate the children's learning-related behaviors in the spring.

Consistent with the research described previously, Brock et al.'s (2009) study found that cool EF was found to predict math achievement, learning-related behaviors and engagement. In contrast, hot executive functioning did not predict academic achievement nor did it predict behavior outcomes, when compared with cool executive functioning. This study fine-tuned the previous results by Merrell and Tymms (2001) and contradicts to some degree the finding of Barry et al. (2002), which suggested that the behavioral components of ADHD contribute more to academic difficulties than do other cognitive constructs. It was found that learning-related behaviors and observed engagement did not account for the correlation between cool executive functioning and achievement in math. The authors concluded that cool executive functioning and math performance have a unique relationship. Overall, it was suggested that cool executive functioning tasks, representing skills of executive attention, inhibitory control, and working memory, are important precursors to math learning (Bull & Scerif, 2001; as cited by Brock et al, 2009). In interpreting the lack of relationship between hot executive functioning and achievement in kindergarten, they noted that cool executive functioning is a better determinant of school readiness.

Working Memory and Math Achievement

As previously discussed, deficits in working memory have also been found to be a cognitive process that has been linked with math difficulties (Bull & Johnston, 1997; Hooper, Swartz, Wakely, deKruf, & Montgomery, 2002; Lyon, Fletcher, & Barnes, 2003). A widely cited research study investigating the relationship between working memory (WM) and mathematical problem solving in children at- risk and not at- risk for serious math difficulties (SMD) was conducted by Swanson and Beebe-Frankenberger (2004). As part of this investigation, a battery of tests was administered to assess problem solving, achievement, and cognitive processing in children in first, second, and third grades from primarily middle-class homes. Three hundred and thirty five children (169 girls, 184 boys) from California's public and private schools were selected for this study. One-hundred and thirty children were classified at-risk for serious math disabilities, based on the criterion of having normal intelligence (standard score > 85), but exhibiting performance below the 25th percentile related to orally presented word problems and digit-naming fluency. Using Baddeley's (1986) conceptual framework of working memory, Swanson and Beebe-Frankenberger (2004) found that younger children and children at risk for serious math difficulties performed poorer on working memory, math calculations, and problem-solving tasks. Working memory was found to predict solution accuracy of word problems when controlling for fluid intelligence, reading skill, math skill, knowledge of algorithms, phonological processing, semantic processing, speed, short-term memory, and inhibition. In their conclusion, the authors hypothesized that working memory plays a significant role in integrating information gathered during problem solving because it holds information to help make the connection with more recent input and because working memory maintains the "gist of information" to help in finding the solution. It was also suggested that the core problems associated with math problem solving are related to operants within the central executive as described in Baddeley's model (2001).

In comparing these results with other studies, it was found to conflict with Fuchs and colleagues (2006), who discovered that working memory was not a significant cognitive correlate in arithmetic, algorithm computation, and arithmetic word problems. It was suggested that working memory was linked as a critical factor because researchers did not look more specifically at multiple abilities of math functioning. Fuchs et al. (2006) did find, however, that working memory served as a predictor in these three aspects of math when phonological processing and sight word efficiency were set for zero.

In examining the conflicting research on the role of working memory in mathematics, Berg (2008) raised the point that many studies did not include a measure of visual-spatial working memory. Fuchs and colleagues (2006) were among the researchers who were criticized for considering verbal working memory as the sole measure of working memory. Berg (2008) differentiated between verbal working memory and visual-spatial working memory in his investigation on the constructs associated with arithmetic calculation in children. Berg (2008) hypothesized that both visual-spatial and verbal memory play a role in various aspects of arithmetic calculation, particularly during the initial stages of calculation. To test this hypothesis, ninety children (44 boys and 46 girls) in grades 3 to 6 from three schools in central Canada served as participants in this study. The children in this research were assessed using two test batteries. The first battery consisted of subtests from the Wide Range Achievement Test-Third Revision (WRAT3) (Jastak & Jastak, 1993) to measure their achievements in reading and arithmetic calculation. In addition to assessing for verbal working memory and visual-spatial memory with the first battery of tests, a second battery was also used to assess processing speed and short-term memory in order to evaluate their contributing roles in working memory. Students were evaluated individually in two sessions within a one week period. Results found that both verbal-working memory and visual spatial memory contributed significantly to arithmetic calculation (4% and 6% respectively). In the presence of the other working memory construct, verbal working memory and visual spatial memory presented a unique variance to arithmetic calculation (3% and 5% respectively). Because the relationship of working memory with arithmetic calculation was examined independently of reading ability, chronological age, processing speed, and short-term memory, this study supported Berg's statements that previous researchers had underestimated the significance of visual-spatial memory in arithmetic.

In regard to the understanding that working memory is a complex process, Berg (2008) also examined the contributory roles of short-term memory and processing speed. Processing speed was not found to be a significant contributor to arithmetic calculation except in relationship to age-related differences in the general sample. These findings conflict with the widely-cited work by Swanson and Beebe-Frankenberger's (2004) described previously. Berg (2008) offered the possibility that the results may differ due to age of the participants. His participants were in grades 3 to 6 and Swanson and Beebe-Frankenberger (2004) examined grades one to three. The hypothesis was raised that these confounding results support the developmental nature of specific cognitive processes and the relationship it has in learning. For example, the current literature suggests that during the early stages of learning arithmetic calculation, processing speed is more pronounced. As students become more proficient in these math skills, processing speed decreases. According to Berg (2008), processing speed is an important construct in the development of automaticity of number representation in long-term memory and decreases when a child begins to rely more heavily on short-term memory and long-term memory to complete more demanding math tasks.

Another notable finding in Berg's (2008) research was the conclusion that processing speed and short-term memory were not eliminated by the contribution of working memory to arithmetic calculation. This raises the question about whether or not other processes may contribute to working memory when performing arithmetic calculation. One theoretical perspective offered by Berg supports the previous sets of studies in which he suggested that attentional processes, such as selective, sustained, and divided attention, may be interacting with arithmetic calculation. This supports Baddely's (2001) working memory model, indicating that the central executive's reconceptualization function is to focus on the multiple domains of attention. In other words, one or more attentional processes may interact with working memory during arithmetic calculations (Baddeley, 2001). Berg's (2008) research returned to the question regarding the role that attentional processing may have on learning, further alluding to the fact that those children with ADHD may have difficulty when struggling to understand math.

In order to further investigate the relationship among the various components of working memory on math achievement, particularly in the area of written arithmetical skills, Andersson (2008) administered arithmetical tasks and various measures of working memory, fluid intelligence, and reading to 141 third and fourth graders from 21 public schools in Sweden. A total of 73 third-graders (29 boys) and 68 fourth-graders (29 boys) participated in the study; the mean age of the total sample was 124 months (SD=6.98). The sample was fairly homogeneous in relation to socio-economic status; the schools were located in a middle-class area. Tests were administered in two separate sessions, a group test session and an individual working memory test session. The arithmetical test, reading test, and Raven's progressive matrices test (Raven, 1976; sets B, C,D) were administered in groups of four or five children. Approximately 1 to 4 weeks after the group test, the working memory tests were administered within the following order: Digit Span, verbal fluency, visual-matrix span, arithmetic fact retrieval, Stroop test, trail making test, Corsi-block span, and counting span.

Andersson (2008) found that, in general, working memory, and the particular memory component, the central executive, contributed to children's arithmetical skills. Specifically, three of the tasks that were linked with the central executive (i.e. counting span, verbal fluency, trail making) and the phonological loop (Digit Span), accounted for 59% of the variance in written arithmetic. Fifty-four percent of variance in arithmetic fact retrieval was accounted for by the 10 tasks assessed in the study, but only two of the central executive tasks (i.e., verbal fluency, trail making), and the reading task emerged as significant predictors.

The researcher indicated that in examining the contribution of the phonological loop and the central executive (concurrent processing and storage of numerical information), it was indicated that children aged 9 to 10 years primarily used verbal coding strategies during written arithmetical performance. Monitoring and coordinating multiple processes, as well as assessment arithmetical knowledge from long-term memory, were specifically viewed as important central executive skills utilized when performing written arithmetical skills. Andersson (2008) indicated that the results of this study demonstrate that all working memory skills are important in math achievement, but the central executive is particularly important because of its role in managing the various processes involved in learning arithmetic. In summarizing the results, it was indicated that the combination of the central executive, phonological loop and the visual-spatial sketchpad are important to help children develop a mix of verbal and visual strategies in order to be efficient learners when solving various forms of arithmetic (Andersson, 2008).

Extending previous research that examined the relationship between working memory and math achievement, De Smedt and colleagues (2009) conducted a longitudinal study on first and second graders in the country of Belgium to examine all components of working memory: the phonological loop, the visuospatial sketchpad, and the central executive. Participants were 106 first graders (63 boys and 43 girls), with a mean age of 6 years 4 months (SD=4 months) from five primary schools. First-grade mathematics data were available for 77 children (mean age = 6 years 8 months, SD=8months). Second-grade mathematics data were available for 83 children (mean age = 7 years 4 months, SD=3 months). Three students were not able to continue with the study due to intellectual ability. Working memory measurements were administered at the start of the first grade. Math achievement was assessed 4 months later (at the middle of the first grade) and 1 year later (at the start of the second grade). Results generated from this study found that working memory was significantly related to math achievement in both grades with working memory clearly predicting later math achievement. The assessments, reported to measure central executive processes, were found to be a unique predictor of both first- and second-grade math achievement; age-related differences were also found when examining the contribution of the slave systems to math achievement. Specifically, the visuospatial sketchpad was found to be a unique predictor of first-grade math, but not second grade achievement. In contrast, the phonological loop was linked as a predictor of second-grade math achievement, but not first-grade achievement.

In discussing their data, De Smedt et al. (2009) described their results as consistent with previous research in which the central executive was found to be a unique predictor of first and second grade math achievement. They indicated that the data collected in this study extends previous research by indicating that the central executive no longer served as a unique predictor of math achievement in the second-grade. In assessing the value of the phonological loop as a predictive factor, it was hypothesized that children may have an increased reliance on verbally or phonologically coded information during calculation. Such a shift may be witnessed by students changing from strategies such as finger counting toward more sophisticated verbal counting approaches or fact retrieval (i.e. Siegler, 1996), the latter believed to rely on the phonological loop (Lee & Kang, 2002; Dehaene, Piazza, Pinel, & Cohen, 2003). In their research, Noel and colleagues (2004) found evidence to support this hypothesis, which found that individuals with high phonological loop ability demonstrated higher frequencies of verbal counting procedures and fact retrieval and lower incidences of finger counting (Bull & Johnston, 1997).

In interpreting the data of the various forms of memory and math, it is suggested that the visuospatial sketchpad is important in the early stages of math development (DeSmedt et al., 2009). The Visuospatial sketchpad, a component of Baddeley's (2007) Model of Working Memory linked for short-term storage of visual and spatial information, is believed to provide individuals with a workspace to represent abstract mathematical knowledge in a concrete form (Holmes & Adams, 2006). Because this was a longitudinal study, the researchers indicated that the observed shift cannot be explained by issues related to sample selection such as the case in cross-sectional studies. It is also important to consider that this study applied only to specific developmental periods, young elementary students. Also, there were differences between the first and second grade tests; this raises issues regarding the assessment tools measuring different mathematical skills. It was suggested that future longitudinal studies be conducted in a way that allows a more direct measurement of the influence of working memory components on math performance (DeSmedt et al., 2009).

In a more recent longitudinal study of 164 (44% African-American or Latino; 57% female) Head-start children , Welsh, Nix, Blair, Bierman, & Nelson (2010) found that working memory, when controlling for earlier numeracy skills, was related to later preparatory math performance in kindergarten. Participants were administered a series of assessment tools at three points: (a) beginning of the prekindergarten year; (b) end of the prekindergarten year; and (c) end of the kindergarten year. Assessments tools included those that assessed domain-specific skills in the areas of emergent literacy and emergent numeracy and domain-general executive cognitive processes associated with learning, including working memory and attention control. Path analyses indicated that working memory and attention control predicted growth in emergent literacy and numeracy skills during the prekindergarten years. Additionally, growth in these domain-general cognitive skills made contribution to predicting kindergarten math and reading achievement when controlling for domain-specific skills. These results emphasize the value for early educators and others who work with young children to recognize the role of working memory and to give some attention to developing the skills necessary for later academic success. Supporting the current research being proposed in this research, Welsch et al. (2010) discussed the implications this research has in programming interventions that focus on training the cognitive processes that are linked with academic achievement. More specific examples of the research of such training will be described later in this chapter.

Another recent longitudinal study, conducted by researchers in the Netherlands, found further support for the idea that that working memory tasks predicated math learning disabilities, even over and above the predicative value of preparatory mathematical abilities (Toll et al., 2011). At the beginning of the study, 227 children (120 boys; 107 girls with a mean age of 6.5; SD= 4.3 months; range = 5.9 to 7.7) participated. These children came from 18 classes in 10 schools with minimal exclusion criteria in order to obtain a representative sample of children in regular education. Because of the children and families moving, grade retention, and grade acceleration, analyses were conducted on 209 students (108 boys; 101 girls, mean age at beginning of study= 6.14 years, SD=4.5 months). Two classifications were made in this study: a) children were grouped into two groups based on their low or typical math performance at the end of second grade, and b) the same children were grouped into three groups based on their mathematical performances throughout the first and second groups. As part of this investigation, three measures of executive functioning were conducted: beginning (October); halfway through (March) first grade, and beginning (October) of second grade. Several executive function tests were conducted to measure shifting (e.g. Sorting Task and Animal Shifting); inhibition (e.g. Animal Shifting, Simon Task, and Local Global), and working memory (e.g. Keep Track, Odd One Out, and Digit Span Backward). All of the executive function tasks were computer tasks that were administered individually, with the exception of the Simon Task and the Sorting Task, which they completed in duos on a laptop computer. Math abilities were also assessed using the Early Numeracy Test (ENT; Van Luit, Van de Rijt, & Pennings, 1994) and the criterion-based, national Dutch test, Cito Mathematics Test (CMT, Janssen, Scheltens, & Kraemer, 2005).

Toll et al. (2011) indicated that in contrast to their expectations that children with poor mathematical abilities would perform worse on all three measures of executive functioning, only on the WM tasks were differences in development and between groups found. The low performing students in Grade 2 and the at-risk or students already showing disabilities in Grades 1 and 2 obtained significantly lower scores on WM than typically performing children. Through the assessment of discriminative analyses, WM ability was found to be the executive function that best predicted math difficulties (Toll et al., 2011). Overall, this research provided additional evidence that a relationship does exist between working memory and math difficulties, particularly during the early elementary years. (e.g. Bull et al., 2008).

In summary, there is sufficient support that a relationship does exist to some degree in the various aspects of math and working memory. Among the weaknesses in the research include how working memory is defined and the tendency to lump assessments together for a general scale of working memory or to focus on only one particular type of memory when several various cognitive processes could be involved.

The research that has been generated has suggested that age and type of math skills may affect the particular processes involved in solving math. Ongoing research on the relationship of math and working memory needs to continue with attention being provided towards examining the developmental progression of math skills and cognitive processes in order to understand how to address the needs of students struggling to learn math across the grade levels. When considering ongoing research on WM and math in this study, the issues in measuring working memory and agreeing upon a definition of this process must be considered.

Issues in Measuring Working Memory

Although the research has supported the fact that working memory is an important cognitive construct involved in math learning, when considering the research on working memory, it is important to examine specifically the difficulties linked with measuring working memory. One particular concern relates to discerning the difference between short-term memory, the information-storage component of working memory, and working memory, which assumes both storage and manipulation of information (Baddeley, 2010). Engle et al.'s (1999) study is among those conducted by research teams who were particularly interested in attempting to separate short-term memory tasks from those requiring more executive control. Engle and colleagues (1999) more specifically defined working memory as "a system consisting of a) a store in the form of long-term memory traces activated above threshold; b) processes for achieving and maintaining that activation, and c) controlled attention." (p. 104). The term, working memory capacity, therefore, refers to controlled attention, which similarity reflects Baddeley's central executive (2007) (Engle et al., 1999; in Miyake & Shah, 1999). Within this framework, working memory capacity is not directly measuring storage, but instead refers to "the capacity for controlled, sustained attention in the face of interference or distraction" (p. 104, Engle et al., 1999 in Miyake & Shah, 1999).

In applying the differences between short-term memory and working memory and the implications these hold in interpreting the research on working memory, there is the consideration of many studies that often refer to forward span tests as a measure of short-term memory and backward span test is considered a measure of working memory (Swanson et al., 1999). Studies conducted by Swanson and Kim (2007), Colom et al., (2005), and Rosen and Engle (1997) have demonstrated, however, that forward and backward span tasks load on a single dimension (Rapport et al., 2008) and thus both are measuring short-term storage. In other words, both of these subtests are measuring the phonological or visual-spatial rehearsal loop component described in Baddeley's model, rather than measuring central executive functioning. Researchers, Engle et al. (1999) reported, "a single transformation of order [from forward to backward] would be insufficient to move a task from the short-term memory storage category to the working memory "(p. 314).Growing out of this research, one theme that has been consistent is that working memory does involve executive control, which is the process that influences the individual's ability to control attention in a goal-directed manner (Miyake & Shah, 1999;

Redict et al., 2011). It should be noted that although there is growing understanding that backward and forward span tasks are measuring short-term memory storage, it is extremely difficult to gain uncontaminated estimates of central executive functions; this is due to its multiple functions (Rapport et al., 2008).

Another issue noted in the measurement of working memory is that many studies do not differentiate verbal from visual spatial working memory and often use complex memory tasks to assess the CE. Other tasks that have been used to measure CE capacity include digit span backward, reading span (Daneman & Carpenter, 1980), listening span (Siegal & Ryan, 1989), and counting span (Case, Kurland, & Goldberg, 1982). In examining these tasks, the stimuli does not simply need to be remembered, but also needs to be manipulated (Pollock, 2009). As described previously, however, issues have been raised about whether each of these tasks truly measure CE (Engle et et al., 1999).

Because of the difficulty in assessing CE using a single task, cognitive psychologist have been applying a latent variable approach to partial task performance related to the CE, attentional controller, and the two subsidiary systems, namely the Phonological Loop and the Visuospatial Sketchpad (Rapport et al., 2008). There have been some questions regarding whether or not CE may reflect memory capacities that are task specific or reflect a single factor (Carpenter & Just, 1988; Pollock, 2009). Further research has suggested that the CE system is divided into two separate components, one for processing symbolic information, i.e. numerical and linguistics, and the other one for the processing and storage of visual spatial information (Seigneuric, Ehrlick, & Yuill, 2000). Other researchers, however, continue to argue that the CE is a domain general system because research has supported the fact that the CE capacity is not dependent on a particular strategy to accomplish a task (Pollock, 2009).

Overall, the findings presented in this section demonstrate the idea that in discussing math achievement and the difficulties that children may have in learning, the cognitive processes linked with executive functioning are involved to some degree in various aspects of math. Attention and working memory are two of the processes that have been found to be linked specifically with children with co-occurring ADHD and math difficulties. It is important to be cautious in interpreting the research, however, due to the challenges in delineating among the various cognitive processes, including the differentiation of memory components such as visual-spatial, verbal working memory, and the central executive. Although some researchers use a working memory index derived from several types of memory assessments, others have focused on one particular subset of skills. Based on the issues presented in reviewing the literature on the interpretation of cognitive assessments, it is also important to be cautious in examining treatment effectiveness of interventions that are reported to improve working memory, attention, and/or executive functioning. The following section is a review of the literature on intervention programs that have been purported to improve working memory and/or attention, including the program that will be implemented as part of this research.

Working Memory Interventions

Despite the differences in theoretical perspectives, WM has been regarded as critical to higher cognitive functions (Morrison & Chein, 2011). The importance of WM and related cognitive processes has been considered in the research when examining both domain-specific and domain-general factors. Domain-specific processes linked with WM include the articulatory rehearsal process described in Baddeley's model of WM (2007), which involves the use of inner speech mechanisms to maintain representations of linguistic and verbally coded items (Baddeley & Hitch, 1974; Morrison & Chein, 2011). Putative domain-general processes involve those mechanisms that control attention, gate information in and out of WM buffers, alleviate interference from irrelevant sources, and oversee the engagement of domain specific strategies (Morrison & Chein, 2011). It has been suggested that both domain-general and domain-specific factors are involved in WM and higher order thinking; however, executive attention processes appear to be more highly predictive of the relationship between WM and higher cognitive skills (Cowan et al., 2005; Lepine, et al., 2005). When considering interventions to address the needs of individuals with working memory deficits, it is important to consider the fact those training protocols targeting domain-general mechanisms may be more likely to generalize to other cognitive processes, thus increasing the probability of overall academic performance. One of the issues faced by educators is that utilizing behavioral interventions and working memory strategies alone to address needs in the classroom will not likely generalize to improve their students' overall academic successes (Morrison & Chein, 2011).

In researching the literature on working memory training, the concern has been raised that the processes being defined as working memory would not be fully endorsed by some theories of working memory (Morrison & Chein, 2011). In other words, some researchers would suggest that working memory is involved or operates when there is no need to manipulate stored information (Unsworth & Engle, 2007), yet other models would suggest that these tasks are training the domain of short-term memory (Morrison & Chein, 2011). In a recently published literature review that attempted to examine whether or not WM training works, Morrison and Chien (2011) noted such concerns. In order to present a comprehensive review of working memory interventions, they included research which investigated participants' memory on items presented recently. This review specifically addressed the impact on WM capacity and the efficiency of this process. Based on their findings, Morrison and Chein (2011) established two distinct categories to classify the types of working memory training approaches, strategy training and core training. Strategy training is described as an approach designed to promote the use of domain-specific strategies to allow participants to remember a particular type of information in increasing amounts (McNamara & Scott, 2001); core training refers to programs that require repetition of demanding WM tasks designed to target domain-general working memory mechanisms (e.g. Klingberg, Forssberg, & Westerberg, 2002).

Strategy training, which typically has been utilized to some degree in the educational system, include teaching and practicing techniques such as chunking (St. Clair-Thompson, Stevens, Hunt, & Bolder, 2010), devising a mental strategy with items (McNamara & Scott, 2001) and imagery (Carretti et al., 2007).   Strategy training approaches can be linked to the articulatory rehearsal process (Comblain, 1994; Conners, Rosenquist, Arnett, Moore, & Hume, 2008; Turley-Ames & Whiffield, 2003). Others have focused on training individuals to elaborately encode information that may not accurately reflect "WM training" because they are being taught to circumvent such processes (Carretti, Borella, & DeBeni, 2007: Cavallini, Pagnin, & Vecchi, 2003; McNamara & Scott, 2001; Morrison & Chein, 2010).

Core training refers to interventions that involve repetition of demanding WM tasks that are reported to train domain-general WM mechanisms (Morrison & Chein, 2011). In a literature review, Morrison and Chein (2011) summarized the purpose of these training paradigms as "a) to limit the use of domain-specific strategies, b) to minimize automatization; c) to include tasks/stimuli that span multiple modalities; d) require maintenance in the face of interference; e)enforce rapid WM encoding and retrieval demands; f) adapt to participants' varying level of proficiency; and g) demand high cognitive workload or high intensity cognitive engagement" (p. 49). They also noted that core training programs incorporate sequential processing and opportunities for frequent memory updating. Research has supported the idea that core training programs have improved the retention and retrieval of temporarily stored information (Morrison & Chein, 2011).

One approach used in core training programs incorporate several exercises that use a wide variety of stimulus tasks designed to improve various components of WM tasks (Morrison & Chien, 2011). It is believed that the training increases WM capacity by strengthening the process related to the domain-general WM processes (Morrison & Chein, 2011). Additionally, it has been supported that this training may improve other cognitive tasks such as fluid intelligence and cognitive control (Morrison & Chein, 2011). Cogmed (Klingberg et al., 2011) will be described later in greater detail; it has been chosen for this research study, and has been cited as one training program that has been found to show significant improvement on untrained assessments of WM, episodic memory, fluid intelligence, and reasoning (Morrison & Chein, 2010).

Two examples of the core training approach described by Morrison and Chein (2010) includes CogMed (e.g. Holmes et al., 2009; Klingberg et al., 2005), which uses a large battery of tasks including backward digit span, location memory, tracking of visual objects, as well as other tasks linked with WM, and Cogito, which includes perceptual speed and episodic memory tasks, in addition to working memory tasks (Schmiedek, Lovden, & Lindenberger 2010). Morrison and Chein (2010) describe the advantage of this type of "kitchen sink" (p. 49) approach; its combination of task increases the likelihood of training related improvement and larger transfer effect. A disadvantage is that it is difficult to determine tasks that underlie subsequent neuropsychological improvement, including which WM processes are involved (Morrison & Chein, 2011).

As more attention is being given to improve the outcomes of individuals through the use of researched based interventions, there is growing interest in the implementation of computerized cognitive training. A summary of the research on working memory training will be reviewed later in this dissertation as will attention training because of its relationship with working memory and because of the difficulty in isolating cognitive constructs in the research. The purpose of this study was to examine school-based interventions that go beyond curriculum instruction and teaching memory strategies; rather, it seeks to examine computer based interventions that directly train cognitive processes. Because there are relatively few studies that have examined the use of computerized cognitive training in the public education system within the United States, this review will include studies of the effectiveness of various cognitive training interventions used in subjects ranging from pre-school to adulthood from other countries and in clinical and college settings.

Computerized Cognitive Training

In light of the research supporting the idea that there may be a neural link between math and emerging math development with working memory, attentional processes, and other constructs underlying executive functioning domains, one consideration is to include interventions into the classroom that directly improve these cognitive skills.

Despite the research linking the significant relationship between working memory and attention on achievement (Gathercole, Brown, & Pickering, 2003), there is limited research in the school setting that examines whether or not cognitive training is effective in increasing academic learning, especially in young people with ADHD. With the increasing evidence to support plasticity of specific cognitive constructs that were once believed as fixed, the research on interventions to improve cognitive processes has been growing in recent years. Computerized cognitive training is one area that slowly has been gaining attention as a promising approach in treating cognitive deficits within a variety of populations. Several models of computerized cognitive training currently exist, with some programs being packaged for purchase by schools and/or other clinics. Examples of computerized programs available to the public through clinics or on the World Wide Web include Brain Buster (Advanced Brain Technologies, 2007), Processing and Cognitive Enhancement Program (PACE, 2007), the Brain Skills Program (Brainskills, 2007), The Captain's Log program (Sanford, 2003), and Cogmed (Klingberg et al., 2002). The following section will provide a review of the literature on several cognitive training programs.

Training in children and young adults. Due to the relatively recent introduction of computerized interventions, a limited number of studies have been conducted on children. There are even fewer conducted on children living in the United States who are receiving such services in the school and as part of their special education programming. One program that has been gaining some popularity and has been described as the "complete computerized mental gym" is Captain's Log (www.braintrain.com). Captain's Log advertises that it helps individuals with ADD/ADHD, brain injuries, psychiatric disorders, and learning disabilities to "learn faster, remember more, think better." Specifically, it reports the ability to stimulate areas of the brain responsible for memory, attention control, conceptual reasoning, impulse control, and visual and auditory processes.

Despite these claims, relatively few studies were found on the effectiveness of the Captain's log program. One study, conducted by Kotwal et al. (1996), examined the effectiveness of the program after completion of 35 sessions within a 3 month period on a 13 year old boy diagnosed with ADHD Significant improvement of ADHD symptoms and academic performance was reported by his parents on informal assessments.

In another study investigating the effectiveness of Captain's log, four children identified with ADHD and emotional/behavioral disturbance received the training four times a week for 30 minute sessions for 16 weeks (Slate et al., 1998). Each participant demonstrated improvement on a post-treatment Integrated Visual and Auditory (IVA) continual performance test and behavioral rating scale. Data generated from teacher reports indicated that three of the four students made improvement. These results suggested that the computerized training program was effective in students with co-morbid diagnoses. These studies do not provide sufficient evidence of the program's effectiveness, however, due to its small sample size and weak experimental design to alleviate exposure to other forms of treatment. Additionally, a concise sample was not included and long-term effectiveness was also not assessed.

As part of a dissertation, Merrill (2007) also investigated the effectiveness of the Captain's Log program in reducing ADHD symptoms. In this study, fifty nine children ranging in age from five to eleven years of age (34 boys, 25 girls) were recruited from two YMCA after-school programs located in southeastern Texas. The subjects participated in the computerized training program for 10 weeks, for 15 to 20 minute sessions twice a week. Participants who were selected included those with a previous diagnosis with ADHD as well as those who did not have a prior diagnosis. Nineteen of the participants had met the criteria for ADHD with nine of these individuals on medications. Participants were randomly divided into a control group and an experimental group. The experimental group participated in the Captain's log program for about 20 minutes and the control group played spelling, math, and reading skills games. One hypothesis was that Captain's Log program would significantly improve Continuous Performance Test (CPT) scores and parent/teacher reports of behavior in students previously diagnosed with ADHD, who met the research criteria. Due to issues linked with a small sample size, a participant drop-out, and number of control participants who left the program, this hypothesis was not able to be assessed. Using a series of ANCOVA procedures, Merrill (2007) did not find any significant results to support the fact that the intervention program improved results on the IVA-CPT and parent/teacher results of behavior on children identified with ADHD, when compared with the children without the diagnosis.

One of the limitations noted by Merrill (2007) is that the research hypotheses could not be fully assessed due to the limited exposure that the participants had with the Captain's Log program. It was suggested that more intensive and frequent exposure to the program could lead to more promising results (Kotwel et al., 1996; Slate et al., 1998). Other issues reported by the researcher included failure with laptops and the fact that parents of participating children did not always send their children to the after-school program. Additionally, Merrill (2007) reported that the school was not working collaboratively with the researcher, thus information from the actual classroom environment was not collected.

One of the most promising computerized interventions that has been researched on working memory and attention in young people was initially developed at the Karolinska Institute in Stockholm Sweden by Klingberg and colleagues (2002). Influenced by animal research on training induced neuro-plasticity (Buonoman & Merzenich, 1998), these researchers from the Department of Neuropediatrics collaborated with professional game developers to create an intensive and adaptive training designed to improve working memory. A preliminary study examining this computerized training paradigm was investigated to see whether or not it improved working memory using a double-blind, placebo controlled design in children between the ages of seven to 15 years, who had been diagnosed with ADHD by a pediatrician, based on the guidelines of the *DSM-IV*. The treatment group included one girl and six boys (mean age =11.0, SD= 2.0) and the control group included 2 girls and 5 boys (mean age =11.4; SD= 3.0) (Klingberg et al., 2002). No significant differences in age were found between the two groups. Three of the subjects in the treatment group and two in the control group were on medication. One of the implications underlying this study was that if working memory is a core deficit of ADHD, improvement of working memory would reduce symptoms of ADHD, particularly motor behaviors. Two key features of this training regime were incorporated to enhance sensory discrimination and induce central plasticity in sensory and motor cortices (Buonoman & Merzenich, 1998; Tallal et al., 1996; Klingberg et al., 2000).

This training was designed to allow the individual to perform close to capacity by using an adaptive staircase method, which adjusts the level of difficulty on a trial-by-trial basis. The fourteen subjects were specifically trained in a visual-spatial working memory task, a visual-spatial version of backwards digit span and a spatial-verbal working memory task. The computerized training program consisted of a) a visual-spatial working memory task with circles presented one at a time on a four-by-four grid, b) backwards digit span, in which a keyboard on numbers are shown and digits read aloud, selecting numbers in reverse order; c) letter-span test, and d) choice reaction time task, which was not described as a working number task, but rather as a reaction time and go/no-go task. As part of the training program, visual and verbal feedback was implemented to increase compliance.

To control for the effect of spontaneous improvement in taking the evaluation repeatedly during the five to six week training period, the placebo group was incorporated into the study design. They participated in a similar treatment program with the exception of not having the two key features previously described. Instead, training occurred less than 10 minutes a day and the difficulty level was not interactively adjusted to the children's level of performance. The children, parents, and the psychologists administering the pre- and post-training tests were blinded, relative to which version of the program the children had practiced and the difference in the effect expected of the two programs.

Pretest results did not demonstrate any difference between the groups on the measurement of motor activity, using an infrared motion analysis system camera (OPTA systems) that detects movement while a child performed a 15-minute continuous performance task and on the following cognitive tasks: a) trained version of the visual-spatial working memory tasks; b) span board, a task in which an individual is to replicate a series of visually presented spatial locations that are tapped out on a stimulus block ; c) Stroop task, which measures the relative speed of reading names of colors, naming colors, and naming colors used to print an incongruous color name (Golden, 1978); d) Raven's colored progressive matrices, a series of nonverbal reasoning tasks, and e) a choice reaction time for two-choice as compared to one-choice trails. Variances in reaction times were also examined (Klingberg et al., 2002).

The level of difficulty on working memory tasks was adjusted by changing the number of stimuli to be remembered. Each day of the training, the subjects completed 30 trials of each working memory task, with daily training occurring for twenty-five minutes. Time between test and retest was five to six weeks after 24.3 days of training. A second and more demanding version of the visuo-spatial working memory and digit-span task were continued by subjects after 10 to 18 days of training on the first training series. A visual distraction was introduced during the delay period on the working memory tasks. During the placebo treatment program, subjects participated on 10 trials per task, with 2 stimuli to remember in the visuo-spatial task and digit span task and three stimuli on the letter-span task. A significant treatment effect was found in the practiced visuo-spatial working memory tasks in the treatment group, when compared with test-retest changes in the control group. Significant differences were also found on the span-board task, a non-practiced visuo-spatial working memory task (Klingberg et al., 2002).

Overall, the results indicated that training significantly enhanced performance on the trained working memory tasks. The researchers noted that more importantly, significant improvement was also found on non-trained visuo-spatial working memory tasks and on the Raven's Progressive Matrices, a nonverbal complex reasoning task.

Motor activity, as measured by the number of head movements during a computerized task, was also significantly reduced in the treatment group (Klingberg et al., 2002).

A second experiment was conducted by the same group of researchers on four male volunteer university students. Each of the subjects was pre-tested on the same tasks described previously. Choice reaction time task was lost during post-training results on two of the subjects. In comparison with the previously described experiment, Advanced Progressive Matrices were administered (Raven, 1990) and no measure of head movement was collected. Eighteen problems were given before testing and a different set afterwards. The subjects participated in 5 weeks of training on the same computerized training programs, with an average of 26 days. It was found that all performances improved gradually, with more information being held in working memory and reaction time also decreased. Improvement was also noted on all four participants on each of the cognitive tasks administered before and after training. These test-retest values were compared with those in the other study by Klingberg et al. (2002). Compared with the placebo group in Experiment One, the improvement was significant for the trained visuo-spatial WM task, span board, Stroop test, and Raven's progressive matrices ($p < .05$). All subjects, however, were correct on each of the tasks at the highest level on the visuo-spatial working memory tasks. Two of the participants achieved highest scores on the span board (both forward and backward version) and two of the participants achieved the maximum score on the Stroop task. The researchers suggested that the differences between the trained group in the second group, as well as the control group in Experiment

One, was probably an underestimate of their performances due to ceiling effects in the second study with the adult sample. On the Raven's Progressive matrices assessment, none of the subjects achieved the maximum score and the improvement was 24.5%, similar to the 26.1% improvement for children in the treatment group in the previous study. Little improvement was seen in the Raven's Progressive Matrices, with the test-retest interval at two weeks being nine percent and after five weeks at two percent (Klingberg et al., 2002).

Overall, results of this study showed that intensive and adaptive computerized working memory training increased the amount of information subjects would keep in working memory. Performances improved for both groups of children with ADHD as well as the adult subjects without ADHD. The results of this study indicate that an initial deficit in working memory is not necessary for improvement to occur. The increased performance for both trained and not trained visuo-spatial working memory tasks show that the training effect generalized to other settings. Inconsistent results were found on the choice reaction time task, which supports previous findings suggesting that some cognitive skills are more likely to benefit from training than other processes (Sohlberg, McLaughlin, Paxese, Heidrick, & Posner, 2000). A significant finding of this training is that although the participants were not directly trained on problem solving or reasoning activities, reasoning ability was found to generalize to non-practiced tasks. It was hypothesized that reasoning ability likely improved because complex reasoning tasks are dependent on working memory and both of these processes rely on the same cortical area affected by the training. Evidence of a relationship between working memory and reasoning tasks was further supported by the significant, positive correlation of visual-spatial working memory tasks with the Raven's progressive Matrices (Klingberg et al., 2002). These results hold significant implications when considering the far-transfer effects of cognitive training. Based on the findings that support WM training as additionally improving complex reasoning tasks, there may be the opportunity for young people to transfer the effects to academic performance as well.

One of the most important aspects of this investigation on computerized interventions is that it provided evidence to refute past neuromyths suggesting that working memory capacity is fixed and cannot be improved (Klingberg et al., 2002). Because this research marked the beginning of a new field of research which examines the training effects of working memory training, there were several notable shortcomings that need to be examined before endorsing the benefits of computerized cognitive training.

Another obvious weakness of this study was the low number of subjects both in the treatment and in comparison groups. The research was also conducted at one site within the facility in which the program was developed, thus raising concerns regarding experimenter bias. Additionally, there were no substantial data collected on the ratings of ADHD symptoms to support the fact that they were appropriately diagnosed and whether or not differences could be noted among individuals, based on subtypes and related presentation of symptoms.

One other concern is that there was no follow-up measurement to assess the degree to which the training lasted and whether the training transferred to other areas of their lives such as academic achievement. In discussing their own results, the researchers recommended that a broader range of measurements needs to be implemented to further examine the role that this training has on reasoning abilities (Klingberg et al., 2002). It is important to note that these recommendations were considered in the development of the research design for this particular study.

To further support the previous research on the computerized, systematic practice of working memory tasks, Klingberg and colleagues conducted another randomized, controlled, double-blind trial, but within multiple centers (Klingberg et al., 2005). This investigation included 53 children ages 7 to 12 years who were identified with ADHD, but who were not being treated with stimulant medication. Inclusion criteria included a diagnosis of ADHD either of combined or predominately inattentive subtypes and access to a personal computer with an internet connection at home or in the school. Fifteen of the 53 students were diagnosed with the inattentive subtype; 9 were girls. Exclusion criteria included a)being treated with stimulants, atomoxetine, neuroleptic, or any other psychoactive drugs; b) fulfilling criteria for diagnosis of clinically significant oppositional defiant disorder; autistic syndrome, Asperger's syndrome, or depression; c) history of seizures during the previous 2 years; d) IQ less than 80 (based on an IQ test administered or the physician's clinical impression and school history); e) motor or perceptual handicap that would prevent using the computer program; f) educational level and socioeconomic situation that made it unlikely that the family would be able to follow the treatment procedure and study requirements (the educational level of the parents was not specified in terms of academic degree); and g) medical illness requiring immediate treatment.

As described previously, the program consisted of both visuospatial working memory tasks as well as verbal memory tasks, with each session taking about 40 minutes. The participants completed 25 training sessions over a 5 to 6 week period. Replicating the previous study, the researchers also used an experimental group and placebo group to examine training effects. Participants were randomly assigned to identical treatments, except for the level of difficulty which varied with the comparison condition remaining on the initial low level, instead of being increased to match the students' WM spans. Results found that the treatment group receiving the high-intensity training improved significantly more than the comparison group on the span-board task, a non-practiced measure of visuospatial working memory. Results were also maintained on follow-up tasks. There were significant effects also found for secondary outcomes tasks measuring verbal WM, response inhibition, and complex reasoning. Analyses showed no effects of gender or clinical site for any of the variables. Treatment effects were also found in the areas of response inhibition (Stroop task), verbal WM (digit-span), and complex reasoning (Raven's task). Data gathered from parent ratings indicated significant reduction in symptoms of inattention and hyperactivity during post-intervention and at follow-up. In summary, the results generated at post-treatment found significant improvements of the experimental group on measures of visual-spatial working memory, nonverbal reasoning, and response inhibition. It supports the results from the previous study by Klingberg et al. (2002), indicating that a computerized training program can decrease symptoms linked with ADHD (Klingberg et al., 2005).

In contrast to the previous study, significant improvement was not found on motor activity (Klingberg et al., 2005). A similar limitation of this study is that the researchers did not formally diagnosis the children as having ADHD because they relied on pediatricians, child psychiatrists, or educators to identify individuals presenting with symptoms of ADHD. Additionally, they did not report co-morbid diagnosis within the sample, although they did exclude those presenting with oppositional defiant disorder, intellectual deficits, depression, and Autism Spectrum Disorder, as described earlier. Additional studies that examined these factors more thoroughly may provide a better representation of individuals with ADHD and co-morbid disorders, particularly those linked with learning disabilities. One other factor to consider is that these two studies were conducted in Sweden, which leads to questions whether or not they represent children of the same age in the United States' population, particularly in regard to the exclusion of individuals taking medications to treat ADHD symptoms. Often, the use of medication is the first line of treatment in this nation. Additionally, the researchers did not expand their research to assess the transferability of the training effects to other important aspects of the participants' lives, such as their academic performances in the school setting. Last, when considering the relationship between poverty and cognitive development, the socio-economic status and educational levels of the individuals in this study were factors in determining appropriateness to participate in the study. This exclusion factor raises the issue of whether the treatment effectiveness would benefit some of the neediest of individuals living in the United States, such as those living in poverty and those who have parents with low educational backgrounds.

To address some of these issues raised from these initial studies, Holmes and colleagues from York University in the United Kingdom conducted additional research on the computerized working memory program (Holmes et al., 2009). In one study, they specifically examined the transference of the training effects to academic performance, using a novel approach which involved looking primarily at work memory deficits as the screener for participating in the working memory training program (Holmes et al., 2009). As part of their investigation, 345 children aged 8 to 11 years, attending six schools in North East England were screened, using two tests of verbal working memory: listening recall and backward digit recall, from the AWMA (Alloway, 2007). Participants selected for this study scored at or below the 15th percentile on these tests. Twenty-two children (12 boys, 10 girls, mean age 10 years 1 month) completed the adaptive training and 20 children (15 boys, five girls, mean age nine years nine months) completed the non-adaptive version. The adaptive and non-adaptive trainings were administered in different schools, with the schools not being informed that two different versions existed. Subsequently, the adaptive version was provided to the other school upon the conclusion of this research. The majority of the students who completed the adaptive program made substantial gains in their working memory performance. Although the training did not find a detectable impact on their academic skills immediately following the interventions, significant gains were found in mathematical skills six months following the training, supporting the fact that the skills were able to transfer to meaningful school functions. The results also found that IQ did not improve with training. This finding suggests that although WM and IQ are related (Kane & Engle, 2002; Jaeggi, Buschkuel, Jonide, & Perrig, 2008), the role of working memory can be discerned from IQ in struggling learners.

Additionally, the researchers suggested that the students' participation in the training program may promote self-awareness and the development of compensatory strategies that capitalizes on their strengths to compensate for their areas of weaknesses. To investigate this thought, the researchers found that 37% of the students who provided feedback on how to improve training activities indicated that closing their eyes and focusing assisted them on memorizing the information. Twenty-seven percent reported using other strategies such as rehearsing the information or tracing the patterns on the computer screen with their eyes. It was suggested that the children who participate in adaptive training may improve attentional focus and also develop a set of strategies to pull from when presented with demanding tasks in working memory (Holmes et al., 2009).

In terms of actual gains in the various systems of working memory, Holmes et al. (2009) found that improvement also generalized to WM assessments that were not directly trained within the intervention. The most significant gains involved the storage and manipulation of visuo-spatial material either of verbal or of visuo-spatial material. These findings support the central executive component of WM , a limited capacity system that controls the allocation of attention when presented with demanding and immediate memory situations (Alloway et al., 2006; Bayliss, Jarrold, Gunn & Baddeledy, 2003: Kane, Hambrick, Tuholski, Wilheim, Payne, & Engle, 2004). These tasks are those that have been supported as being the most predictive of children's learning abilities. The adaptive training did not, however, have as strong an impact on verbal short term memory, a subcomponent of WM linked with the frontal and parietal neural circuits (Smith & Jonides, 1997) associated with language learning (Baddeley, Gathercole, & Papagno, 1998).

This study was the first to demonstrate that commonplace deficits and associated learning difficulties can be ameliorated and even overcome by intensive adaptive training over a relatively short time (Holmes et al., 2009). In examining the current climate in the United States regarding the failure of public schools' special education programs in reducing the achievement gap between regular education students and their peers with learning disabilities, this research provides relevance for the need to research these interventions more thoroughly within the American school system. Although the research is meaningful in examining the impact that adaptive computerized training can have on the outcomes of students in the school setting, the issues continue to be raised about whether or not the results of these interventions can be generated to individuals typically represented in the school setting in the United States.

Expressing similar concerns, Holmes et al. (2010) conducted additional research to examine the effects of cognitive training developed by Klingberg et al. (2005), when compared with stimulant medication on working memory deficits in children with ADHD. Twenty-five children between the ages of eight to eleven years of age, diagnosed with ADHD and who were taking stimulant medication, were recruited through psychiatrists and pediatricians in the local community. Although the researchers indicated that the students were diagnosed with ADHD, the procedures used to identify the disorder were not described (e.g., structured interviews). Unlike the previous studies conducted by the researchers at the Karloski Institute, participants were administered standardized instruments to measure components of working memory (Klingberg et al., 2002). The Automated Working Memory Assessment (AWMA) (Alloway, 2007; Alloway, Gathercole, & Pickering, 2006) was administered to assess both verbal and visuo-spatial storage in Working Memory. These children were pre-tested on and then off the medication and then again assessed at post-training. They were also evaluated at a 6-month follow-up session while on medication.

Using Baddeley's (2000) working memory as the conceptual framework underlying their research, they found that cognitive training improved verbal, visuo-spatial, and executive aspects of working memory. Significant gains were also maintained on three of the four aspects of working memory after six months, with gains not being experienced on verbal short term memory. Similar to Holmes' et al. (2009) previous study, intelligence scores were not affected by either intervention. Those on medication improved only on visual-spatial performance. Although the research in England has yielded positive results, increased research is needed to assess the programs' effectiveness in the United States' public school systems. One question continues to be raised regarding whether or not medication usage affects performance on the computerized cognitive training program. As indicated previously, research examining the role of medication on the training program would more accurately represent many students in the United States who are being treated for ADHD.

A team of researchers from Ohio State University and the University of Toledo also piloted the computerized training program developed by Klingberg et al. (2002; 2009) in order to assess the effectiveness of working memory training with children and adolescents who represent a more typical sample of the population found in the United States (Beck et al., 2010). Specifically, these children were currently using stimulant medication and had co-occurring diagnoses. Participants in this study were 52, predominantly Caucasian (96%), children and adolescents from 7 to 17 years of age (M=11.75; 16 girls). The students involved in this study were recruited from a private school for children with ADHD and/or learning disabilities located in large Midwestern city. Individuals included in this study were those who were found on parents' rating forms to be within the Clinically Significant range (T> 64) on the working memory scale of the Behavior Rating Inventory of Executive Functions (BRIEF; Gioia, Isquith, Guy, & Kenworth, 2000), or endorsing at least six of the inattentive symptoms from the *DSM-IV-TR* (2000). Forty-six of the participants (88%) had initial BRIEF Working memory t-scores above 64 and the 6 other participants met the criteria of having six or more inattentive symptoms from the *DSM-IV* (APA, 1994). All participants met the criterion according to the P-Chips for ADHD on the combined type (29%) or predominantly inattentive type (71%). Individuals in the program also had co-occurring conduct problem disorders (oppositional defiant disorder or conduct disorder, 46%), anxiety disorder (39%), and mood disorders (8%). Twenty-nine percent of the sample represented with one co-morbid diagnosis. Unlike the previous studies on working memory interventions, 61% of the participants were taking stimulant medication. Forty-nine children completed the interventions.

The research staff trained the parents of the participants in the administration of the working memory intervention to include how to supervise and encourage the children, and how to implement an individually tailored reward system during the training period. Participants in the experimental group received the working memory intervention and weekly calls from the research staff. The control group did not receive these services. Similar to other studies, training was conducted in the home under the supervision of one parent. Training also included 25 sessions completed in six weeks. An Index score was derived; this involved calculating the difference in performance between the range of the first three sessions and the session with the highest performance on one verbal and nonverbal working memory exercise (Beck et al., 2010).

The most robust finding was found when comparing the experimental group immediately following treatment to the waitlist group who had not yet started training. Similar to the results found in Klingberg et al. (2005), moderate to strong effect sizes were found on parents' ratings of ADHD symptoms (d=0.76), inattention (d=0.79), and reduction in attentive symptoms (d=1.49) when the effects sizes were calculated in the same manner (Beck et al., 2010). These results also support the idea that working memory training had a beneficial impact in reducing parent rated inattentive behaviors and ADHD symptoms at post-treatment and at a 4-month follow-up. Additionally, significant changes in measures of executive functioning were found at post-treatment and at follow-up. Parents rated improvements after treatment and at the 4-month follow-up on the following three BRIEF scales, Working Memory, Initiate, and Plan/Organize; domains that are described as core deficits in children and adolescents with ADHD. Teachers' ratings found improvement only on the Initiate scale at post-treatment and Initiate and Working Memory at the 4-month follow-up. The waitlist support group at post-treatment demonstrated similar results in parent-rated improvements on the two inattentive scales and on the ADHD Index scale, but only a trend towards significance on Initiate and Plan/Organize at post treatment and no significant changes on working memory. It was hypothesized that the parents' weaker ratings of changes in executive functioning changes in the waitlist control group may be related to parents' sensitivity. Specifically, the waitlist group finished at the end of the school year and the first treatment group ended in December (Beck et al., 2010).

Similar to the previous studies conducted to assess the effectiveness of the computerized program on young people in the United States, Mezzacappa and Buckner (2010) also implemented the computerized training program with nine second and fourth grade students, ranging in ages from 8 to 10.5. One exception to this study, when compared with the previous research, is that this intervention was conducted in a public school system during the school day. Training on the computerized working memory computer occurred daily for 5 weeks for 40 to 45 minutes during the school day, each day. Teachers rated the children's behaviors before and after the intervention. Standardized assessments on verbal and visuo-spatial working memory were also conducted. Verbal working memory was assessed using the Digit Span subtest of WISC-IV (Wechsler, 2003). The outcome measure was the raw change in sequence length. Visuo-spatial working memory was assessed using the Finger-Windows subtest of the Wide Range Assessment of Memory and Learning (WRAML) (Sheslow & Adams, 1990). Parents and teachers also completed the Home and School versions of the ADHD Rating Scale-IV (ADHD-RS-IV) (Cogmed, 2010) before and after the interventions. The ADHD-RS-IV is a verbatim questionnaire of the 18 symptoms, nine for inattentive and nine for hyperactivity, that comprise Criteria A for each of the two subtypes of ADHD in the *DSM-IV* (APA, 2000). Analyses by the researchers focused primarily on the teachers' responses because not all questionnaires were returned by parents. Teachers' responses at baseline on the ADHD-RS-IV found that seven of the nine students showed combined inattentive and hyperactive-impulses symptomology and the other two showed primarily inattentive symptomology (Mezzacappa & Buckner, 2010).

Overall, the results of this study found teacher ratings of total ADHD symptoms improved on average by 26 percent. Comparable improvements of 36% were found on the WISC-IV Digit Span Backward and on the WRAML Finger-Windows, 33%. In examining the data closely, the teachers' ratings of total ADHD symptoms improved. On the Finger-Windows test, scores improved in seven students and worsened in one. The declines in performance reported on these three measures were not unique to one child. Overall, the authors suggested that training working memory in the school setting may be a potential intervention to address students' problems with attention or hyperactivity in the classroom. Cognitive intervention strategies such as those proposed in this study are particularly promising when considering the benefits of providing the services to more needy individuals such as those living in economically disadvantaged communities.

One of the significant factors to consider in this particular study is that the training was administered within the school setting, thus opening an opportunity to individuals who may not have the necessary home support. It also helped to improve the integrity and the fidelity of the program by directly monitoring the children's participation in the activity as it was designed, as opposed to being supervised by parents in the home. Students were children with ethnic minority backgrounds living in Boston, and all qualified for the free breakfast and lunch programs. Because the pilot study was implemented in a poor urban community, it contrasts with several of the previously described studies indicating that students were enrolled in private schools or lived in households with the appropriate financial means and educational background to implement the training in their homes. These studies did not provide significant information to describe the socio-economic background of students accurately in order to make further comparisons with this particular group. When examining the ensuing debates occurring in the United States about financial inequality of the public school system, it is important to consider the benefits of school-based interventions in reducing the achievement gap between those living in poverty and those living in middle and upper class communities who have more opportunities to receive such training from private providers (Altonji & Mansfield, 2011).

There were several limitations in this study, including a small sample size, no control group, and the use of teachers as the sole means for recruiting and evaluating participants. Because teachers were not blind to the intervention status of the participants and were aware that the students had to leave their classes to participate in the training, this could have influenced their ratings of the students' behaviors. Although the study was small, positive changes were noted on the standardized measures of working memory showing individual growth. The changes on the improvement in teachers' ratings were consistent in changes of working memory reported in previous investigations. It was recommended by the authors for longer-term follow-up. It was also suggested to examine whether training differentially affects inattention or hyperactivity (Mezzacappa & Buckner, 2010).

An additional study carried out to examine the feasibility of utilizing computerized cognitive training on regular education students in a public school system was conducted by Yuan (2007) at Stanford University as part of a dissertation. Other areas investigated in this study include exploring the adequacy of simple memory span tasks to measure WM; testing the training effects over 2 to 3 weeks, and exploring the potential difficulties in the implementation process. Using the environment and coaching process in the study by Klingberg et al (2005), Yuan (2007) adapted the training to be used in the middle school setting. A pilot study was initially carried out during a summer school session in Northern California, in which the students were required to participate in the summer program in order to progress to the next grade. Participants were randomly assigned either to an experimental or to a control group after they took four tests of WM, fluid intelligence, and science achievement. T-tests on these pre-test measures showed that they did not differ significantly on all measures. Students in the experimental group received computerized training on WM and the control students took computerized science lessons. Students in both groups took computerized training for four days a week for four weeks. In the main study, thirty-seven 7th and 8th grade students participated between January and March and trained for 24.65 days, on average.

Results showed that computerized working memory training effectively improved regular education students' working memory in the school setting with a greater increase in short-term memory than in cognitive control. Similar to studies previously reported, no significant differences were observed immediately after the training between the experimental and control group students in the area of fluid intelligence. Significant differences were also not observed immediately in the area of science achievement. It was suggested by the research that additional follow-up is warranted to allow enough time to transfer changes in WM to fluid intelligence and science achievement (Yuan, 2007). Based on this recommendation, the current research was designed to help address the question of whether or not far-transfer effects occur at 4-weeks and 4-months after the intervention in the area of fluid reasoning.

Investigating another type of computerized training, Rueda et al. (2005) examined the impact of computerized attention training (CAT) using a normative sample of four and six year olds. A total of forty-nine 4-year old children (25 males; mean age: 52 months, SD: 2.2 months) and twenty-four six-year-old children (12 males; mean age 77 months, S.D. 3.2 months) participated in the study. All were recruited from a data base on births in the Eugene-Springfield, OR area. Three experiments were conducted with twenty-four 4-year-olds participating in Experiment 1; twenty-five 4-year olds in Experiment 2, and twenty-four 6-year olds in Experiment 3. Children were randomly divided for each experiment into an experimental group (n =12) and control (n=12; n=13 in Experimental group 2, only) groups.

Each experimental group received assays on attention (Child ANT) (Rueda et al., 2004), intelligence (Kauffman Brief Test of Intelligence Tests- KBIT) (Kaufman & Kaufman, 1990) and parent-reported temperament (Children's Behavior Questionnaire, CBQ) (Rothbart et al., 1994). They were then provided with 5 days of training over a 2 to 3 week period. The 5 days of training were divided into nine (Experiment 1 and 2) or ten (Experiment 3) exercises. These exercises were structured to include tasks that the experimenter believed were related to executive attention. The tasks were divided into levels, with children progressing to the next level, making a number of correct responses in a row. Electroencephalogram (EEG) recordings were conducted when participants were performing the Child ANT.

On the final day of training, the participants received the same assays administered on the first day, except temperament questions were taken home by the families to be filled out two weeks after the final session. Experimental groups one and two differed only in the control group. In Experimental group one, the 12 control children came to the lab only twice; on day one for assessments and two to three weeks later for the second testing session. In Experimental group 2, the control group was brought in for five sessions over a two to three week period in which they watched a popular children's video. In experiment 3, involving the 6-year-old participants, the experimental and control groups were treated the same as in Experiment 2. Experiment 3, however, required the participants to complete one more exercise in their training because they were faster than the 4-year-olds. In summarizing the research, Rueda et al.

(2005) found that the children who participated in the training showed more improved performance after five days of training on executive attention tasks, when compared with untrained controls. It was also suggested that although the development of the executive attention network is under strong genetic control, it can be affected by educational interventions during development. Similar to concerns discussed previously, one of the limitations of this study is that it did not examine transfer effects on achievement and on long-term effectiveness of the intervention. It would also be beneficial to assess the impact this training may have on other cognitive constructs because of its relationship with other neuropsychological processes affecting learning.

Another group of researchers conducted a study to examine another attention training program called the Computerized Progressive Attention Training program (CPAT) (Shalev, Tsal, and Mevorach, 2007). These individuals examined the effectiveness of this intervention in reducing attention deficits in twenty children with ADHD between the ages six to 13 years of age. Tasks were designed to provide direct intensive exercising of attentional networks, specifically in the areas of sustained, selective, orienting, and executive attention in children. The purpose of their research was to examine whether or not attention training in children with ADHD could lead to improved academic performance. This study investigated whether or not there was a transfer of skills to behavioral and school performance. Significant improvements were found in reading comprehension and passage copying. Additionally, parents reported improvements in attention.

One limitation of this study included a failure to include in the evaluation battery, any objective measure of attentional difficulties before and after training. It was recommended for further assessments on CPAT to include attentional measures in order to assess the extent to which improvements in academics were correlated with improvements in various attentional measures. Similar to the concerns presented in other computer training programs, an additional limitation included not having any long-term follow-up of the effects of the interventions and whether the improvements represent an enduring change in ability or if the improvements were short-lived. Another issue in this study is the lack of teachers' evaluations regarding the children's classroom functioning and academic performances. The researchers recommended including additional tools to assess the effectiveness and generalization effects of attentional training, including opportunities to receive input from teachers (Shalev, Tsal, & Mevorach, 2007).

To assess if working memory training generalizes to improve off-task behavior in children with ADHD, researchers with the University of California conducted a randomized double-blind study design to compare the performances of children on a computerized working memory program with those in a placebo group (non-adaptive program) (Green et al., 2013). Twenty-six children (18 males; age seven to 14 years old) diagnosed with ADHD completed training in approximately 25 sessions in their homes. The Restricted Academic Situations Task (RAST) observation system was utilized to examine off-task behaviors during the completion of an academic task. The Conners Parent Rating Scale (Conners, 2009) and subtests from the Wechsler Intelligence Scale for Children (WISC-IV) (Wechsler, 2003), used to compose the Working Memory Index, were administered.

In summarizing the results, no significant differences were found between groups when comparing improvements based on the parent rating scale because both the active treatment and placebo groups demonstrate a significant decrease in behaviors as measured by the CPRS-R (Conners, 2009). It was suggested that differences found on the rating forms from this study, relative to previous research such as that conducted by Klingberg et al. (2005), is that the individuals in this study were taking stimulant medication; the use of medication could have influenced the rate of improvement. Another factor, reported by the authors, which could have affected the rating of behaviors, when compared with the research by Beck et al. (2010) and Klingberg et al. (2005), is the population of participants selected. The individuals in these particular studies demonstrated a higher preponderance of comorbid disorders and inattentive behaviors, whereas studies by Green et al. (2013) did not. It was suggested that because of their more significant needs, parents may have been more sensitive to detect changes in behaviors. Use of medication was not found to be associated with better performance on any of the measures, noting that both groups had similar Full Scale IQs as assessed by the Wechsler Abbreviation Scale of Intelligence (WASI) (Wechsler, 2003).

In examining the data generated from the RAST, the active treatment groups showed a significant decline in off-task behavior, when comparing post-test observations to pre-test measurements in relation to the control group. No significant training effects were found in fidgeting with both groups because they maintained pre-intervention levels. Training was found to contribute to lowering the time spent on playing with objects (Green et al., 2013).

Regarding non-trained working memory tasks, Green et al (2013) found that there were no significant differences between the two groups at pre-intervention. A significant interaction between group and time were found on the WM tests in the treatment group that was not observed in the placebo group. The researchers indicated that the results were not surprising; the participants in the treatment group made progress because the training exercises were very similar to the assessment tasks. In summarizing the findings, they indicated that working memory training can generalize to improve non-.trained ADHD impairment in behavior, but they also recommended that further research should be conducted in order to assess the addition of behavioral coaching to build and maintain skills in children with ADHD.

Two articles were published during the period in which this research was being conducted to further examine the impact of far transfer effects on young children. One study conducted by Gray et al. (2012), examined the effects of computerized working memory training on attention, working memory, and academics in adolescents with severe learning disabilities and co-morbid ADHD. Dahlin (2013), a researcher in

Sweden, examined whether or not a computerized working memory intervention could impact math performance in young children with ADHD.

A study by Gray et al. (2012) involved sixty 12 to 17 year old young people with learning disabilities and ADHD, from a semi-residential program in Canada; they were randomized to one of two computerized intervention programs: working memory training (Cogmed RM) or math training (Academy of Math; www.autoskill.com). Eight of the original sixty students (13%) withdrew from the study. The math training program was an active comparison program that is described to have beneficial effects on math development across 10 essential skill areas, including number sense, calculation, equations, measurement, and geometry (Torlakovic, 2011). Academy of Math included features similar to those of the WM training program, including individually based algorithms and built-in reinforcements. Students in both groups completed 45-minute training sessions, four to five days a week for five weeks. The individuals continued to receive stimulant medication, as well as intensive academic remediation at the school. Individuals in this study were evaluated prior to the interventions and three weeks following its completion. Criterion measured included the following: Digit Span Forward and Backward to measure auditory-verbal and working memory respectively, and Spatial Span from the Cambridge Neuropsychological Testing Automated Battery (CANTAB), (Fray, Robbins, & Sahakian, 1996) to measure visual-spatial short-term and working memory.

Near transfer effects were assessed using CANTAB Spatial WM to assess strategy skills and WM capacity. The Working Memory Rating Scale (Alloway, Gathercole, Kirkwood, & Elliot, 2009) was used to assess WM as observed in the classroom. The D2 Test of a Attention (Brickenkamp & Zillerman, 1998) was used to measure attention and concentration performance. This test of visual discrimination allowed for measurement of processing speed, rule compliance, and quality of performance. Far transfer measures included the Wide Range Achievement Test- 4th Edition Progress Monitoring Version (WRAT-4PM) (Roid & Ledbetter, 2006) to assess word reading, sentence comprehension, spelling, and mathematics. To measure attention and hyperactivity at home and schools the Strengths and Weaknesses of ADHD symptoms and Normal Behavior Scale was used (SWAN, Swanson et al, 2001).

Consistent with the hypotheses of the study, it was indicated that the participants who received the WM training showed improvement on two of the four criteria measures of working memory; however, not all of the indices demonstrated significant improvement. The most significant finding was that the WM training had a robust beneficial effect on a measure of auditory-verbal WM (DSB) that resembled the training activities, in addition to an effect on visual-spatial WM (SSP) for those with a co-occurring diagnosis of ADHD. Based on previous research, they expected to observe improvement on spatial WM; however, there were no significant group differences on this measurement. It was suggested that longer or more intensive training may be necessary to improve severe difficulties in WM (Gray et al., 2012).

No significant training effects were found on the other cognitive abilities, behaviors, or academic achievements. After analyzing data subscale totals or when isolated, there were no training effects found on the teachers' and parents' rating forms on inattention, hyperactivity, and oppositional behaviors. Additionally, there were no effects found on academic measures, although the results for the WRAT-4 were in the predicted direction for the math training group. A moderate correlation was found between the WM Index improvement and parent ratings of behavior at home, using the IOWA Conners (Pelham, Milich, Murphy, & Murphy, 1989). No beneficial effects on behaviors were rated by the teachers.

To assist in explaining the findings, it was suggested that the training effects on strategy development had not taken effect directly after the intervention or that they may be dependent on the level of strategy development by the participant. The authors also reported previous research by Gibson et al. (2011), in which it is possible that more complex WM tasks are not targeted through the intervention as are the tasks that align with those similar to Digit Span.

In examining the clinical implications of this study, the findings support the fact that WM training can enhance some components of WM for individuals who have experienced on-going struggles in learning. This current study was initiated prior to the publication by Gray et al, (2012) and raised similar questions regarding transfer effects of the training to individuals with co-occurring learning disabilities and ADHD. The current study, however, looked more specifically at individuals with math difficulties and ADHD, and Gray et al. (2012) did not examine specific types of learning disability diagnosis. Additionally, they did not assess long-term outcomes of the interventions. It was suggested that the WM training may enhance aspects of WM in youth with ADHD, but additional development of the training program is needed to promote transfer effects to other domains.

In a study conducted in Stockholm, Sweden, Dahlin (2013) investigated whether a computerized working memory training program could impact math performance in children in grades three to five (mean age=10.7). Fifty-seven children identified with attention deficits participated in the program at school for five weeks, on a daily basis, but the control group did not participate in any additional training. Forty-two students constituted the treatment group; 7 (seven female) and 15 (four female) made up the control group. The children, who were being educated in small groups in a regular school, had attention deficits and special education needs. It was reported that the reason for the children being placed in a small class was the fact that they required significant assistance that was not able to be provided in the regular education program. The 57 children were enrolled in 16 different schools, with two to five children in each class taking part in the study.

This study was a quasi-experimental study with a pretest-treatment, post-test - post-test design. Three sessions of assessments were completed. The treatment group participated in five weeks of computerized training of WM (Cogmed working memory training) at school, on a daily basis for 30 to 40 minutes. In this study, an adult supported each child, one at a time, during the entire training period; the training took place in a room next to the classroom. Parents received a daily report of each child's performance; the report was signed by the adult responsible for the child's training session at school. The psychologist phoned the person responsible for the each child's WM training on a weekly basis to give feedback and advice.

The children were administered the Basic Number Screening Test (BNST) (Gillham & Hesse, 2001), a nonverbal screening tests designed for children aged seven to 12 years, to assess for a variety of "number concept" items and "number operations" items. They were also provided with addition and subtraction skill tests to measure specific arithmetic skills.

To assess for working memory and nonverbal reasoning, the participants were given the Digit Span Test of the Wechsler Intelligence Scale for Children (WISC-IV). In this study, the researcher reported that the tasks involving the individual repeating the numbers in the same order in which they were presented; this taps into the phonological loop (Swanson, 2006) and is a measure of verbal short-term memory. When repeating the numbers in reverse order, it was indicated that the test is tapping the CEF in WM (Swanson, 2006) and is considered a verbal working memory task. To assess for visuo-spatial short-term memory, the Span-Board Test, a subtest from the Wechsler Adult

Intelligence Scale (WAIS) was administered. In the second part of the test, the student is asked to repeat the items in reverse order, a task that is reported to load onto the Visual-spatial sketchpad and the CEF in WM (Swanson, 2006). To assess for non-verbal reasoning ability, the "Raven" (Raven's Colored Progressive Matrices) was administered (Raven, 1995).

Math improvement as measured by the Basic Number Screening Test (BSNT) was observed in the treatment group, when compared to the control group, directly following the five weeks of training. When comparing an additional post-intervention test at approximately seven months later, the significant differences no longer remained when examining the entire treatment group including both boys and girls. Because there were relatively few girls in the study, the researcher examined the outcome data for the boys. When examining the boys' data only, the boys in the treatment group improved on the BNST at Time Two (directly following the training) and at Time Three (approximately seven months following the first post-test), when compared with boys in the control group. On the addition and subtraction test, no effects appeared. Dahlin (2013) noted that the proportion of boys and girls not only clearly affected the results in the study but was also unexpected. When comparing the results to previous research in which improvement in math was not observed until six months after the training, the researcher questioned whether it would be beneficial to examine if the proportion of boys and girls could impact the findings (Holmes, Gathercole, & Dunning, 2009)

When examining the measures of working memory, neither verbal short-term memory (Digit-Span forward) or verbal working memory (Digit-back) were found to improve significantly for the treatment group. The most improved performance on the working memory measures was on the Span Board forward and back at the seven month follow-up assessment, when compared with baseline in the experimental group (both boys and girls) and boys only. It was suggested by the researcher that WM training may benefit math achievement, but because the intervention and control groups were not randomized, the results must be interpreted with caution. These results were consistent with research conducted by Holmes et al. (2009) in which WM training had no effects on verbal STM (the phonological loop), but did demonstrate effects on visuo-spatial STM and verbal and visuo-spatial WM. It was hypothesized that the WM training may not have an impact on STM (the phonological loop) but that the CEF (central executive function) is affected by it.

Consideration of the results on the WM measurements in the area of math supports the reasoning presented by Passolunghi & Siegel (2004), who indicate that individuals struggling in math have a persistent weakness in the central executive function, especially in the WM task Digit Span back measure (Dahlin, 2013). Dahlin (2013) indicated that the interactive, computerized working memory training program may be beneficial in improving WM capacity for boys with attention and special education needs and it can possibility contribute to math improvement. It was also indicated that the span board back results were highly correlated to math at T1, T2, and

T3. The researcher concluded that memory capacity is malleable and that it appears to affect untrained skills for both adults and children (Caviola et al., 2009; Thorell et al., 2008; Klingberg et al., 2005; Jaeggi et al., 2008; Holmes et al., 2009).

Another research team who has published several articles on working memory training, Holmes and Gathercole (2013) also recently published their research on utilizing the training within a primary school setting in the south of England. Two field trials were conducted in which teachers administered the working memory training to their own pupils in the school. The RM version of Cogmed Working Memory Training was employed, following the standard protocol of 20 to 25 sessions. Trial 1 consisted of twenty-two students aged eight to nine from a mixed-ability class and trial 2 consisted of 50 children aged 9 to 11 years with the lowest academic performance. Twenty-five of the children were recruited from Year 5 (mean age 9 years 5 month) and 25 from Year 6 (mean age 10 years, 6 months). Students in Trial 2 consisted of students who had the lowest Teacher Assessment scores of their respective groups. The participants in this study were matched with a group of 50 students who were not assigned to the intervention group. Trial 2 was matched to other students with similar performance on Teacher assessments and on gender and age (within 30 days).

Participants were administered multiple standardized tests of four aspects of working memory from the Automated Working Memory Assessment (AWMA) (Alloway, 2007). The Cogmed Improvement Index (CI) was also calculated through the computerized training program. The average CI score was found not to be significantly different from that reported in the research trials; $p > .05$, when compared with the average CI of 24 (Bennett, Holmes, & Buckley, 2013; Holmes et al., 2009; 2010). There was also no significant correlation between the number of sessions completed and the gains on the training tasks, as measured by the CI; thus, all children were included in the analysis regardless of the number of training sessions completed for each of the trials.

Results found that the children in Trial 1 improved significantly on both trained and untrained tasks, with effect sizes comparable with those in previous studies. There were significant gains found on all measures except Digit recall and Counting recall. These include: word recall, dot matrix, block recall, backward digit recall, Mr. X, and spatial recall. Improvement was also found to be similar when examining the data in Trial 2. It was also indicated that the individuals participating in the training made significantly greater progress across the academic year in math and English. Training gains were also found for the whole-class trial of children eight to nine years of age. Significant improvements were found on all assessed aspects of working memory, with the greatest improvements observed in the areas of visuo-spatial short-term memory and visuo-spatial working memory. As reported by Holmes and Gathercole (2013), this was an important finding because these aspects of memory are strongly linked with learning and thus raises the possibility that improving these specific skills could contribute to academic progress (Gathercole et al., 2004).

Additional findings from the Holmes and Gathercole (2013) study indicated that students in Trial Two in Year Six of their schooling made significantly greater performance in English than their matched untrained peers. Greater advances in math attainment levels were also found for low-achieving students in Year Five and Year Six. It was indicated that for the younger children, this reflected a drop in performance across the school year for the comparison group. These finding are significant when considering that the individuals in Trial Two were rated as among the lowest achieving students, which led them to be recruited for this study.

To address the extent to which the magnitude of training gains varied as a function of baseline performance, the researchers split the group into two groups with a lower score in working memory (*M*=97.01)and a higher baseline working memory performance (*M*=113.9) (Holmes & Gathercole, 2013). In examining the data closely, the training gains were most substantial for the children with low working memory. This is a factor that is important to consider when examining research of individuals that may initiate the training with average memory skills and would have lower thresholds to reach their optimum levels of working memory performance. In other words, individuals with average to above average skills in working memory may show less growth on assessments than individuals with poor or below average working memory skills.

Overall, the results of the Holmes' and Gathercole's study (2013) indicated that improvements on training activities were equivalent to previous research both for a mixed-ability class and for low achieving students who were trained in groups ranging from 12 to 25 individuals. Based on these findings and the high rate of compliance by both groups, it was suggested that it is feasible for working memory interventions to be conducted in large groups within the school day. It was also indicated that in these conditions, the students also showed good rates of progress on trained activities.

In contrast to the previously reported research indicating positive gains on the computerized working memory training, Egeland et al. (2013) found less promising results when examining far transfer effects on various neuropsychological assessments. In this study, sixty-seven children with ADHD were randomized into a control group or a training group. The working memory training (Cogmed's RoboMemo program) was performed on a daily basis in a school for five to seven weeks. The interventions were monitored by a teacher or other person designated by a school official during the school day. Tests took place at the Departments for Child and Adolescent Psychiatry in Vestfold Norway or Telemark Hospital Trusts, also in Norway. Participants received verbal and visual feedback about their performances on a daily basis. Every fifth day each received an additional, individualized reward. Four individuals had to discontinue training for a week due to a flu epidemic. They participated in additional training days when they returned to school.

Neuropsychological measures that were administered included the Color Word and Trail Making Test (TMT) from the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001) and the Conners Continuous Performance Test-II (CCPT-II) (Conners, 2002). The scaled scores from the CW 1 and 2 and TMT 2 and 3 were averaged into a composite measure of processing speed. The average scaled scores for speed and errors on CW3 and 4 made up of Controlled Attention. TMT4 is reported separately as a different measure of controlled attention. Within the CCPT-II, several composite measures are derived for each dimension. These include: Focused Attention, Hyperactivity-Impulsivity, Sustained Attention, and Vigilance. Two memory tests were also applied in this study: Children's Auditory Verbal Learning Test-2 (CAVLT-2) (Talley, 1993) and Benton Visual Retention Test, Fifth edition (BVRT) (Benton-Sivan, 1992). Three measures from the CAVLT-2 were examined: Level of Learning, Free Delayed Recall, and Recognition. The BVRT was reported as a test of working memory.

Academic skills were assessed by two subtests from Key Math (Connolly, 1998) and reading was assessed by LOGOS (Hoien,2005). Rating scales were also completed by parents and teachers to include the ADHD-Rating Scale IV (DuPaul et al., 1998), Strengths and Difficulties Questionnaire (Goodman, 1998) and the Behavior Rating Inventory of Executive Function (BRIEF) (Gioya et al., 2000).

In summarizing the results of this study of the working memory training in the school setting, the composite measures of processing speed was the only measure that demonstrated significant improvement in the training group. The findings in this study are consistent with the findings from Klingberg et al., (2002) of increased processing speed; however, Klingberg found a large effect but Egeland (2013) found only a small effect after the training. Participants in the training group did demonstrate near transfer effects on working memory capacity after training that supported previous research, indicating that it is probable to improve performance on working memory tasks after training. When examining far transfer effects, no other neuropsychological processes showed improvement. Although results were not convincing relative to the transfer effects of working memory, data from the reading assessments were more compelling. The decoding of words improved in accuracy, but did not improve in speed. Text reading also improved. In examining the rating scales, no significant differences were observed.

One of the questions raised in this study was whether or not medication could have influenced performance. It was indicated that medicated subjects demonstrated better performance at baseline on Focused Attention, and also upheld arousal, even when not continuously active, as evident from the interstimulus- effect on the CCPT-II (Conners, 2002; Egeland, 2013). The authors questioned whether or not the medication could have exhausted the possibility for future improvement. A related question that was raised asked whether more impaired students were medicated, based on the data demonstrating that unmedicated individuals performed better than their medicated peers on the BVRT (Sivan, 1992). Other than these differences, there were no other differences noted between those on medication and those who were not.

Similar to the finds by Beck and colleagues (2010), BRIEF (Gioia et al., 2000), results found significant improvement at home but not at school. In examining previous research conducted by Klingberg et al., (2002), in which it was concluded that WM impairment was not necessary to make improvement in the area of working memory, the authors of this study indicated that it may be difficult to determine treatment effects because previous research either had recruited individuals with low working memory skills or did not provide information about the functional level of the individuals with ADHD (Blum et al., 2001; Egeland et al., 2013). As hypothesized by Egeland et al. (2013), subjects who take medication have already optimized their behavior and thus will show less treatment effects, regardless of average or below the norm pre-training performance in working memory.

In considering the questions raised in Egeland and colleagues' (2013) research, limitations noted in the study included not controlling the use of medication, and also the study's not being blinded to the teachers, parents, and test administrators, each of whom was aware of the individuals in the training group. To address concerns with committing Type 1 errors if all measured were analyzed individually, the researchers chose to compute robust composite measures. They reported that using a different statistical method could have contributed to the insignificant findings in the research.

Overall, Egeland et al. (2013) indicated that one of the primary questions that needs to be asked is if the WM training leads to far-transfer effects in order to increase individuals' functioning in everyday life or if the increase in near transfer actually represents a narrow training effect on a task. The researchers did indicate that despite the positive results linked with the improvement of processing speed and reading effectiveness, the results may not provide sufficient justification for WM training because similar results could be achieved through direct training in reading skills. They also suggest that previous research indicating that WM can be improved even if there is not an initial impairment cannot be substantiated. It was recommended that further research be conducted to take control of issues related to task and measurement error, as well as to retest effects that would be expected to regress significantly towards the mean.

When examining the research on computerized training, it became apparent that there is a gap between neuroscience and education because there are few relevant studies examining the effectiveness of computerized cognitive training in the school setting. One of the limitations is that there are relatively few studies conducted on children and adolescents within the United States. Additionally, when initiating this study, those studies that had been collected had not specifically examined those identified with learning disabilities and ADHD. Although a few additional studies have been published within the past year investigating the computerized working memory intervention in the school setting, more research is needed.

Other important factors that need to be investigated further are not only the far-transfer effects that these trainings could have on academic achievement, but also the potential of its use when incorporated into students' school day. As noted within the review, another factor that has not been thoroughly reviewed is the long-term effects of this computerized training on trained tasks, near transfer effects, and far-transfer effects, particular on academic achievement. These issues and noted limitations were considered when examining the design and implementation of the interventions within this particular research study.

Computerized training in special populations. Research on computerized cognitive training has also been extended to examine its effectiveness with other populations to include pre-school children and those with intellectual disabilities. For example, Thorell et al. (2009), also at the Karolinksa Institute in Stockholm, Sweden, investigated the effects of computerized training on preschool children from four different preschool programs with children between the ages of 4 and 5 years old (M=56 months, SD=5.18). One of the purposes of their research was to investigate whether training would not only improve working memory, but also whether inhibition and other processes linked with executive functioning could also be improved. Within this study, an active control group played commercially available computer games and a passive control group took part in only pre- and post-training. Children at two of the preschools formed the experimental groups. These individuals were randomly assigned (matching the groups with regard to age and gender) either to a Working Memory training group (n= 17, nine boys, mean age = 54 months) or to the inhibition training group (n= 18, nine boys, mean age = 58 months), which involved children completing five specific tasks that are linked to the three fundamental forms of inhibition: inhibition of a prepotent motor response (go/no-go paradigm) (Trommer, Hoeppner, Lorber, & Armstrong, 1988); stopping of an on-going response (stop-signal paradigm) (Logan & Cowan, 1984), and interference control (flanker test) (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999). All children at the third preschool formed the active control group (n=14, seven boys, mean age =58 months) and the fourth preschool formed the passive control group (n=16, seven boys, mean age = 60 months). All analyses were conducted controlling for age. None of the children had received a psychiatric diagnosis and none of them met the symptom criteria of ADHD, according to parents or teacher ratings on the ADHD Rating Scale- IV (DuPaul, Power, Anastopoulous, & Reid, 1998) (Thorell et al., 2009).

For five weeks, children in the two training groups and the active control group played computer games for 15 minutes each day that they attended preschool (Thorell et al., 2009). Children in the training group played games that were specifically designed to improve either visuo-spatial working memory or inhibitory control. Participants in the active control group played commercially available games that were selected, based on their low impact on WM and inhibitory control. Reinforcement was provided at the end of each training week and a larger gift was provided upon completing the posttests. Continuous feedback was provided to the children during the training. The mean number of training days for the working memory training group was 23 days (SD=2.5), 23 days (SD= 2.8) for the inhibitory group, and 22 for the active control group (SD=3.2).

Unlike the previous studies, eight different pre- and post- tests were administered to the subjects to examine various measures of EF directly, including looking at interference control, response inhibition, visuo-spatial working memory, verbal working memory, auditory attention, visual attention, problem solving, and response speed. The groups did not differ on any of the measures collected at pre-test. The experimenter who conducted the pre- and post-testing was blind to the assignment of each child. The order of the laboratory tests was randomized and in the same order for pre- and post-test sessions. In reviewing the results, the researchers found that typically developing pre-school children demonstrated improvement in working memory on all trained tasks. They also demonstrated training effects on non-trained tests of spatial and verbal working memory, as well as improvement in attentional processes after participating in cognitive training (Thorell, Lingdqvist, Nutley, Gunilla, & Klinberg, 2009).

When examining the effects of the training, the active control group was compared with the passive control group, using one-way analyses of covariance (ANCOVAs) with the difference scores between pre- and post-test measures as dependent variables and age as co-variants. Because no significant effects were found on any of the measures, the two control groups were combined in all subsequent analyses. No significant improvement relative to the control groups on tasks measuring working memory or attention was found. Planned comparisons showed that for both types of working memory, the working memory group showed significantly larger improvement over time, compared with the control group. The effect size for the comparison between the working memory and the control groups was large both for spatial and for verbal working memory. Significant improvement on working memory was not found within the inhibition group over time. The effect of spatial and verbal working memory was small when comparing the inhibition group and the control groups. Participants trained on the inhibition tasks showed improvement over time on two of the three trained task paradigms, go/no-go tasks, which measures response inhibition and the flanker test, a measurement of interference control (Thorell et al., 2009).

In summary, it was suggested by the researchers that training in one skill transferred to other related executive functioning skills. Unlike the previous research, which also looked at the verbal domain of WM, Thorell et al. (2009) examined only visual-spatial training. The results found, however, that there was a transfer effect of visuo-spatial training to the verbal domain of working memory. This finding supports neuroscience research suggesting that areas of the brain linked with working memory are activated regardless of the type of stimuli being held in working memory (Curtis & D'Esposito, 2003; Hautzel et al., 2002; Klingberg, 1998). The training effects on the inhibitory control tasks were not significant either for commission errors on the go/no-go task or for the errors on the Stroop test. In comparing the effects of the training of working memory and inhibition, it could be suggested that cognitive processes or functions vary in how easily they can be improved through training. The working memory group was found to improve significantly over time, when compared with the control group on inhibitory control tasks, but the inhibition group did not. Effect sizes were in the medium range for the comparisons between the working memory group and the controls and small for the comparison between the controls and the inhibition groups (Thorell et al., 2009). The authors concluded that the significant effects of working memory training as part of early intervention programming for individuals with deficits warrants additional research when considering the implications such interventions could have in improving children's outcomes.

Adding to research on computerized training in other populations, Van der Molen et al. (2010) examined the effectiveness of a computerized working memory training on memory, response inhibition, fluid intelligence, scholastic abilities and the recall of stories in adolescents with mild to borderline intellectual disabilities (M- BID; I Q Scores 55-85) receiving special education services. This model, called "Old Yellow," is a specific computerized program based on the working memory task ,"Odd-one-out", involving a sequence of three similar looking figures shown on the computer screen. Two of the figures are identical and the other one is slightly different. A total of 95 adolescents living in the Netherlands with mild to borderline intellectual disabilities were randomly assigned to one of three training groups: to one adaptive to the child's program in WM, to a non-adaptive WM training group, or to a control group. The results found that verbal short-term memory improved significantly from pre- to post-testing in the group who received the adaptive training, when compared with the control group. These treatment effects were also maintained at the 10-week follow-up period. Both the adaptive and non-adaptive WM training groups were found to have higher scores at follow-up than at post-intervention on visual STM, arithmetic and story recall, when compared with the control condition. Additionally, the non-adaptive training group showed a significant increase in visuo-spatial WM capacity. These findings were again promising when considering its use with individuals receiving special education services. It was found that WM can be effectively trained in individuals with mild to borderline intellectual abilities (Van der Molen et al., 2010).

One research team examined the impact that computerized working memory training would have on adolescents who were born at extremely low birth rates (Lohaugen et al, 2011). The decision to work with this particular population was related to concerns found in the research that brain lesions such as focal and diffuse periventricular leukomalcia, often seen in preterm children, have impacted these individuals' abilities to perform more complex functions such as arithmetic and attention. Also, early disturbance in cerebral cortical development has been suggested as having a negative impact on working memory functions in preterm children. The researchers were investigating whether or not the working memory training may prove to be an effective intervention to address the cognitive and academic needs of individuals with Extremely Low Birth Weight (ELBW). The study consisted of inviting 34 adolescents born in 1992 to 1993, aged 14 to 16 years old, with extremely low birth rate (ELBW) and admitted to the neonatal intensive care unit (NICU) at St. Olav's University Hospital in Norway. Eight consented to the study. Two of the individuals did not complete the training and thus were excluded, leaving 16 ELBW participants (11 girls). The mean gestational age of these individuals was 25.8 weeks (SD, 1.8 weeks), with a mean birthrate of 778 grams (standard deviation, 118 grams). One boy and one girl had cerebral palsy and two participants had mildly reduced hearing. Four ELBW adolescents did not return for the 6-month follow-up visit.

A control group included 19 age-matched term-born adolescents (six girls) without learning disabilities with full scale IQ score >80. Seven of these participants were recruited from local schools and 12 subjects were recruited from a group of neonates that were in the NICU during the same time period as at the participants born with ELBW. These particular individuals were admitted to the NICU within the first two days of their lives for issues with transitional clinical problems (grunting, lethargy) and discharged within 72 hours after birth as healthy babies with no diagnosis. Two of the control participants did not return for the 6-month follow-up visit. Additionally, eleven age-matched healthy, term- born control subjects that did not train,to evaluate the practice effect of performing repeated working memory task were recruited.

Baseline evaluations were conducted to assess for the participants' intellectual abilities, using the Wechsler Intelligence Scale for Children-Third version (Kaufman, 1994). The results were standardized, using Scandinavian age-appropriate norms. The groups were dichotomized into two groups of subjects with IQ>80 and <80 to examine training effect differences on working memory because individuals with IQs below 80 have been included in previous research (Klingberg et al., 2005).

Participants in this study were trained in the home setting, with a family member overseeing the daily performances of the participants. Training consisted of using the Cogmed RM program for 30 to 40 minutes a day for 5 days. A trained psychologist served as the coach and contacted the family via telephone once a week to provide feedback and motivational support based on the training data for the 5 days.

Outcome measures in this study included the Cogmed training index. Non-trained working memory tasks were assessed with neuropsychologist tests of verbal (digit span, letter number sequencing) and visual (spatial span) working memory. Lohaugen et al. (2011) reported that there were no standardized Norwegian memory tests available for adolescents; therefore, the generalization effect of the working memory training in learning and remembering verbal material was examined using the Wechsler Memory Scale-III (Wechsler,1997). Raw score data were used because the test was not standardized for adolescents. These assessments were administered prior to the training, immediately after the training, and after 6 months. The ADHD rating scale-IV was completed by the individual's mother before and after the training period (DuPaul et al., 1998).

The results indicated that individuals in the ELBW group had lower full, verbal, and performance IQ scores on three of the four IQ indices (verbal comprehension, working memory, and perceptual organization) than the control subjects. There were no significant differences found on the processing speed index and no significant differences in the full IQ between the trained (IQ=100) and non-trained (IQ=102) control group. In examining the index scores, it was found that the ELBW did demonstrate a significantly lower start index, but after training there were no differences in the groups.

On the non-trained tasks, both ELBW and the control participants demonstrated improvement from baseline on tasks measuring visual and verbal working memory immediately after the training and at the 6-month follow-up assessment. No differences on any tests were found between time point 2 and time point 3 (i.e. six month follow-up visit). In examining the subgroups and based on IQ scores above 80 and below 80, both groups of students improved performance on the assessments with the exception of the digit span forward test for individuals with the low IQ and the letter-number sequencing total score for individuals with IQ above 80.

The results of the verbal learning tasks also indicated that both groups improved their scores. Delayed memory of a word list was the only verbal tasks in which no improvement was noted. The ELBW group improved their scores immediately after the training on the ability to remember an oral story, to learn an oral story after the first reading and to remember and recognize an oral story. These improvements remained until six months after the training with the exception of the memory of an oral story. The ability to learn an oral story after a second reading did improve. No statistical differences were found between time 2 and time 3 for individuals in the ELBW group. Control subjects improved their scores on three of the verbal learning tasks immediately after the training and on five of the seven tasks when comparing results at the 6-month follow-up assessment to baseline. Five of the seven tasks were also found to improve from time point 2 to time point 3. When analyzing the repeated measures analysis for all three time points, the results were essentially the same on the non-trained working memory task and the verbal learning tasks (Lohaugen et al., 2011).

In analyzing the results on the ADHD-Rating scale, parents reported higher total ADHD-rating scale scores in the ELBW group than in trained control groups. They also scored higher on the hyperactivity/impulsivity score. When adjusting for socio-economic status and sex, the total ADHD rating scale score was not different. The ELBW group had significantly lower ADHD-total scores and inattention scores than before the training. No significant differences were observed on the hyperactivity/ impulsivity score. No changes were observed in the control subjects after training.

When examining practice effects, there were no significant differences found between baseline and the 6-week follow-up results seen in the non-trained control group. These results support previous research indicating that it is unlikely that the improvement seen in working memory is related to practice effects on these particular types of tasks (Basso et al., 2002;Spreen & Strauss, 2006).

In summarizing the results of the study by Lohaugen and colleagues (2011), one main finding is that the children with ELBW improved their performance on trained and non-trained working memory tasks after participating in a computerized working memory training program. Another interesting finding is that individuals with low IQ also benefited significantly from the training. Third, the individuals with ELBW demonstrated improvement in working memory to a level comparable with the control group participating in the training. Additionally, the participants demonstrated a generalizing effect on verbal learning, which is a skill that is linked to academic achievement. Last, the researchers indicated in their findings that the learning and memory tasks in the ELBW group remained stable 6 months following the intervention.

One of the strengths of this research is that the participants were administered a variety of neuropsychological processes to measure transfer effects. Also, to address questions regarding re-test effects, a group of individuals not participating in the training were assessed multiple times with the assessments and found there was limited practice effects on these tasks. One area that could not be ruled out when examining the positive improvement is the attention that the subjects received from parents and coaches, which could have contributed to increased motivation. Another limitation of this study is that there was uneven distribution of the sexes in the two study groups and because of the limited number of participants, the researchers were not able to stratify the data based on gender; however, including sex as a covariate did not change the overall results.

A significant variable in this study, one that holds significance for future research is the inclusion of subjects with IQs below 80. This particular study indicates that individuals with lower ability levels also could benefit from the computerized working memory training program. This is particularly noted as an important group to include because they are likely to exhibit significant deficits in working memory and executive functioning skills.

In summarizing the research presented in this literature review of computerized training, the results are promising when considering the impact it may have on children with deficits in attention and working memory. Groups of individuals found to have such deficits include those diagnosed with ADHD and children with learning disabilities. Although several positive outcomes were derived from the collection of studies reviewed in this chapter, there are also notable limitations that need to be considered in future research on computerized training in individuals with co-occurring conditions of learning disabilities and ADHD. As part of this design, the researcher attempted to address some of these issues by conducting post-intervention assessments at 4-week and 4-month follow-up sessions that included examining near-transfer and far-transfer effects on various cognitive processes linked with memory and learning, academic achievement; fluid reasoning; and behavior, as rated by teachers and parents.

Administering these assessments prior to the intervention and at the 4-week post-training and 4-month post training mark, the researcher examined the confounding data regarding the particular memory and learning skills being specifically trained by the program. Additionally, the data were used to corroborate with other research regarding the particular deficits linked with children with ADHD and math disabilities. The data collected from the Conners 3 (Conners, 2009), BRIEF (Gioia et al., 2000), and DSM-IV Rating Scale (Cogmed America, 2007) were examined to assist in analyzing the impact of behavior and attention in the school setting. Guiding this research is the Functional Working Memory Model of ADHD (Kofler, Rapport, Bolden, & Altro, 2008), based on the Baddeley's Model of Working Memory (Baddeley, 2007) described below.

Conceptual Frameworks for Study

In examining the achievement difficulties experienced by children and adolescents with ADHD, it has become increasingly apparent that incorporating behavioral interventions and strategies into the classroom is not having a significant impact in improving their learning outcomes. Through this review of the literature, there is growing support that school districts must become more cognizant of the neuropsychological processes affecting the success in learning by students with disabilities and must examine interventions that may truly lead to improving their academic success. In choosing the conceptual framework for this research, the focus began by examining the work of several theorists who have attempted to explain the complex neuropsychological processes that result in the presentation of symptoms in individuals with ADHD. As described previously, two such models include the behavioral inhibition model proposed by Barkley (2006) and the functional working memory model of ADHD, emerging from ongoing research by Rapport et al. (2008). Because the primary objective of this research was to address the gap in interventions for children with ADHD and math difficulties, specific cognitive processes linked with math achievement was examined. In summarizing the research on executive functioning and math, working memory and attention were two of the particular constructs that emerged. Based on this finding, the framework underlying this research involved conceptualizing ADHD from a neuropsychological perspective by examining models of working memory.

The primary conceptual framework for this study was the Functional Working Memory Model of ADHD (Kofler, Rapport, Bolden, & Altro, 2008). Because this particular model is based on Baddeley's Model of Working Memory, it is important to begin with an overview of this model (Baddeley, 2007). It is also important to consider that Baddeley's Model of Working Memory is one of the most well-researched and frequently cited theories on working memory in the literature (Kofler et al., 2008). Through the process of examining the specific neuropsychological processes linked with working memory, it will provide the theoretical framework necessary to examine the effectiveness of a computerized program designed to train working memory, but will also assess its short-term and long-term treatment effects on academic achievement, inattention, behavioral symptoms, various memory processes, and fluid reasoning in children and adolescents with math difficulties and ADHD.

Baddeley's Model of Working Memory

In reviewing the existing theoretical models of ADHD and related executive functioning domains, one specific domain that has gained interest in the research on

ADHD and learning is working memory (Barkley, 1997, 2006; Nigg, 2001; Semurd-Clinkeman, Pliszka, & Liotti, 2008). Although theories of memory can be traced from the beginning of modern psychology, it is only in more recent history that more intricate models of working memory have emerged (Dehn, 2008). There are several models of working memory in the literature at this time. Some have more empirical support (Baddeley, 2007), but others are fairly abstract and difficult to test (i.e., neural node network model) (Kofler et al., 2008). Two important aspects of working memory that are consistently described in WM models are how much working memory can hold and how efficiently it can be used (Miyake & Shah, 1999).

One model that has received substantial research in more recent years was initially proposed by two British psychologists, Baddeley and Hitch (1974). In years following their original theory, this model of working memory has evolved to become known as Baddeley's model (2007). This multi-component conceptual model of working memory serves as the basis of this study because of its extensive research that provides compelling support for its basic tenets and for its useful conduit for examining an array of working memory mechanisms and processes (Kofler, Rapport, Bolden, & Altro, 2008). Within this model, working memory has been defined as "a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks such as comprehension, learning, and reasoning (Baddeley, 1986, p. 34)." Baddeley and Hitch's (1974) original multifaceted model was designed as hierarchical in nature with the central executive serving as the top-level, domain-free factor that oversees various subcomponents or storage systems, the phonological loop and visuospatial-sketchpad (Dehn, 2008). These passive systems are used for temporary storage of verbal information and visual-spatial information. The central executive is a flexible system responsible for the control and regulation of various cognitive processes. Specifically, it is believed to regulate working memory by directing attention, guiding the flow of information, coordinating the execution of two or more tasks at once, and interacting with long-term memory (Baddley, 2000). The central executive is theorized to shift between tasks or retrieval strategies and is involved in the processes of selective attention and inhibition. It is also believed to bind information from a number of sources into coherent episodes through its coordination with the slave systems (Baddeley & Logie, 1999; Baddeley, 2002; Swanson & Beebe-Frankenberger, 2004). The Episodic Buffer has been added since Baddeley and Hitch's original conceptualization of the model (Baddeley, 2007). Each of the specific components is described in figure 2.1in further detail.

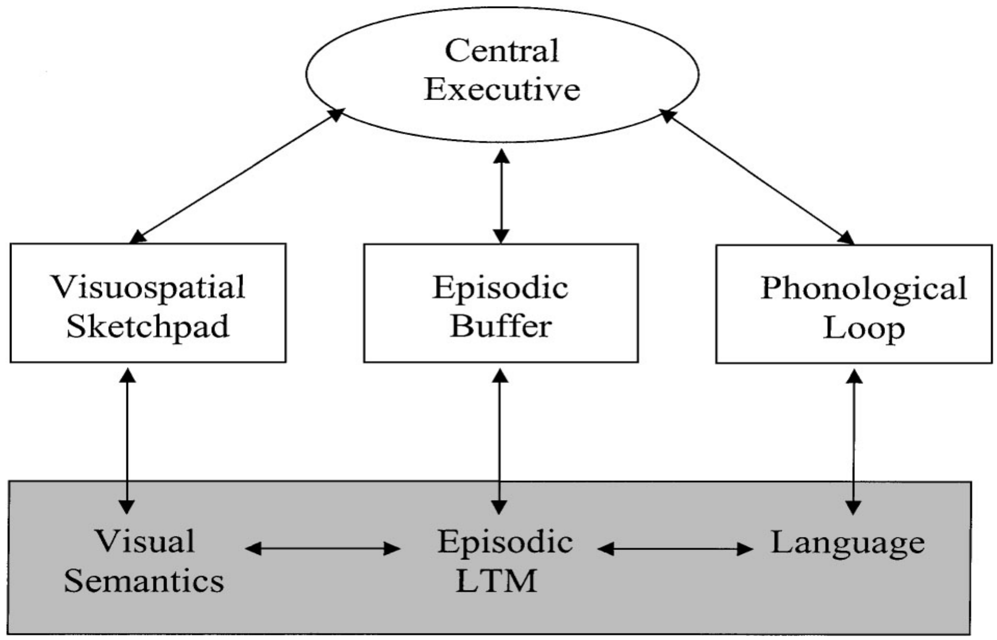

Figure 2.1

Baddeley's Model of Working Memory (Baddeley, 2007)

Central executive. The central executive, which is often considered the core of working memory, is the unit held to be responsible for controlling the three subsystems and for regulating and coordinating all of the cognitive processes linked with working memory (Baddeley, 2003b; Dehn, 2008; Torgesen, 1996). The central executive can be compared to an executive board from which it manages processes such as such as attention, selection of strategies, and the integration of information from various sources. It is believed to be activated when there is a demand to perform multiple cognitive or dual-processing tasks by helping the individual simultaneously process and store information (Dehn, 2008; Savage, Cornish, Manly, & Hollis, 2006; Tronsky, 2005). In the academic setting, the central executive is involved any time information needs to be transformed or manipulated, such as in completing mental arithmetic (Dehn, 2008). Baddeley (1986; 1996b, 2003b, 2006) has over the years described several core functions performed by the central executive to include the following: " a) selective attention, the ability to focus attention on relevant information while inhibiting disruptive effects of irrelevant information; b) switching, the capacity to coordinate multiple concurrent cognitive activities, c) selecting and executing plans and flexible strategies; d) the capacity to allocate resources to other subsystems of working memory, and e) the capacity to retrieve, hold, and manipulate information that is temporarily activated from long-term memory" (Dehn, 2008, p. 23). Deficits in the central executive are also described as linked functionally to inattention (Kofler et al., 2009) and hyperactive behaviors (Alderson et al., 2010; Rapport et al., 2009).

Researchers, Miyake, Friedman, Emerson, Witzki, Howerter, and Wager (2000,) identified three focused and related central executive functions through their examination of Baddeley's model. These three specific functions are inhibition, switching, and updating. Inhibition is described as the person's ability to attend to one stimulus while screening and suppressing information that is not pertinent to the task. Switching, also referred to as shifting, entails the process of alternating between different sets, tasks, and operations. Updating is a continuous process of revising older information with newer, more relevant information (Dehn, 2008; Swanson, Howard, & Saez, 2006). In addition to controlling working memory, Baddeley (1986) hypothesized that the central executive also plays a significant role as a supervisory attentional system responsible for the control, regulation and monitoring of complex cognitive processes. Additionally, the central executive has a relationship with the activation, retrieval and manipulation of long-term memory and is involved the conscious encoding of information into long-term memory (Baddeley, 1996; Dehn, 2008).

Phonological loop. The phonological loop, originally referred to as the articulatory loop, is conceptualized as the component of WM that is responsible for holding verbal information in the mind (Baddeley, 1986, 2003; Baddeley, Gathercole, & Papagno, 1998; Dehn, 2008). Baddeley divided this loop into two subcomponents: a subvocal, articulatory rehearsal process and a temporary, passive phonological input store (Dehn, 2008). Information that is presented orally to the listener gains immediate, direct, and automatic access to the phonological loop where it is briefly stored in a phonological form (Hitch, 1990; Logie, 1996; Dehn, 2008). This information is transformed within the phonological loop into phonological codes which includes aspects of the acoustic, temporal, and sequential properties of verbal stimulus (Gilliam & Van Kleeck, 1996; Dehn, 2008). It is believed that these phonological codes are matched with previously exciting phonemic codes and words stored in long-term memory. Additionally, they are linked with meaningful representations, thus facilitating higher level processing of verbal information such as putting words together to form an idea (Dehn, 2008).

Unless action is performed to preserve this phonologically coded information within a two second period or less, this information will not hold in this subsystem (Baddeley, 1986; Hulme & Mackenzie, 1992; Dehn, 2008). After two seconds, the retention of verbal information appears to depend on rehearsal or repetition of the information. To help explain this concept, it is valuable to look at the phonological loop as a type of an audio tape recorder with a limited length of recording time. The information is recorded in the order in which it is perceived and will decay or be recorded over unless a type of activity is performed to rehearse this information. It is also important to consider that the amount of storage on this phonological loop is dependent on the time it takes to articulate it (Dehn, 2008). Research examining verbal memory has found that the recall of short, one-syllable words consistently shows better recall than longer words, based on the assumption that longer words take longer to articulate, thus taking up more storage on the phonological loop (Dehn, 2008; Baddelely, 2003). Baddeley (1986) and Hulme and Mackenzie (1992) found that subjects can recall as much information as they can articulate within that 2 second period. If a person's speech rate is two words per second, for example, then his or her memory span will be approximately four words. This finding is also important to acknowledge when considering that subvocal rehearsal rate is thought to be consistent with overt speech rate (Dehn, 2008). Based on this research, the capacity of the phonological loop has been defined as: words held in loop = the length of the loop x speech rate (Hulme & Mackenzie, 1992, Dehn, 2008, p. 16). Although there is evidence supporting the relationship between word length and articulatory rehearsal speed with verbal short-term memory span, other influences, such as prior knowledge, have been found to affect performance within this slave system (Dehn, 2008).

Visuospatial sketchpad. The visuospatial sketchpad is the part of the working memory system held to be responsible for the short-term storage of visual and spatial information. Similar to the phonological loop, the visuospatial sketchpad is further divided into two systems, the visual cache and the inner scribe. The visual cache is a passive visual subsystem which stores static visual information or representations (i.e., colors and shapes). The inner scribe, or spatial subsystem is an active rehearsal system which allows the individual to attend to sequential locations such as motion and direction (Baddeley, 2006, 2007; Dehn, 2008). It also plays an important role in the generation and manipulation of mental images (Baddeley, 2006; Dehn, 2008). Additionally, the visuospatial sketchpad is believed primarily to maintain spatial or patterned stimuli and has been linked with the control and production of physical movement (Logie, 1996; Dehn, 2008). It is believed that eye movement, manipulation of the image, or some form of visual mnemonic become involved in the refreshment of the visual trace of the stimuli (Baddeley, 1986; Baddeley, 2007).

Regarding the rate of forgetting, decay in the temporary storage area appears to be similar to that of phonological processing, because the memory is short-lived, with the visual short-term storage system being limited to about three or four objects within a few seconds (Dehn, 2008). Generally, the rate of forgetting appears to be related to the complexity of the stimuli and the length of time the stimulus is viewed (Baddeley, 1986). The spatial component of the visuospatial sketchpad serves to update dynamic information as well as to refresh the decaying information in the visual cache. In relation to academic concerns, this system plays an important function in reading by allowing an individual to encode printed letters and words visually while maintaining a visuo-spatial frame of reference. The reader is then capable of backtracking and keeping his or her place within the text (Baddeley, 1986; Dehn, 2008). Research on the visuospatial sketchpad suggests that it is a system better suited for holistic processing and the phonological loop is more closely linked to sequential processing; however, most individuals verbally recode their visuospatial input. The visuospatial sketchpad is also believed to rely more heavily on the central executive components than on phonological storage (Gathercole & Pickering, 2000; Dehn, 2008).

Episodic buffer. Baddeley (2000, 2007) extended the model by adding the episodic buffer as a slave system responsible for linking information across domains. This includes integrating units of visual, spatial, and verbal information into a particular time sequence, such as the memory of a story. This component of working memory is also believed to have links to long term memory and semantic memory (Baddeley, 2000; Swanson, Jerman, & Zheng, 2008). Further research needs to be conducted on the episodic buffer, in particular, because many of its functions still appear to be unclear. It is unknown, for example, whether other constructs such as the various domains of attention are part of the system or whether they are performed by separate cognitive systems (Bull & Scerif, 2001).

Functional Working Memory Model of ADHD

The framework for this study was the Functional Working Memory Model of ADHD (Kofler et al., 2008). Within this model, Kofler, Rapport, Bolden, and Altro (2008) view working memory as a core, causal cognitive process responsible for ADHD; behavioral inhibition deficits are considered by-products of working memory deficits. Kofler and colleagues (2008) describe inhibition as a by-product because it is dependent on the individual's ability to register environment stimuli. In other words, information has to be activated in working memory before a decision can be made to register the information (Rapport, Chung, Shore, & Isaacs, 2001). Additionally, deficits in working memory are presumed to account for secondary features such as hyperactivity, inattention, and impulsivity. Associated features and outcomes include impairment in the following areas: cognitive test performance, academic achievement, social skills, organizational skills, classroom deportment, and delay aversion (Kofler et al., 2008). These features include those concerns frequently reported by parents and teachers when describing children with ADHD. These include issues with disorganization, inattention, poor social skills, delay aversion, hyperactivity, and impulsivity. These specific deficits affect children with ADHD to varying degrees across various domains. Performance on cognitive tests is directly impacted by working memory processes and academic achievement reflects the cumulative effects of poor working memory (Kofler et al., 2008).

In summary, the conceptual framework of this study was selected, based on the hypothesis that working memory is the primary deficit of ADHD; this also provides a rationale to explain the co-morbidity of learning difficulties and ADHD due to the role that working memory also has on achievement. Throughout this literature review, a case has been presented to demonstrate that a neuropsychological relationship exists between the subtypes of ADHD and poor math achievement. The challenges in assessing working memory and differentiating it from other cognitive processes such as attention were also discussed and were considered in the design of this study. Despite the difficulty in differentiating among the various cognitive processes linked with working memory, there is research to suggest that computerized cognitive training programs, such as CogMed (Klingberg et al., 2002), are promising interventions to address the needs of children with ADHD and memory and learning difficulties. Because there is relatively limited research about computerized cognitive training in children with disabilities in the public school system, the goal of this study was to address this gap and to build on the questions that have been raised when reviewing the existing research data.

CHAPTER 3: METHODS

Methods

This research utilized a quasi-experimental design to assess the effectiveness of a computerized cognitive training program with a coaching component on children with co-morbid ADHD and math difficulties by comparing pre- and post-assessments on trained and untrained tasks of memory and learning, fluid reasoning, and academic achievement ,as measured by individually administered standardized assessments. Benchmark assessments were not able to be used because of changes made by the district in the universal screeners used at different grade levels. To assess for treatment effects on behavioral symptoms of ADHD, data were also collected from the following behavioral rating forms: the Behavior Rating Inventory of Executive (BRIEF) (Gioia et al., 2000); DSM-IV Training Evaluation (Cogmed America Inc., 2007); and the Conners 3rd edition (Conners, 2009). Post-tests were administered at 4 weeks and 4 months after the completion the Cogmed working Memory training. As part of a pilot program, this research also investigated a new tool, the Cogmed Progress Indicator, that was developed by Cogmed Systems to illustrate the effects gained from the training in a more direct and objective manner. A set of tasks were designed to be performed five times throughout the training, with the first session being conducted on the first day of training. The coach and end user were able to track the progress and receive a clear report of the training effects at the end of the training period (Cogmed Systems, 2012).

Research Design

Design. This research involved a quantitative quasi-experimental design to assess the effectiveness of a computerized cognitive training program. Specifically, it involved a pre-test, 4 week post-test, and 4 month follow-up post-test study without a control group to assess the effectiveness of the intervention; this was done with a purposive sample of individuals receiving special education services. This study also served as a pilot to examine further the user's progress on non-trained memory tasks using the tool, Cogmed Progress Indicator (CPI), developed by Cogmed Systems (2012) and incorporated into the training.

Epistemology. This study utilized a quantitative, quasi-experimental design to evaluate whether or not the implementation of a computerized cognitive training program had a significant effect on achievement, on selected cognitive processes, and on observed behaviors on a purposive sample of individuals identified with a disability. Specifically, the data derived from the sample were examined to assess the effectiveness of the computerized cognitive training on children identified with math difficulties and ADHD, or on individuals who present with ADHD symptoms when not formally diagnosed. This study served as a pilot to examine further the transfer effects on non-trained tasks through a new measurement designed by Cogmed Systems called the Cogmed Progress Indicator (CPI), incorporated into the training program.

Through the use of statistical analyses, quantitative research allowed the researcher to address the research questions by either accepting or rejecting the hypotheses raised regarding the effectiveness of the proposed intervention and examining the relationship between variables (Neuman, 2003). Two of the most important goals of this quantitative study were to evaluate if the implementation of a computerized cognitive training program would improve the participants' achievement and specific cognitive processes as measured by various standardized instruments. Another important goal was to assess if the training contributed to decreasing the presentation of ADHD symptoms when compared with pre-test standardized behavioral assessment tools. A quantitative approach in this study was more appropriate than a qualitative approach because it provided the data necessary to effectively assess the participants' levels of improvement on various measures of performance.

A quasi-experimental design was selected because this study was designed to address the specific learning needs of a targeted group of participants, specifically those currently receiving special education services who were struggling in math and experiencing concurrent concerns with the symptoms linked with ADHD. Because the intervention targeted specific learning needs of students within a school setting, a randomized sample was not practical, particularly because the study was implemented within the school day when schedules have little flexibility. The quasi-experimental design allowed for an estimate of true experimental design under conditions in which the manipulation of specific and significant variables cannot be adjusted because it is in a classical experimental design (Creswell, 2008; Neuman, 2003). Quasi-experimental designs are desirable in the school setting, which does assist in understanding more clearly the relationship between interventions and effectiveness (Neuman, 2003).

Generally, there are risks in using a quasi-experimental design, particularly, because it can be susceptible to the internal validity threat of selection (Trochim, 2001). An additional concern in this study is that the participants selected most likely differed in myriad ways such as in their history of interventions, families' educational backgrounds, participation in tutoring services outside of school, and background knowledge. Incorporating pre-tests helped address some of these issues at the beginning of the study by selecting students with similar needs. Another concern relates to maturation of the individuals from the time the study began to the conclusion of the research period, which spanned about 6 months. Although all students were assessed within the same time period, the likelihood existed that participants within the pre-adolescent and adolescent time frame did tend to mature at different developmental rates.

Research Questions and Hypotheses

Research questions. Questions that were examined using quantitative research methodology include the following:

1. Do the participants show significant improvement on the trained tasks over the intervention training period when implemented in the school day,

as measured by index improvement scores collected by the training software program?

2. Do the participants show significant improvement over the intervention period on untrained tasks when implemented in the school day, as measured by the Cogmed Processing Index (CPI) collected by the training software program?

3. Does the training result in near-transfer and far-transfer effects on different tasks of memory and learning, as measured by the WRAML2 at 4 weeks and 4 months following the conclusion of the training?

4. Does the training improve far-transfer effects in the area of fluid intelligence, as measured by standardized assessments at 4 weeks and 4 months after the completion of the training?

5. Does the training result in far-transfer effects in the area of math, as measured by standardized achievement test at 4 weeks and 4 months after the conclusion of the training?

6. Does the program improve executive functioning skills, as measured by the BRIEF rating scale as measured at 4 weeks and at 4 months after the completion of the training?

7. Does the program reduce the frequency of inattention and hyperactivity symptoms in the classroom and home, as rated by teachers and parents as measured at 4 weeks and at 4 months using standardized tools after the completion of the intervention?

Hypotheses. The following hypotheses were generated for this study.

1. Participants will make gains on the trained tasks from the computerized training program administered during the school day, as measured by index improvement scores calculated by the training software program.

2. Participants will demonstrate gains on non-trained tasks, as measured by the Cogmed Process Indicator as piloted in this study.

3. Participants will make near transfer and far transfer gains in memory performance, as measured by the WRAML-2 when assessed at 4 weeks and 4 months after the completion of the training.

4. Participants will demonstrate far-transfer effects, as measured by significant improvement on fluid reasoning tasks when comparing pre-test assessments with post-test conducted 4-weeks and 4 months after the completion of the training.

5. School-aged students ranging from the ages of 9 to 18 years of age with ADHD and math difficulties (25^{th} percentile rank on individually

administered achievement tests prior to intervention) and/or performance below grade level on local/statement assessments participating in the computerized training program will show significant growth in their math performance, as measured by individually administered pre and post achievement tests and benchmark assessments.

6. Participants will demonstrate significant improvement on executive functioning skills when comparing pre-test assessments with post-test assessments conducted at 4 week and 4-months after the completion of the training.
7. Teachers' ratings of inattention and hyperactivity will be rated significantly lower at 4 weeks and 4 months after the completion of the training, when compared with the ratings gathered at baseline.

Setting

The setting was a computer room, located in a quiet place in each of the school buildings, which is used primarily for computerized assessments. Each student used the same laptop station each day; the station included headphones and an external mouse to ensure compliance with the standardized procedures established by the developers of the Cogmed Working Memory training program. The laptops were also placed in front of a wall, thus eliminating any possible visual distractions. Training occurred consistently, at the same time of the day during the duration of the training.

Participants

Participants in this study included individuals ranging in age from 11 to 18, enrolled in a rural school district located in South Central PA. The total school district enrollment was appropriately 3,200. The district has three elementary schools, one middle school, and one high school. A purposive sample was used; the individuals selected for this study were those who had been identified as having a disability, based on IDEA and state guidelines. The targeted sample was aimed specifically at those with math difficulties, who were identified with one of the subtypes of ADHD or who displayed clinically significant behaviors linked with ADHD. Because of the demographics of the school, all of the participants in the study were Caucasian. The purposive sample included students from the 5th grade to the 12th grade. There were 11 females and 14 males who completed the minimum of 20 intervention sessions within the two-month time. Two students were in the 5th grade, three in the 6th grade, five in the 7th grade, ten in the 8th grade, one in the 10th grade, and two in the 11th grade. Nineteen of the individuals were identified as students with a specific learning disability and four had the primary diagnosis of Other Health Impairment based on their diagnosis of ADHD. Each of the individuals has had a diagnosis of ADHD at some point since entering school. Twelve of the students were currently on medications for treatment. Five of the remaining students were treated with medication at one point, but had not been on medication for at least the previous six months. Information from the school's health records and from parents indicated that the remaining six students were never on medication to treat their ADHD symptoms. There is also a probability that a percentage of students would meet the criteria to be considered economically disadvantage; approximately 30% of the entire student population receives free and reduced lunch. Because of the school's guidelines on issues of privacy and protection of students' rights, specific questions regarding each one's particular socioeconomic status was not asked. Additional details regarding the inclusion and exclusion criteria of the participants selected for this study is listed under procedures.

Criteria for inclusion of participants. Inclusion criteria for this study were those in the school setting receiving special education services. The initial list of participants for consideration in this study was generated from the special education data base listing individuals identified with OHI. The examiner also reviewed files of students who had been diagnosed with ADHD, but may have been identified for special education for other disabilities such as specific learning disabilities, speech and language impairment, or emotional disturbance. It is important to note that careful consideration was taken into account when examining the inclusion of all students in the study, particularly those with emotional disturbances to ensure that they do not have any significant mental health concerns that would exclude them from participating in the intervention.

The researcher conducted a review of the records to confirm whether or not these individuals had been formally diagnosed by a physician or psychologist as having

ADHD. Students who had been identified in the evaluation report as presenting with symptoms within the clinically significant range, but who had not been formally diagnosed with ADHD, were included in the initial list of potential participants. Additional names were also generated from special education teachers and other school personnel; these were students identified with a disability, who demonstrated symptoms that are linked with ADHD or whose health records or other reports indicated diagnosis of ADHD.

From this generated list of individuals, additional reviews of records were conducted to assess the students' current levels of achievement and to review exclusion criteria. Because one of the purposes of this study was to examine the co-occurrence of ADHD and math difficulties, students included in this study were individuals who have demonstrated below grade level achievement in math as found on state and local benchmark assessments (Basic or Below Basic/ or below 25th percentile) and/or found to have standardized scores below the 25th percentile rank in subtests that measure math skills in at least one of the following areas: numerical operations/math calculations, problem-solving, math fluency, and/or math composites. Participants who met these criteria were included in this study regardless of their levels of academic performance in other areas, such as reading. Final selection of the participants included those who had schedules that permitted them to participate in the intervention at the prescribed level of intensity. This entailed collaborating with administration, school counselors, and teachers regarding schedule changes.

Exclusion criteria. Exclusion criteria included: a) fulfilling criteria of diagnosis of clinically significant oppositional defiant disorder and/or conduct disorder (with T-scores within the Clinically Significant range on assessment tools derived from pre-intervention assessment or as generated from history such as psychiatric evaluation and official reports of involvement in the law), Autism Syndrome, Asperger's syndrome, or depression; b) history of seizures during the previous 2 years; and 3) IQ or General Ability Index (GAI) falling below the standard score of 80. The General Ability Index was presented as an option for those individuals who demonstrated significant weaknesses in the areas of working memory or processing speed with the standard scores on the Verbal Comprehension Index and Perceptual Reasoning Index greater than 80. This list of exclusion criterion included, at the minimum, the exclusion criterion established by Cogmed America (2007).

Treatment, Instrumentation, and Materials

A variety of materials were used to collect data on the participants' levels of achievement, working memory skills and related constructs, behavioral/emotional symptoms, and fluid reasoning. A review of the participants' records included collecting data on their performance on benchmark assessments. There were challenges in obtaining several points of data on some of the benchmark assessments because during the intervention period, the school made a transition to another benchmark assessment as part of a pilot program. Specifically, Measure of Academic Progress (MAP) assessments were previously being used to assess benchmark skills in math. During the year of the intervention, the district transferred to a method of assessment in the winter months, thus three data points were not able to be collected on each of the participants. Additionally, the high school students were not required to participate in benchmark assessments because of their involvement in a state assessment test needed for graduation.

Data collection to assess for the presentation of various symptoms linked with ADHD and executive functioning skills included using established instruments developed by Cogmed America (2007) and two standardized behavioral/emotions surveys: the Conners 3 Edition (Conners 3; Conners, 2009); and the Behavioral Rating Inventory of Executive Functioning (BRIEF). The BRIEF (Gioia et al., 2000), and the Conners 3 (Conners, 2009) were completed by a different teacher of each student. Parents were also provided the instruments, but they either they did not return the form to the school or missed questions on the tool that prevented the scales from being calculated. The Conners 3 Self-Report form (Conners 3 SR) (Conners, 2009) was given to each participant to complete. To assess for working memory skills and the effects that training has on related constructs of memory and learning, the WRAML-2(Sheslow & Adams, 2003) was administered as pre-test and post-test measurements at 4 weeks and 4 months after the completion of the training. A series of subtests from the Woodcock-Johnson III Normative Update Achievement tests and Cognitive Tests were administered (McGrew et al., 2007). Additional data were also collected from a structured interview format designed by Cogmed America (2007), which helped guide the coaching sessions in finding out the individuals' strengths, needs, goals, and frustrations.. Demographic information was collected during the parent interview and included information about medical history, psychopharmalogical treatment, social history, and parents' educational history.

Treatment.

Cogmed RM. Students participated in the program, Cogmed RM, which was developed by Cogmed Systems, out of Stockholm, Sweden (www.cogmed.com) (Klingberg et al., 2002). Cogmed RM is a software based program reported to improve working memory and designed for children and adolescents. It was designed to consist of 25 sessions with training sessions taking 30-45 minutes to complete. The software contains several exercises that vary automatically during the training period. The participant completes one exercise at a time until all of the exercises have been completed. Each of the exercises must be completed in order to finish the training for that session. The difficulty level of the training is adjusted automatically and follows the user's capacity. Upon the conclusion of the exercise, the participant is provided with a reward game to play called RoboRacing. As the students progressed through the training they were provided a Cogmed Training Index Score to measure their progress on the tasks, when compared with baseline. An extreme outlier was removed from the data base to conduct a paired-sample t-test on the Cogmed Progress Indicator to determine this analysis for a sample size of 22. The mean increase of 22 participants was found to be 27.87.

Cogmed Progress Indicator. As part of a pilot study, the participants in this study also participated in additional exercises integrated with the working memory training program to measure training improvement called the Cogmed Progress Indicator (CPI). Cogmed Systems reported that the CPI is designed to complement the currently used training index. The CPI consists of a set of tasks to be performed five times; these are distributed throughout the training (the first session being on the first day). The outcome was referred to as progress and was used to provide feedback to the user, as well as to the coach, to examine the transference of training effects to non-trained tasks. Baseline scores were reported as zero percent with all subsequent measurement points compared with the baseline. The coaches and users were able to track the progress and received a clear report of the training effects at the end of the training period. The CPI tasks were reported as not being able to be separated from the training; however their performance was mandatory when cued to do so in order to proceed to the next training session.

As reported by Cogmed Systems, the progress indicator consisted of three tasks, one that measured working memory directly and two that measured related abilities: following instructions and arithmetic. The tasks were selected, based on research findings reporting training effects on specific tests (Holmes et al., 2009, Bergman Nutley et al., 2011). The working memory task "Shapes" was therefore derived from one of the visuo-spatial working memory tests included in the Automated Working Memory Assessment battery (Alloway, 2007), the Odd One Out. “The following instructions” task was based on a paper and pencil test developed by Gathercole et al. (2008). The math task was developed by Cogmed Systems and consists of math problems with two or three terms either to add or to subtract as quickly as possible, followed by selecting the correct answer from four options. This “speeded math challenge” requires the user to solve as many problems as possible in one minute.

According to Cogmed Systems (2012), the CPI underwent substantial piloting in Sweden obtaining test- retest data (five measurement points without training) from 350 individuals between the ages of six and 15. The math challenge is presented to everyone at the baseline measuring point (regardless of age or math ability) and if no more than 30% correct answers are obtained, this task did not appear in the following sessions.

The reliability of the tasks have been tested and correlations between the first two time points and the % of improvements seen across all five time points without any training are listed in Table 3.1. These effects were not subtracted from each individual’s gains in the CPI but were provided to give an estimate on how much of the gain could be explained by the fact that the CPI is performed five times.

Table 3.1

Table of test-retest average of the Cogmed Progress Indicator (CPI) across time

Task on CPI	*N*	*r* (T1-T2)	test-retest % average T1-T5
Following instructions	301	0.53	1%
Shapes	305	0.70	4%
Math	268	0.88	5%

T=time point

An examination of the data collected on the Cogmed Progress Indictor (CPI) in this study indicated that the scale used to measure progress on each of the non-trained tasks was changed between the first group of participants and the second group of participants. In consulting with the staff that manages the software of the working memory intervention program and the measurements of the CPI, it was indicated that the technical aspects were changed in a manner that did not allow the data to be converted into similar meaningful measurements. Also, due to some difficulty in logging in and time constraints, not all students completed each of the assessments as scheduled in the training program. Because of the low number of individuals in each group, one option to measure progress on the untrained tasks was to utilize the percentages generated by the intervention training program in order to measure changes in performance from the baseline measurement to each of the computer generated assessments administered at the beginning of the 10th, 15th, 20th, and 25th session.

The percent change on the untrained task from baseline to the particular assessment period was used in the statistical analyses listed in this section. The specific results are listed in the Results. The following Tables indicate the mean and standard deviations of the CPI assessments for group one and group two used to measure working memory, following directions, and math skills.

Table 3.2 lists the total mean score of the ten participants from group one on the non-trained tasks calculated using the CPI assessments in the area of working memory.

Table 3.2

Mean score and standard deviation of group of students from group 1 who participated in the CPI computerized assessment on working memory

Variable	N	Mean	Standard Deviation
Working Memory Baseline Assessment	12	430.83	89.41
Working Memory Session 10 Assessment	14	364.64	91.51
Working Memory Session 15	13	424.23	65.41

Assessment			
Working Memory Session 20 Assessment	14	430.00	107.94
Working Memory Session 25 Assessment	7	401.43	105.70

Table 3.3 lists the total mean score of students from the second group of participants on the CPI computerized assessment in working memory.

Table 3.3

Mean score and standard deviation of group of students from group 2 who participated in the CPI computerized assessment

Variable	N	Mean	Standard Deviation
Working Memory Baseline Assessment	9	4.26	0.96
Working Memory Session 10 Assessment	9	4.73	1.40
Working Memory Session 15 Assessment	9	4.46	1.28

Working Memory Session 20 Assessment	9	4.62	1.24
Working Memory Session 25 Assessment	8	4.49	1.19

Table 3.4 and Table 3.5 report the mean score and standard deviation of scores derived from the computerized working memory assessment on following directions. Table 3.4 lists the mean score and standard deviation of students from group 1 and Table 3.5 provides the mean and standard deviation of students from group 2.

Table 3.4

Mean score and standard deviation of mean data on from group 1 participants on the CPI computerized assessment on following directions

CPI Variable	N	Mean	Standard Deviation
Following Directions Baseline Assessment	13	351.15	78.24
Following Directions Session 10 Assessment	13	351.54	107.17
Following Directions Session 15	13	345.00	101.71

Assessment			
Following Directions Session 20 Assessment	14	339.00	93.67
Following Directions Session 25 Assessment	7	335.00	117.65

Table 3.5

Mean score and standard deviation of mean data on group 2 participants on the CPI computerized assessment on following directions

Variable	Mean	Standard Deviation
Following Directions Baseline Assessment	3.43	0.76
Following Directions Session 10 Assessment	4.00	0.68
Following Directions Session 15 Assessment	3.67	1.40
Following Directions Session 20 Assessment	4.04	1.02

Following Directions Session 25 Assessment	3.78	1.53

Note. N=9.

Table 3.6 and Table 3.7 report the mean score and standard deviation of scores derived from the computerized working memory assessment on math challenge. Table 3.6 lists the mean score and standard deviation of students from group 1 and Table 3.7 provides the mean and standard deviation of students from group 2.

Table 3.6

Mean score and standard deviation of group of students from group 1 who participated in the CPI computerized assessment on math challenge

CPI Variable	N	Mean	Standard Deviation
Math Challenge Baseline Assessment	14	137.57	42.48
Math Challenge Session 10 Assessment	12	152.64	50.14
Math Challenge Session 15 Assessment	14	139.36	58.40
Math Challenge Session 20 Assessment	14	151.43	58.31
Math Challenge Session 25 Assessment	10	170.50	66.64

Table 3.7

Mean score and standard deviation of group of students from group 2 who participated in the CPI computerized assessment on math challenge

CPI Variable	N	Mean	Standard Deviation
Math Challenge Baseline Assessment	15	58.67	57.82
Math Challenge Session 10 Assessment	12	49.87	65.20
Math Challenge Session 15 Assessment	9	16.93	5.16
Math Challenge Session 20 Assessment	9	16.79	5.35
Math Challenge Session 25 Assessment	10	36.65	63.23

Individualized assessments. Participants were administered a series of pre- and post-intervention assessments within two weeks prior to the start date of the training program, 4 weeks after the completion of the training, and 4 months following the treatment. The BRIEF (Gioia et al., 2000), Conners 3 (Conners, 2009), and the DSM-IV checklist (Cogmed America, 2007) were administered as a pre-test assessment and at the 4 week and 4 month post-test assessment period. The participants met with the researcher to complete the Conners 3 Self-Report (Conners, 2009) during the first session of each assessment phase. Subtests from The WJ-III NU Tests of Achievement (McGrew et al., 2007) were used to assess math achievement during the second session of each of these three assessment periods. To alleviate the impact of practice effects on the measurements, three different forms of the assessment were used: Form A, Form B, and Form C.

The fluid reasoning subtests of the Woodcock Johnson III NU Tests of Cognitive Abilities (McGrew et al., 2007) were also administered during the second session of the pretest, 4 week, and 4 month post-test phase. The WRAML-2 (Sheslow & Adams, 2003) was administered during the third session of each assessment phase. When interpreting the data, practice effects on the results of the WRAML2 (Sheslow & Adams, 2003) and WJ-III Cog NU (McGrew et al., 2007) need to be considered. The WJ-III NU Tests of Achievement (McGrew et al., 2007) and WRAML-2 (Sheslow & Adams, 2003) batteries were administered in the order as they were standardized.

Conners 3rd Edition (Conners 3) (Conners, 2009). The Conners 3 (Conners, 2009) was administered as a pre-test and post-test assessment to assist in assessing treatment effects 4 weeks following the training and 4 months after completion of the training. The Conners 3(Conners, 2009) is a tool designed to assess ADHD and its most common comorbid problems and disorders in youth aged six to 18 years of age. The Conners 3 Parent, Teacher, and Self-Report are full-length forms that closely parallel each other and include every Conners 3 item. These forms assess the following content scales; *DSM-IV-TR* Symptom Scale, the Conners 3 ADHD Index (Conners-3 AI), and the Conners 3 Global Index (Conners 3GI). It also includes assessing Anxiety and

Depression Screening items, Several Conduct critical items, the validity scale, and questions regarding level of impairment (Conners, 2009). These particular areas are not included in the statistical analyses in this study.

In examining the development of the Conners 3 (Conners, 2009), the normative sample of an extended collection data project resulted in the collection of ratings from 1200 parents and 1200 teachers (about youth six to 18 years), and 1,000 youth (ages eight to 18). The composition of the normative sample represented the general U.S. population in terms of ethnicity, race, gender, and age (according to the 2000 U.S. Census). Diversity was noted in terms of the parents' educational levels and geographic locations of the sample (Conners, 2009). Separate norms are provided in one-year intervals (17- and 18- year old norms are grouped together). Data were also collected from several clinical populations.

Raw scores on the Conners 3 are converted to standard scores for meaningful interpretation (Conners, 2009). All T-scores have a mean of 50 and a standard deviation of 10. High T-scores, raw scores, and percentile ranks indicate a greater number or higher frequency of reported concerns. The general guideline is that T-scores greater than or equal to 70 demonstrate a "Very Elevated" Score. This guideline suggests that individual presents with many more concerns than are typically observed, when compared with peers of the same age and gender. An elevated score falls within the T-score range of 65 to 69; High Average score falls within the 60 to 64 range; Average score is within the 40 to 59 range, and T-scores below 40 fall within the Low range. Conners (2009) noted that these guidelines serve as approximations and should not be considered as absolute rules.

Reliability. Gallant et al. (2007) and Gallant (2008) assessed the reliability of the Conners 3, which is reported in the Conners 3 (2009) technical manual. Results generated from the reliability analyses revealed that the Conners 3 forms have high levels of internal consistency (assessed with Cronbach's alpha) for the majority of the scales. On the Conners 3- Parent Content scales, the mean Cronbach's Alpha was a .91 (ranging from .85 to .94). In measuring the internal consistency on the *DSM-IV-TR* Symptom Scale, the mean Cronbach's Alpha was .90 (ranging from .83 to .93) and on the Validity scales, the mean Cronbach's Alpha scale was .67 (ranging from .59 to .75) (Conners, 2009).

On the Conners 3 –Teacher Content scale, the mean Cronbach's Alpha was .94 (ranging from .92 to .97). On the *DSM-IV-TR* Symptom Scale, the mean Cronbach's alpha was .90 (ranging from .77 to .95), and mean Cronbach's Alpha scale was .72 (ranging from .70 to .73) on the Validity Scales.

Reliability assessments on the Conners 3- Self-Report Content scales found the mean Cronbach's alpha was .88 (ranging from .84 to .92) and .85 (ranging from .81 to .89) as the mean Cronbach's alpha for the *DSM-IV-TR* Symptom Scale (Conners, 2009).

On the Validity Scale, the mean Cronbach's alpha was .56 (ranging from .50 to .62) (Conners, 2009).

When examining the Positive and Negative Impression scales for the three forms, weaker internal consistency was displayed when compared with the content scales and the *DSM-IV-TR* Symptom Scale Estimates. Conners (2009) indicated that these results could be influenced by the small number of items composing both of these scales because fewer numbers of items tend to lower the Cronbach's alpha (John & Benet-Martinez, 2000). Additionally, because of the manner in which the validity items were developed (i.e. items that are not typically endorsed), the items tended to have small variance; thus, the lack of variability attenuated the reliability estimates of the scale (Conners, 2009).

Test-retest reliability. Gallant (2008) assessed test-retest reliability estimates for the various Conners 3 scores over a 2- to 4- week interval, with a sample of 84 parents, 126 teachers, and 80 youth (Conners, 2009). Overall, test-retest reliability scores were found to be significant, thus indicating acceptable temporal stability. On the Parent Content scales, the mean adjusted test-retest correlation was .85 (ranging from .72 to .98) and the mean adjusted test-retest correlation from the *DSM-IV-TR* Symptom scales was .89 (ranging from .84 to .94). On the Teacher Content scale, the mean adjusted test-retest correlation was .85 (ranging from .78 to .90) and the mean adjusted test-retest correlation for the *DSM-IV-TR* Symptom scales was .85 (ranging from .83 to .87). On the Conners 3 –SR Content scales, the mean adjusted test-retest correlation was .79 (ranging from .75 to

.83) and the *DSM-IV-TR* symptoms scale was .76 (ranging from .71 to .83) (Conners, 2009). Consistency was also found between multiple parent and/or teacher ratings of the same child (inter-rater reliability; see technical manual for more specific information) (Conners, 2009).

Validity. Results of the Exploratory Factor Analysis (EFA) indicated that the factor structure of the Conners 3 revealed that the Conners 3-P and Conners-SR models had adequate fit. The Conners-3 T indices were found to be slightly lower (Conners, 2009).

Across-informant correlations. As reported in the technical manual, consistency (all *rs* significant, $p < .001$) was found between the different informants' ratings of the same youth across the Conners 3: mean parent to teacher $r = .60$ (ranging from .52 to .67), mean parent to youth $r =.56$ (ranging from .49 to .56), and mean teacher to youth $r =.48$ (ranging from .43 to .56).

Convergent and divergent validity. The Conners 3 scores were correlated with other measures of childhood psychopathology, including the Conners' Rating Scale Revised (CRS-R; Conners, 1997; N = 246), the Behavioral Assessment System for Children, Second Edition (BASC-2; Reynolds & Kamphaus, 2004; N =365), The Achenbach System of Empirically Based Assessment (ASEBA; Achenbach, 1991a, 1991b, 1991c, N=96), and the Behavioral Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000; N =181). In summary, the correlations were found to converge and diverge in a meaningful way. Scales that assessed similar constructs tended to be moderately to strongly intercorrelated; other scales that did not assess similar constructs had smaller intercorrelations (Conners, 2009).

*Discriminate validity***.** A series of analysis of covariance (ANCOVA) was conducted; these found that the means for the target clinical groups were significantly higher than the general population means and the means from the other clinical groups. Regarding the classification accuracy of the scores, the scale scores were reported as showing good mean on the overall classification rates (77.61 for the Conners 3-p, 75.59% for the Conners 3-T, and 72.92% for the Conners 3-SR) (Conners, 2009). More specific information can be found in the technical manual of the *Conners 3rd Edition Manual* (Conners, 2009).

Behavior Rating Inventory of Executive Functioning (BRIEF (Gioia et al., 2000). The Behavior Rating Inventory of Executive Functioning (BRIEF, Gioia et al., 2000) is a tool used to assess difficulties associated with executive functioning in the school setting. The BRIEF is an 86-item teacher and parent questionnaire that entails brief descriptions of behavior problems; on the questionnaire, the rater must indicate the frequency of the these behaviors . Responses are aggregated to form eight subscales, two summary index scores, and an overall general ability index. The eight subscales and what they measure are listed on Table3.8. T-scores (with population M=50, SD=10) are used to calculate each measure. The higher scores indicate more executive function problems with scores 1.5 SD above the mean (scores of 65 or greater) of potential clinical significance. The Metacognition Index is derived to include the scales of Working Memory, Initiate, Plan/Organize, Organization of Materials, and Monitor. The following is a summary of the behaviors being assessed on the eight subscales.

Table 3.8

Subscales of the Behavior Rating Inventory of Executive Functioning (BRIEF; Gioia et al., 2000)

Inhibit Scale	Measures the ability to control impulses and to stop one's behavior at the proper time.
Shift Scale	Assesses the ability to move freely from one situation, activity, or aspect of a problem to another as the situation demands; it also taps behaviors relating to transition and to the ability to solve problems in a flexible manner.
Emotional Control Scale	Relates to the ability modulate emotional responses appropriately.
Initiate Scale	Measures the ability to begin a task or activity and to generate ideas independently.
Working Memory	Measures the ability to hold information in mind for the purpose of completing an activity.
Plan/Organize	Assesses abilities to anticipate future events, set goals, develop appropriate steps ahead of time, carry out tasks in a systematic manner, and understand and communicate a main idea.
Organization of materials	Relates to one's ability to maintain relevant parts of the environment in an orderly manner.
Monitor Scale	Measures the ability to check work, assess performance, and

	to keep track of own and others' efforts.

Adapted from (Gioia et al. 2000).

Reliability. Both general clinical and normal data sets were used to examine internal consistency, interrater reliability, and test-retest reliability. To assess for interrater reliability, the Cronbach's (1951) alpha (α) was used. Internal consistency was high on both Parent and Teacher Forms of the BRIEF, ranging from .80 to .98 (Gioia, 2000). In assessing for interrater reliability, the correlations between parent and teacher raters were moderate for the normative group (overall *r*= .32). On two of the scales, there were notable differences between the parent and teachers ratings: Initiate *(r* =.18) and Organization of Materials (*r* =.15). The test designers noted that such differences may be attributed to differences in environmental structure between home and school, where prompting from teachers would assist students in beginning projects and in organizing materials (Gioia et al., 2000). Parents rated both boys and girls as having significantly more problems on all of the scales, when compared with teachers' ratings (Gioia et al., 2000).

Reliability studies show high test-retest reliability (Gioia, Isquith, Guy, & Kenworth, 2000). Test-retest reliability was examined both in clinical and in normative subsamples for the Parent Form and in a subsample of the normative sample for the Teacher Form (Gioia et al., 2000). The mean test-retest correlation across the clinical scales was .81 within the parent normative subsample (*n* = 54) across an average interval of 2 weeks. The test-retest correlations were .84 for the Behavioral Regulation Index, .88 for the Metacognition Index, and .81 for the Global Executive Composite. Test-retest correlations were strongest for the clinical scales on the Teacher Form (mean *r* =. 87; range = .83-.92) over an average 3.5-week interval. Test-retest correlations were .91 for the Global Executive Composite, .90 for the Metacognition Index, and .92 for the Behavioral Regulation Index. Little changes were found in T scores over the test-retest period (mean intervals =2 weeks for the Parent Form clinical subsample; 3 weeks for the Parent Form normative sample; and 3.5 weeks for the Teacher form normative subsample) (Gioia et al., 2000).

Content validity. Items were selected from clinical interviews with parents and teachers. An expert panel of 12 pediatric neuropsychologists independently assigned potential questionnaire items to a primary scale and, in some cases, to a secondary scale. Items were flagged when poor interrater agreement was found; however, these items were not immediately eliminated. As the scales were refined using item-total correlations, interrater agreement served as an external conceptual check. The majority of the items retained in the scales were found to have high interrater agreement, thus supporting that the item content within each scale adequately sampled the intended executive function domain. Gioia et al. (2000) reported that this finding supported the content validity of the BRIEF.

Construct validity. In order to assess the construct validity of the BRIEF, the multitrait-multimethod matrix, (Campbell & Fiske, 1959), was used to examine convergent and discriminant validity of the BRIEF. Because other instruments were not yet published that specifically measured executive functions, the BRIEF was compared with more general measures of behavioral functioning in children. Based on the presumption that executive functions influence behavior, certain scales within specific behavioral rating scales were hypothesized to correlate, or converge, with related BRIEF scales (Gioia et al., 2000). Scales and summary indexes of the BRIEF were correlated in assessing the construct validity in a variety of clinical samples. Measures of attention and behavioral functioning were compared, using in the following scales: The ADHD-Rating Scale-IV (ADHD-IV; DuPaul, Power, Anastopoulso, & Reid, 1998); Child Behavior Inventory (CBCL, Achenbach, 1991a); Teacher's Report Form (TRF, Achenbach, 1991a), Behavior Assessment System for Children (BASC) (Reynolds & Kamphaus, 1992), and Conners' Rating Scale (CRS; Conners, 1989). In summarizing the data, the correlational analyses found evidence of convergent and divergent validity for the Parent and Teacher forms of the BRIEF. Measures of Executive Function on the BRIEF were reported to correlate in an expected fashion with other measures of general behavioral functioning and less strongly or not at all, with measures of emotional functioning (Gioia et al., 2000). It should be noted that due to difficulty in assessing the patterns of relationships, correlational matrices were also recommended by the test developers (Gioia et al., 2000).

Exploratory factor analysis (EFA). Factor analyses conducted on the Parent and Teacher Forms supported a two-factor model. The Initiate, Working memory, Plan/Organize, Monitor, and Organization of materials scales were found to load consistently on one factor (Gioia et al., 2000). Combined together these scales defined a metacognitive problem-solving dimension. The Emotional Control, Shift, and Inhibit scales defined a behavioral regulation factor, which consistently loaded on a second factor. The Inhibit Scale had secondary loadings on both factors (Gioia et al., 2000). The two factors were found to demonstrate a moderate correlation with each other consistently, thus indicating a relationship between Metacognition and Behavioral Regulation (Gioia et al., 2000).

In examining the BRIEF Parent and Teacher Forms with a variety of clinical diagnostic samples, differing profiles of executive function were found. It was indicated by Gioia et al. (2000) that this supports the ability of the BRIEF to differentiate among clinical groups. Additionally, the Working memory and Inhibit Scales were found to exhibit predictive validity, sensitivity, and specificity for detecting the likely diagnosis of ADHD, Predominately Inattentive Type; ADHD, Combined Type, or no clinical diagnosis (Gioia et al., 2000).

Wide Range Assessment of Memory and Learning- Second Edition (WRAML-2) (Sheslow & Adams, 2003). Each participant in the treatment group was administered a series of subtests from the Wide Range Assessment of Memory and Learning- Second

Edition (WRAML2) (Sheslow & Adams, 2003) to assist in assessing transfer effects that the intervention may have on various aspects of memory and learning. This battery was administered by the researcher, a certified school psychologist and diplomate in school neuropsychology by the American Board of School Neuropsychology. The WRAML-2 is an individually administered test battery designed to assess memory ability. The battery comprises six core subtests that yield three Indexes: a Verbal Memory Index, a Visual Memory Index, and an Attention/Concentration Index. These three indices together form the General Memory Index. There are also two subtests that are reported by the test developer as explicitly focusing on Working Memory: Verbal Working Memory and Symbolic working Memory. These two Working Memory subtests scaled scores are combined to obtain the Working Memory Index. Index standard scores have a mean of 15 with a standard deviation of 15.

All core subtests of the WRAML-2 are developed to progress from easy to harder. Each subtest can be converted from raw scores to scaled scores with a mean of 10 and standard deviation of 3. The following is a list of the descriptions of the core indices and corresponding subtests.

Verbal memory index. To measure Verbal Memory, participants were administered the story memory and verbal learning subtests.

Story memory. Story memory is purported to assess auditory memory of extended, meaningful verbal material, which is linked with listening to conversations or classroom instruction, as well as reading text (Adams & Reynolds, 2009). After two stories are read to the participant, he or she is asked to recall parts of the story. Some of the information must be provided verbatim to give credit but other information can be paraphrased (gist).

Verbal learning subtest. This subtest is a list- learning task, designed to assess auditory memory of meaningful verbal information that is without context (Adams & Reynolds, 2009). The participant is provided with four trials to learn new, unrelated, common, single syllable words that are designed to reflect those skills that are tapped when trying initially to learn a list of items. The total number of words over the four trials constitute the subtest raw score (Sheslow & Adams, 2003).

Visual memory index. The following two subtests, Design Memory and Picture Memory, compose the Visual memory Index.

Design memory subtest. This subtest is used to assess short-term visual retention of information in which the participant is exposed to simple geometric shapes on a 4 X 6 card for 5 seconds and is then asked to redraw them in their proper locations after a 10-second delay. This subtest has been considered as having the most subjective scoring of the WRAML-2 subtests, but the test manual reports interrater reliability to be around .98 (Adams & Reynolds, 2009). Raw score is based on number of correctly recalled shapes and their relative positions across the five cards.

Picture memory subtest. The participant is shown a visually complex scene for 10 seconds. A similar alternate scene is shown and the participant is asked to identify the elements that have "been moved, changed, or added" (Sheslow & Adams, 2001). This subtest is designed to assess an individual 's ability to remember new and contextually related visual information that is similar to opportunities in which visual content is tapped; this might occur when passing by a billboard or remembering information from a room that was just visited (Adams & Reynolds, 2009). The raw score consists of the number of correctly identified changes across all four different "familiar" scenes that are presented to the examinee. Information gathered from the technical manual of the WRAML-2 (Sheslow & Adams, 2001) indicates that the attention-concentration scale has been linked with short-term memory and has the highest correlations with reading, math, and written language from the WJ-III tests of achievement.

Attention/Concentration Composite: The following two subtests, Finger Windows and Number Letter, compose the Attention Concentration Composite.

Finger windows subtest. This subtest has been reported to assess short-term memory of sequential and rote visual patterns, which is similar to being asked to recall a route found on a map (Adams & Reynolds, 2009). In this subtest, an 8 X11-inch plastic template with nine asymmetrically located holes or windows is used to measure the participant's ability to imitate a sequence presented by the examiner. Specifically, the participant is asked to imitate the sequence by placing his/her finger through the same window in the correct order (Adams & Reynolds, 2009; Sheslow & Adams, 2001). Level of performance is determined by the total number of correct sequences. Length of series can range from one window to nine windows (Adams & Reynolds, 2009; Sheslow & Adams, 2001).

Number letter subtest. This subtest is used to measure the ability to remember rote, sequential auditory information using the digit span format, but including both numbers and letters. It has been described as more difficult than digit-recall only because it requires the use of two symbol systems and it minimizes the use of the chunking strategy (Adams & Reynolds, 2009; Sheslow & Adams, 2003).

Working memory index. The following two subtests, Verbal Working Memory and Symbolic Working memory, are used to compose the Working Memory Index.

Verbal working memory: Participants between the ages of 9 through 13 years of age listen to a list of words, some of which are animals and some that are not. They are then asked to repeat all of the words, recalling the animal words first, followed by the non-animal words in any order. They are then asked to perform a second, but more difficult task. After hearing the list of animal and non-animal words, the participant is first asked to recall the animals in order of their typical size (smallest to largest), followed by all the non-animal words in any order. Individuals over the age of 14 years begin with the more difficult task first. The participant is then asked to recall the presented animal words in size order, following by the non-animal words also in the order of relative size (Adams & Reynolds, 2009; Sheslow & Adams, 2003).

Symbolic working memory. Symbolic working memory is a subtest described by Dehn (2008) as measuring executive working memory. Adams and Reynolds (2009) describe this subtest as measuring verbal and visual working memory. In contrast to the Verbal Working Memory task, this subtest is completed by the individual using a non-verbal response (Adams & Reynolds, 2009). This subtest requires the participant to actively "manipulate" information presented prior to recall. Similar to the Verbal Working Memory subtest, participants are challenged at two levels of difficulty. At the first level, the examiner randomly dictates a series of numbers and asks the participants to point out the numbers dictated in correct numerical order on the Number Stimulus Card. For the second task, a random number-letter series is dictated and the participant is asked to point out the dictated numbers, followed by the dictated letters in correct order on the Number-Alphabet Stimulus card (Adams & Reynolds, 2009; Sheslow & Adams, 2001). This subtest also represents a measurement of near-transfer effects because it resembles a task being trained in the intervention, but is different in presentation and design (Bergman Nutley et al., 2011).

Delay recall and recognition subtests. The WRAML-2 also contains several subtests to measure delay recall and recognition. These subtests were administered as part of the standardization of the instrument; although the data generated from the results would be beneficial to examine, the statistical analysis is directed towards the primary core tests of the WRAML-2 with the addition of the Working Memory Composite because the process of examining retention and memory entails further analysis of related cognitive processes linked with learning and memory outside of those addressed in this study. Delay recall subtests are included as additional tools to assess for retention of memory or of forgetting. Two recall subtests found in the WRAML-2 include Story Memory Delay Recall and Verbal Learning Delay Recall. By comparing the relative level of performance between immediate and delay recall formats, it provides an opportunity for the examiner to assess the extent of memory forgetfulness (Adams & Reynolds, 2009; Sheslow & Adams, 2003). Story Memory Recognition, Verbal learning recognition, design memory recognition, and picture memory recognition are additional subtests that will be administered to assess memory. The following is a summary of these additional subtests.

Story memory recall and recognition. At approximately 20 minutes after administration of the Story Memory subtest, the examinee is asked to retell as much as the story as possible. The Story Memory Recognition subtest is administered to assist in assessing whether the information is stored, but cannot be retrieved or is no longer stored. Using a multiple-choice format, three possible answers are offered. Only the items that were not recalled on the Story Memory Recall trial need to be queried (Adams & Reynolds, 2009; Sheslow & Adams, 2003). A General Recognition Index (mean = 100; SD =15) is derived from the four subtests using the recognition format: Story Memory Recognition; Design Memory Recognition; Picture Memory Recognition; and Verbal Learning Recognition (Adams & Reynolds, 2009; Sheslow & Adams, 2001).

Verbal learning recall and verbal learning recognition subtest. About 20 minutes after the administration of the Verbal learning subtest, the examinee is asked to recite the list of isolated words. Performance is expected to drop by one word, compared with Trial 4 of the immediate memory phase. Because of the difficulty in distinguishing between issues with memory retrieval and memory storage, this subtest also provides an opportunity for the examinee to respond with a "yes" or "no" regarding whether or not he or she thinks the word was on the list. Some of the incorrect words may be semantically similar or phonologically similar (Adams & Reynolds, 2009; Sheslow & Adams, 2003).

Design memory recognition subtest. Similar to the procedures described previously, the examinee is shown successive pages on which numerous designs appear and he or she is to determine whether he/ she saw the design that was on one of the cards shown during the original administration of the Design Memory subtests (Adams & Reynolds, 2009; Sheslow & Adams, 2003).

Picture memory recognition subtest. After approximately 15 to 20 minutes following the administration of the core Picture Memory subtest, the examinee reviews mini pictures and must determine whether or not the picture was part of a scene showed earlier in the session. Half of the scenes were shown earlier (Adams & Reynolds, 2009; Sheslow & Adams, 2003).

Demographic effects. The age related growth curve of the WRAML2 is steepest from age 5 to 9 years, with very little changes during adulthood (25 to 64 years). Declines were noted in individuals after 65 years of age (Sheslow & Adams, 2003).

Gender. Factor analyses and item bias did not show effects on gender (Sheslow & Adams, 2003; Strauss, Sherman, & Spreen, 2006).

Education. Factor analyses and item bias did not indicate any effects of education of WRAML2 performance (Sheslow & Adams, 2003).

Ethnicity. Elimination of bias was taken into consideration in the construction of the WRAML2 through item analysis and factor analyses, which were described in the manual. No effects of ethnicity on text structures were indicated (Strauss et al., 2006).

Reliability. Person and item separation indices culled from Rasch Item Analysis was used to assess the reliability of each subtest on the WRAML-2. Person separation reliabilities for the WRAML-2 core subtests range from .85 to .94. The optional subtests range from .56 to .93. Person separation reliabilities provide information about the capacity of the test to distinguish among a sample of persons, based on the total number of correct items (Sheslow & Adams, 2003). These statistics are consistent with other measures of internal consistency and, as such, estimate the amount of measurement error. The test designers report that the Verbal Leaning and Delay Recall subtests have too few items on the respective subtests to expect higher person separation reliabilities (Sheslow & Adams, 2003). Additionally, due to the nature of the recognition subtests, the tasks do not conform well to calculation of internal consistency. There are not enough hard items to yield a more normal distribution of scores due either to a limited ceiling or to the effect of guessing that is inherent in true/false tests (Sheslow & Adams, 2003).

Item separation reliabilities are calculated to determine how well the items define the specific variable being measured. Item separation reliabilities for the Core subtest were found to be either .99 or 1.00 and the range for the subtests is .90 to 1.00 (Sheslow & Adams, 2003; Strauss et al., 2006). The test developers conclude that the items on the subtests are sufficiently separated into a continuum from easy to hard that is complete and well-spaced (Sheslow & Adams, 2003).

Internal consistency. To assess the internal consistency for each of the subtests and indexes, the Cronbach's (1951) coefficient alpha was used. This statistic is considered to be a conservative estimate of a test's reliability and provides a lower bound value of internal consistency (Allen & Yen, 1979; Carmines & Zeller, 1979; Sheslow & Adams, 2001). The entire norm sample was used in the calculation, thus 80 individuals within each of the 15 respective anchor age groups was included. Alpha reliabilities are considered strong for the GMI and for the Screening Memory Index (Strauss et al., 2006). Median coefficients ranged from .86 to .93 with a median of .93 for the General Memory Index and Memory Screening Index. The alphas of the Core Indexes within the age groups were found to range from .82 to .96. The median alphas for the six Core subtests range from .81 to .92. Within the anchor age groups the coefficient alphas for the Core subtests range from .71 to .95. The coefficient alphas for the optional subtests of Verbal Working Memory, Symbolic Working Memory, Sound Symbol, Sentence Memory, Story Memory Delay Recall, Verbal Learning Delay Recall, and Sound Symbol Delay Recall ranged from .69 to .92 for the median coefficient alphas and a within-age-group range of .63 to .96. The median coefficient alpha for the Working Memory Index is .90 with a range of .85 to .94. Reliabilities were found to be less optimal for some of the recognition subtests (e.g., Design Recognition see Table 3.16).

Table 3.9

Coefficient Alpha Reliability for the WRAML2 Core Indexes, by Age group Proposed in this Investigation

Age Group	N	Verbal Memory Index	Visual Memory Index	Attention/ Concentration Index	General Memory Index
8-0 to 8-11	80	.91	.85	.83	.90
9-0 to 10-11	80	.91	.87	.88	.93
11-0 to 13-11	80	.90	.85	.87	.93
14-0 to 17-11	80	.92	.91	.91	.95

Table 3.10

Coefficient Alpha Reliability for the WRAML2 Core subtests, by Age Group Proposed in this Investigation

Age Group	Story Memory	Design Memory	Verbal Learning	Picture Memory	Finger Windows	Number Letter
8-0 to 8-11	.91	.88	.83	.72	.81	.80
9-0 to 10-11	.95	.84	.80	.83	.82	.84
11-0 to 13-11	.92	.86	.81	.78	.82	.88
14-0 to 17-11	.91	.91	.85	.83	.86	.86

Table 3.11

Coefficient Alpha Reliability for the WRAML2 Optional Subtests, Delay Recall Subtests, and Working Memory Index, by Age Group Proposed in this Investigation

Age Group	Verbal Working Memory	Symbolic Working Memory	Story Memory Delay Recall	Verbal Learning Delay Recall	Working Memory Index
8-0 to 8-11	----	---	.92	.71	----
9-0 to 10-11	.85	.89	.96	.78	.92
11-0 to 13-11	.80	.85	.93	.78	.89
14-0 to 17-11	.82	.88	.92	.79	.91

Table 3.12

Coefficient Alpha Reliability for the WRAML2 Recognition Subtests and Recognition Indexes, by Age Group Proposed in this Investigation

Age Group	Story Recognition	Design Recognition	Picture Recognition	Verbal Learning Recognition	Verbal Recognition Index	Visual Recognition Index
8-0 to 8-11	.72	*.40*	*.48*	*.67*	*.79*	*.54*
9-0 to 9-11	.89	*.49*	*.52*	*.68*	*.87*	*.54*

11-0 to 13-11	.75	*.54*	*.53*	*.66*	*.83*	*.61*
14-0 to 17-11	.82	.68	.71	.70	.86	.78

Standard Error of Measurement (SEM). SEMs for the WRAML2 Index scores were described by Strauss et al. (2006) as respectable, with most falling between 4 and 6 points (i.e. GMI, Verbal Memory Index, Attention/Concentration Index, Memory Screening Index, Verbal Recognition Index, and Working Memory Index). On the Visual Recognition Index, the SEM is about 10 points, which translates into a large confidence interval. In other words, an individual with an obtained score of 100 has a 95% chance of his or her performance falling within the 80 to 120 range. Core subtests SEMS were found to be less than 1.7 scaled score points with the exception of Design Memory Recognition and Picture Memory Recognition, which were 2.3 and 2.1 points, respectively (Sheslow & Adams, 2003).

Test-retest reliability. Test-retest reliability refers to the stability or consistency of test scores from one testing session to another. The test designers noted inherent problems in measuring stability of a memory test because giving the test a second time provides an opportunity for learning and thus can spoil the stability measurement. To assess test-retest reliabilities, a sample of 142 individuals (mean age = 26.9; SD=24.0 years; range of 5 to 84 years) was selected with a nearly equal split by gender (53.5%

females and 46.5% males) and an equated representation of ethnicity, educational attainment, and geographic region. Each sample participant was administered all of the WRAML2 subtests a second time, with the median interval administration of 49 days (Sheslow & Adams, 2003). It is important to note, however, that the interval between the two testing sessions ranged from 14 to 401 days. The first testings showed average performances, with the average scaled score near 10 and the average index score near 100. The corrected stability correlations range from .53 to .85. The General Memory Index correlation between testing was .81. A learning effect was also noted with an average gain for the General Memory Index of 6.7 standard score points. Subtest gains ranged from 1.6 to .2 scaled score points. On the optional subtest and related indexes, the corrected correlations ranged from .47 to .80

Practice effects. An average gain of 6 to 7 points was found when examining practice effects on the WRAML2 (Strauss et al., 2006). The index gain ranged from 2.7 to 7.1 standard score points. The largest effect can be found for the Memory Screening Index (gain =8.1) and the smallest increase is for Attention/Concentration (gain =1.7). The scaled score increases ranged between negligible practice effects such as observed in Symbolic Working Memory (gain =0.2) to almost 2 scaled score point gains on Design Memory and Design Memory Recognition (Sheslow & Adams, 2003).

Table 3.13

Test-retest reliability for the WRAML2 Core Subtests and Indexes

Subtest/Index	N	First Testing Mean	First Testing SD	Second Testing Mean	Second testing SD	Gain*	r	Corrected r**
Story Memory	142	11.0	2.7	11.9	2.5	.9	.68	.75
Verbal Learning	142	9.7	3.0	10.9	3.1	1.2	.77	.78
Picture Memory	142	10.4	2.9	11.2	2.7	.8	.63	.65
Design Memory	142	10.8	3.2	12.3	.3	1.6	.59	.53
Finger Windows	142	9.4	3.3	9.6	3.3	.2	.69	.62
Number Letter	142	10.5	3.3	10.9	3.2	.4	.67	.60
Verbal Memory Index	142	101.3	13.6	107.6	13.3	6.3	.82	.85
Visual Memory Index	142	103.5	15.5	110.7	14.1	7.2	.69	.67
Attention/ Concentration Index	142	99.6	16.9	101.3	16.4	1.7	.75	.68
General Memory Index	142	102.8	14.3	110.8	13.0	8.1	.76	.78

*Gain =Second testing minus first testing

**Reliability coefficients were corrected for the variability of the norm group based on the standard deviation of the first testing using Guildford's (1954, p. 392) formula.

Table 3.14

Test-retest reliability for the WRAML2 Optional Subtests and Indexes

Subtest/ Index	N	First Testing Mean	First Testing SD	Second Testing Mean	Second testing SD	Gain*	*r*	Corrected *r***
Verbal Working Memory	105	10.6	3.1	11.4	2.9	.8	.77	.76
Symbolic Working Memory	102	9.7	3.3	9.9	3.0	.2	.73	.69
Story Memory Delay Recall	141	10.4	2.8	11.4	2.6	.9	.74	.78
Verbal Learning Delay Recall	142	9.2	2.9	9.9	3.2	.7	.72	.73
Story Memory Recognition	142	10.4	2.7	11.8	2.5	1.4	.52	.62
Design Memory Recognition	142	10.9	2.9	12.7	3.3	1.8	.47	.49
Picture Memory Recognition	142	10.5	3.2	10.8	3.3	.3	.53	.47
Verbal Learning Recognition	141	9.5	2.9	9.8	2.7	.3	.58	.59

Verbal Recognition Index	141	99.7	14.8	104.7	13.4	5.1	.63	.64
Visual Recognition Index	142	103.8	15.0	110.3	16.4	6.6	.60	.60
General Recognition Index	141	102.1	14.0	109.2	14.6	7.1	.66	.71
Working Memory Index	102	101.1	15.0	103.8	14.4	2.7	.80	.80

*Gain =Second testing minus first testing

**Reliability coefficients were corrected for the variability of the norm group based on the standard deviation of the first testing using Guildford's (1954, p. 392) formula.

*Interscorer reliability***.** Interscorer reliability was found to be high for the subtest requiring subjective judgment (e.g. Design Memory r =.98; Sheslow & Adams, 2003).

Validity. In revising the 1st edition of the WRAML, exhaustive test revisions were reported to include reviews by expert users, creation of a "tryout" battery, administration of the instrument to several hundred children and adults, analysis and refinement, and a full standardization process (Sheslow & Adams, 2003; Strauss et al., 2006). The core subtests of the WRMAL 2 were also evaluated for item bias with regard to gender and ethnicity. Further details can be found in the manual (Sheslow & Adams, 2003). Internal validity was assessed through investigation of item content, subtest intercorrelations, exploratory factor analysis, confirmatory factory analyses, and differential item functioning. External validity is addressed through correlations between the WRAML2 and other psychological tests and the investigations of a variety of clinical studies (Sheslow & Adams, 2003).

Intercorrelations of WRAML2 indexes and subtests. Most of the correlations among the subtests of the WRAML2 were significant at the .01 and shows a low to moderate relationship with the other subtests. Picture Memory had the lowest correlation with the other subtests; however, it did have a significant relationship with both Design Memory and Picture Memory Recognition. The test developers reported that this is consistent with the predicted factor structure. These correlations are based upon the entire standardization of 1200 for each index except for Working Memory. The *n* for correlations on the Working Memory Subtest is 880 because it can be given only to individuals nine years and older. Additional information regarding the intercorrelation between subtests can be found in the WRAML2 manual (Sheslow & Adams, 2003).

The intercorrelation among subtests also was found to vary by age. In children between the ages of five to eight years, the subtest intercorrelations support the Verbal Memory Index, with verbal subtests having moderate intercorrelations67 (*r* =.42). Intercorrelations found between the subtests used to derive the Attention/Concentration Index and between those of the Visual Memory Index were found to be modest (*r*= .26 and *r*= .19 respectively) (Sheslow & Adams, 2003; Strauss et al., 2006).

In individuals aged nine to adulthood, there appeared to be more homogeneity to the index scores. Verbal subtests (*r* =.51) and Working Memory Index (*r*=.62) correlated highly. It is also important to note that the correlations between subtests belonging to the Attention/Concentration Index and the Working Memory Index were also found to be within the moderate to high range (*r*=.39 to .57) (Sheslow & Adams, 2003; Strauss et al., 2006). Based on this finding, it was suggested that the two indices may not represent distinct cognitive domains (Strauss et al., 2006). Correlations on the visual subtests used to derive the Visual Memory Index in the older participants were also found to be respectable (e.g. r= .41 between Design Memory and Picture memory) (Sheslow & Adams, 2003; Strauss et al., 2006).

In comparing the correlation between the GMI and the Screening Battery, the test designers found it to be very high (*r*=.91). Less than 1 standard score point difference was found between index scores in the standardization sample (Sheslow & Adams, 2003; Strauss et al., 2006).

Exploratory Factor Analysis (EFA). The Confirmatory Factor Analyses (CFA) described by the test developers support the three-factor model as opposed to a two-factor model or a one-factor model of memory in which 3 factors would summarize data from 6 core subtests. It was predicted that there would be a verbal memory factor consisting of Story Memory and Verbal Learning; a visual memory factors consisting of Design Memory and Picture Memory, and an attention/concentration factor consisting of Finger Windows and Number Letter. To explore the three-factor model, several EFA's were conducted (Sheslow & Adams, 2003).

The first EFA was conducted with the entire sample of 1200 individuals. A principal components factor analysis was performed to test the predicted three-factor solution, using an oblique rotation. It was found that over 70% of the variance can be explained by the three factors with loadings consistent with the predicted factors. Five age groups were selected to further examine the three-factor model across ages: 5 to 10; 11 to 20; 21 to 40; 41 to 60; and 60 and up. The three-factor solution is supported in each of these investigations with about 20% of the variance contributed by each of the factors (Sheslow & Adams, 2001).

Among the six core subtests, Picture Memory and Number-Letter has the largest unique variance, which was reported as suggesting high subtest specificity (Sheslow & Adams, 2003). Consistency of the three factor solution was also discovered across age, gender, ethnicity and education (Sheslow & Adams, 2001; Strauss et al., 2006). By including the Working Memory subtest, a four-factor solution was yielded, but the high redundancy between the Attention/Concentration and Working Memory subtest need to be considered. A three factor solution was also found when investigating the research on the optional three subtests supporting the optional index scores (Working Memory, Verbal Recognition Index, and Visual Recognition Index; Sheslow & Adams, 2003; Strauss et al., 2006).

Correlations with other memory scales. The WRAML2 was correlated with other measures of memory, the Wechsler Memory Scale-III (WMS-III), the Children's

Memory Scale (CMS), the Test of Memory and Learning (TOMAL), the California Verbal Learning Test (CVLT), and the California Verbal Learning Test –II (CVLT-II) (Sheslow & Adams, 2003).

Correlation between the WMAML2 and CMS, conducted on 29 children, indicates that these tests measured similar constructs, but differed on two measures (Sheslow & Adams, 2003). One, the GMI showed a moderate correlation with the corresponding scale on the CMS (r =.49). It was found that the GMI correlated more highly with the Attention/Concentration Index on the CMS (r= .64), which was attributed to the distinction between the two tests. In other words, the WRAML includes Attention/Concentration in the calculation of the GMI (Sheslow & Adams, 2003; Strauss et al., 2006). Significant overlap was observed when comparing the attention/concentration factors (r =.58), but only a moderate overlap was found on the Verbal index scores (r =.58). Visual index scores were found to correlate only moderately (Sheslow & Adams, 2003; Strauss et al., 2006). It was founded that the WRAML2 Visual Index correlates more highly with the CMS Verbal Immediate Index and Attention/Concentration factors than the CMS Visual Index (r= .55 and r=.52, versus r= .37, respectively) (Sheslow & Adams, 2003; Strauss et al., 2006).

Regarding mean score differences, the Verbal Memory Index and the Attention/ Concentration Index were found to be around four to five points higher than the index scores on the corresponding subtests from the CMS (Verbal Immediate and

Attention/Concentration). The Visual Index was found to be within 1 point of each other and the GMI mean scores were less than 1 stand score point from each other (Sheslow & Adams, 2003).

In comparing the TOMAL with the WRAML2, the visual index score was found to be highly correlated with the Visual Memory Scores (*r* =. 58), but the TOMAL Verbal Memory Index was found to have a modest overall correlation with the WRAML2 Visual Memory score (*r* =.26). The TOMAL composite score was about six points higher, but the GMI and found to be highly related (*r* =.69) (Sheslow & Adams, 2003; Strauss et al., 2006).

Comparisons of the WMS-III with the GMI of the WRAML2 were found to be highly correlated in adults, based on a sample size of 79. The Working Memory Index was also found to be highly correlated in both assessment tools (*r* =.60 for both) (Sheslow & Adams, 2003; Strauss et al., 2006). In supporting the idea that Working Memory and Attention/concentration measure a similar construct, the Working Memory Index of the WMS-III was found to be highly related to the Attention/Concentration Index of the WRAML2. The verbal indices on both instruments were also found to be high (*r* =.66 for WMS-III Auditory Immediate and WRAML2 Verbal Memory). In contrast, the Visual Memory Index of the WRAML2 correlated moderately with the Visual Immediate Scale of the WMS-III (*r* =. 42) (Sheslow & Adams, 2003; Strauss et al., 2006). The Visual Memory Index was also found to have a moderate overlap with the verbal index of the WMS-III *(r* =.22 to .42). Overall, mean scores for the WMS-III was higher than the WRAML2 scores (see p. 131 of Sheslow & Adams, 2003; Strauss et al., 2006).

In examining the correlations between the CVLT/CVLT-II and the WRAML2, a high degree of association was found on the WRAML2 Verbal Memory score and the CVLT Trail 1 to 5. The Visual Memory Index was found to be only moderately correlated with the CVLT in participants. Sheslow and Adams (2003) indicate that this correlation provides support for the construct validity of the verbal/visual dichotomy in WRAML2 index scores (r=.64 and r=. 36, respectively) (Strauss et al., 2006).

WOODCOCK JOHNSON- Third Edition, Normative Update (WJ-III NU (McGrew et al., 2007). To assist in assessing for far-transfer effects of the computerized intervention, subtests from the WJ-III NU Tests of Achievement and WJ-III NU Tests of Cognitive Abilities was administered during pre-test and post-test sessions. The WJ III is based on Cattell-Horn-Carroll theory of cognitive abilities (CHC) theory (McGrew, 2005; McGrew & Woodcock 2001). To analyze items response data and construct the scales that compose the WJ III NU, the Rasch model was used (Rasch 1960; Wright 1968; 1977). This model was also reported in the technical manual as important in score interpretation (McGrew et al. 2007). The WJIII NU entails a recalculation of the normative data based on 2005 U.S. census statistics (U.S. Censure Bureau, 2005) and updated norm construction procedures for the Woodcock Johnson III (WJ III)

(Woodcock, McGrew, & Mather, 2001). The WJ IIII NU consists of two distinct, co-normed batteries: Woodcock Johnson III Tests of Cognitive Abilities (WJ III Cog), used to measure various combinations of general intellectual ability *(g*), broad and narrow cognitive abilities, and aspects of executive functioning (Woodcock, McGrew, &Mather, 2001); it also involves the Woodcock-Johnson IIII tests of Achievement (WJ III ACH) (Woodcock, McGrew, & Mather, 2001), which includes oral language and achievement tests in Forms A and B. The Woodcock-Johnson III Tests of Achievement Form C/Brief Battery (WJ III Form C/Brief Battery) (Woodcock, Schrank, Mather, & McGrew, 2007) is a third form, with nine achievement tests measuring the skills also assessed on the standard battery of Form A and Form B (McGrew, Schrank, & Woodcock, 2007).

Each of the tests in the WJIII NU is based on a single, nationally representative sample. Through the co-norming process, the developers report that it helped ensure that the batteries function together for an accurate and valid diagnostic system for assessing domain-specific skills with related cognitive abilities and also helped to assist in making score comparisons (McGrew et al., 2007).

Validity. In order to ensure validity of the instrument, the original WJIII sample was selected to represent the U. S. population from ages 24 months to 90 + years. Normative data were gathered from more than 8,800 participants in more than 100 geographically diverse communities in the United States. Using a stratified sampling design, individuals were randomly selected while controlling for 10 specific community and individual variables and 13 socio-economic status variables. The sample consisted of 1,143 preschool participants; 4,784 kindergarten through twelfth-grade participants; 1,165 college and university participants, and 1,843 adult participants. The WJ III NU provide age-based norms by month from ages 24 months to 90+ years and provides grade-based norms for kindergarten through 12th grade, for 2-year college, 4-year college, and graduate school. Continuous-year norms were used to yield normative data at 10 points in each grade (McGrew et al., 2007).

Within the technical manual, the authors discuss the cognitive processing requirements for each of the tests in the WJ III NU. This includes a review of CHC theory and related research in cognitive psychology. Through the use of updated pictographic patterns of growth and design among the broad abilities and areas of achievement, the average score changes consistent with development growth and decline of cognitive and achievement abilities across the life span was demonstrated (McGrew et al., 2007). Of the data preferences, assessments were also conducted on 3,478 individuals in 11 special populations to include individuals with specific learning disabilities, language disorders, head injuries, mental retardation, gifted abilities, ADHD, and those diagnosed with Autism Spectrum Disorders (McGrew et al., 2007).

Among the clinical populations investigated, individuals within the ADHD sample included those with Predominately Inattentive, Predominately Hyperactive-Impulsive, and Combined type of ADHD. Almost one-third of the sample (29.8%) also received a co-diagnosis of a specific learning disability. When examining both the children/adolescent and adult samples, Processing Speed was found to have a relatively low score; these groups also demonstrated relatively low scores in academic achievement (i.e. Brief Reading, Brief Math, Brief Writing, and Academic Knowledge) (McGrew et al., 2007). Those identified with math disorders were found to have lowest scores in the areas of fluid reasoning and long-term retrieval (McGrew et al., 2007). The authors noted that this finding supports research by Proctor, Floyd, and Shaver (2005), who found that individuals with math weaknesses also scored lower in Fluid Reasoning (Gf). When assessing the clusters in achievement and cognitive abilities with those individuals identified as having reading disabilities, the processing speed and short-term memory were found to be the lowest. Long-term retrieval was found to be a relatively low score for children and adolescents with reading disabilities. These findings were reported to support the research linking the role of processing speed, associative memory, and short-term memory with reading decoding skills (McGrew et al., 2007).

Reliability. Each of the WJ III tests across the age range of intended use, which included all norming participants tested at each technical age level, was calculated using reliability statistics. With the exception of the speeded test and tests with multiple-point scoring systems, the subtests were calculated using the split-half procedure. Split-half correlations entailed using data provided by even and odd test items (McGrew et al., 2007). Rasch analyses procedures were used to calculate the WJIII speeded test (Visual Matching, Retrieval Fluency, Decision Speed, Rapid Picture Naming, Pair Cancellation, Reading Fluency, Math Fluency, and Writing Fluency). A review of the median reliabilities reported for each of the WJ III NU tests of achievement showed strong reliabilities of .80 or higher (McGrew et al., 2007). It was recommended by McGrew et al. (2007) that although there are strong reliabilities for individual tests, the WJ III Cluster scores are the recommended scores for interpretation. Cluster scores, which are based on combinations of two or more tests, resulted in consistently higher reliabilities (McGrew et al., 2007). A review of the technical manner found that the median reliabilities for each cluster indicated that most are .90 or higher (McGrew et al., 2007).

Test-retest reliability. Two different test-retest studies were conducted, with the first study reporting correlations for 15 cognitive and achievement tests with retest intervals extending less than 1 year to 10 years, and the second study showing correlations for 17 achievement tests and 12 achievement clusters with a retest interval of 1 year. The total sample for the first study included 1,196 participants. The second study was based on a sample size of 457 participants ranging in age from 4 to 17 years. Overall, the test-retest reliabilities for all ages had a median retest reliability of .94. The findings support the reliability of the repeated measures across participants of different developmental levels (McGrew et al., 2007).

*Inter-rater reliability***.** Three of the achievement tests required a subjective evaluation of the subjects' responses, namely, Writing Samples, Writing Fluency, and Handwriting. For the Writing Fluency subtest, records of 35 participants at each level were drawn randomly from the norming data. The results of an inter-rater reliability study found a typical intercorrelation of .98 among the three ratings of a subject's production at each of the four levels (Grade 3, Grade 7, College, and Adult) (McGrew et al., 2007).

Woodcock Johnson- Third Edition, Normative Update (WJ-III NU) Tests of Cognitive Ability (McGrew et al., 2007). As part of this research, subtests identified to measure Fluid Reasoning *(Gf*) of the WJ IIII NU Tests of Cognitive Ability were administered. This includes one test from the standard battery, Test 5, Concept Formation, and Test 15 from the Extended Battery, Analysis and Synthesis. These two subtests are used to derive an Index score of Fluid Reasoning, described in the technical manual as a broad cognitive ability. Concept Formation is reported to measure the narrow CHC ability of index. Cognitive processes linked with this aspect of Fluid Reasoning include rule-based categorization, rule switching, and induction/interference. In this subtest, the subject must identify, categorize and determine rules from stimuli that are presented to them visually (drawings). The narrow CHC abilities linked with the Analysis/Synthesis tasks includes general sequential reasoning and quantitative reasoning. On these subtests, the subject analyzes puzzles (using symbolic formulations) to determine missing components (McGrew et al., 2007).

Woodcock- Johnson –Third Edition, Normative Update Tests of Achievement (WJ-III NU) (McGrew et al., 2007). The WJ III NU Tests of Achievement is part of a co-normed set of tests used for measuring academic achievement. The battery is used for individuals ages 2 to 90 and older. The following subtests were administered: Calculation, Math Fluency, and Applied problems. Cluster scores were derived from the corresponding subtests.

Broad math cluster: Calculation, Math Fluency, and Applied Problems.

Math calculation skills cluster: Calculation and Math Fluency

Brief math cluster: Applied Problems and Calculation.

Additional information about the technical aspects of the tests can be found in the Woodcock-Johnson III Normative Update Technical Manual (McGrew et al., 2007).

Data Collection

Individual assessments. The researcher met individually with each participant for three separate sessions during three different phases of the research: pre-test; post-test at 4 weeks, and post-test at 4 months, as described in the consent to assess their level of performance. Each session during each phase followed the same protocol to include administering the assessments in the manner in which they were standardized. The first session involved overseeing each student completing the Conners 3 (2009) Self-Report form. During the second session, the participant was administered subtests from the WJ-III NU Tests of Achievement Form A (pre-test), Form B (post-test at 4 weeks), or Form C (post-test at 4 months). The subtests were administered in the following order:

Calculation, Math Fluency, and Applied Problems. Following the administration of the WJ III NU Test of Achievement, the participant was administered two subtests of the WJ III NU Tests of Cognitive Ability reported to measure Fluid Reasoning (G*f*).: Concept Formation and Analysis and Synthesis. During the third session, the researcher administered subtests of the WRAML2 in the order in which it was standardized. Each testing session followed the same protocol, again noting that a different form was used when administering the WJ III NU Tests of Achievement (McGrew et al., 2007).

Parents and teachers of the participants were given the BRIEF (Gioia et al., 2000), the Conners 3 (Conners, 2009) Parent or Conners 3 Teacher Form (Conners, 2009), and the DSM-IV Rating Scale (Cogmed America, 2007) when parent consent forms to participate in the research were received by the researcher. These results were to be completed by each rater and returned to the researcher the week of the start-up session. A table of the assessments, including the time when they were administered is listed in Table 3.15.

Table 3.15

Table of Assessments for Pre-tests, Post-tests at 4 weeks, and Post-tests at 4-months

Session	Individualized Assessments	Parent/Teacher Behavioral Surveys
Pre-test Assessments Administered across 3 sessions	Session 1: Conners 3 (2009) Self-Report form Session 2: WJ-III NU Test of Achievement Form A: Calculation, Math Fluency, Applied Problems WJ III NU Tests of Cognitive Ability Concept Formation Analysis and Synthesis. Session 3: WRAML-2	BRIEF (Gioia et al, 2000) Parent or Teacher Conners 3 Teacher Form (Conners, 2009) DSM-IV Rating Scale (Cogmed America, 2007)
4-week Post-test Assessments	Session 1: Conners 3 (2009) Self-Report form Session 2: WJ-III NU Test of Achievement Form B, Calculation, Math Fluency, Applied Problems WJ III NU Tests of Cognitive Ability Concept Formation Analysis and Synthesis. Session 3: WRAML-2	BRIEF (Gioia et al, 2000) Parent or Teacher Conners 3 Teacher Form (Conners, 2009) DSM-IV Rating Scale (Cogmed America, 2007)

4-month Post-test Assessments	Session 1: Conners 3 (2009) Self-Report form Session 2: WJ-III NU Test of Achievement Form C Calculation, Math Fluency, Applied Problems WJ III NU Tests of Cognitive Ability, Concept Formation , Analysis and Synthesis Session 3:WRAML-2	BRIEF (Gioia et al, 2000) Parent or Teacher Conners 3 Teacher Form (Conners, 2009) DSM-IV Rating Scale (Cogmed America, 2007)

Procedures

Permissions. After approval from the Institutional Review Board from The George Washington University, permission was sought from the school district in which this study took place, a public school setting located in South Central, PA. A proposal was also submitted to Cogmed to approve the research.

After the participants had been selected by following the process described previously, parents were sent a letter asking for permission for their child to participate in this study. Parents received follow-up calls from the researcher to address any questions they may have had and to provide further clarification as needed.

Initial interviews. After the consent forms from the parents were received, the researcher and coaches scheduled to meet individually with the participant's parent and the participant to conduct an initial interview and review the training program. During this phase of the process, the research and coaches followed the Cogmed Working

Memory Training Template (Cogmed America, 2009). The majority of the sessions were conducted over the phone due to the parents' work schedules not aligning with the school district's schedule. In these cases, the students were met with individually after speaking with the parents. Another session was conducted with the participants' teachers and the Cogmed coach to complete the Initial Interview, following the template provided by Cogmed America (2009). Areas that were addressed included a review of the following areas: What is Working Memory?; How does Cogmed Working Memory Training Work?; it also included areas such as practical information regarding the participant's experiences with the computer and gaming; background information about the child's medical and educational history; school information; questions about attention; questions about hypoactivity; questions about hyperactivity and impulsiveness; questions about other problem areas, and expectations on training and motivation.

Start-up session. Following the initial interview with parents and teachers, the Cogmed Coach met with the participant in the training room within the week prior to the start of the training program to conduct the Start-up session following the template established by Cogmed America (2011). The Coach's discussion included: working memory and its influence academics and functioning in daily life, how Cogmed working training works, and practical information about the training. Particular points that were included the importance of breaks, the value of training to the limits of your capacity, and recognizing that trying your hardest may result in missing trials. Each participant was then presented with the software program and given an opportunity to practice the various activities. A weekly reward, a half-way through reward, and final rewards were discussed and defined during this session. An additional purpose of this session was to review expectations and define goals. The participant was provided with specific information about the training session such as the role of the training aide, the days and time of the training, and a reminder of the importance of trying his or her hardest in order to be successful. Last, the participant reviewed the Cogmed Training Web with the Cogmed Coach.

Participant training. Following the start-up session, the participants began the training process. Participants selected for the experimental group in this study participated in a computerized working memory training program developed by the company, Cogmed Systems out of Stockholm, Sweden (Klingberg et al., 2005). The school in which this study was implemented has served as one of the pilot programs assessing the use of Cogmed in public education system in the United States. This study deviated slightly from the recommended model of 5 sessions per week for 5 weeks, to 4 sessions a week for 7 weeks during the school day.

Students engaged in a variety of working memory tasks in a computerized game format for approximately 35 minutes a day, 4 days a week, for 7 weeks during the school day. Each session primarily included 15 trials on each of the 8 exercises that have been reported to train working memory. The exercises included working memory tasks such as backwards digit span and visuo-spatial WM tasks. Most of these tasks involved the presentation of objects in a specific sequence and then a reproduction of this sequence by the participants. This training had been designed to include an algorithm that continually increases or decreases, depending on the difficulty of each exercise and child's performance, so that he or she was working at his or her specific WM capacity (Klingberg et al., 2002; 2005).

As part of a pilot study, the students in this study also participated in additional exercises integrated with the working memory training program to measure training improvement called the Cogmed Progress Indicator (CPI). Cogmed Systems report that the CPI is designed to complement the currently used training index. The CPI consists of a set of tasks to be performed five times, distributed throughout the training (the first session being on the first day). The outcome is referred to as progress and provides feedback to the user, as well as to the coach, in order to examine the transference of training effects to non-trained tasks. Baseline scores were reported as zero percent, with all subsequent measurement points being compared with the baseline. The coach and end user were able to track the progress and received a clear report of the training effects at the end of the training period. The CPI tasks cannot be separated from the training; they are mandatory and are performed, when cued in order to proceed to the next training session.

As reported by Cogmed Systems, the progress indicator consists of three tasks, one that measures working memory directly and two that measure related abilities:

following instructions and arithmetic. The tasks were selected, based on research findings reporting training effects on specific tests (Holmes et al., 2009, Bergman Nutley et al., 2011). The working memory task, “Shapes”, was therefore derived from one of the visuo-spatial working memory tests included in the Automated Working Memory Assessment battery (Alloway, 2007), the Odd One Out. “The Following Instructions” task was based on a paper and pencil test developed by Gathercole et al., 2008. The math task was developed by Cogmed Systems and consists of math problems with two or three terms either to add or to subtract as quickly as possible; the participant then selects the correct answer from four options. As many problems as possible should be solved during one minute.

According to Cogmed Systems (2012), the CPI has undergone substantial piloting in Sweden obtaining test- retest data (five measurement points without training) from 350 individuals between the ages of 6 and 15. The math challenge is presented to everyone at the baseline measuring point (regardless of age or math ability) and if no more than 30% correct answers are obtained, this task will not appear in the following sessions.

The reliability of the tasks had been tested and correlated between the first two time points and the percentage of improvements seen across all five time points without any training. These effects were not to be subtracted from each individual’s gains in the CPI but are provided to give an estimate on how much of the gain could be explained by the fact that the CPI is performed five times (Cogmed Systems, 2012). It is important to note that one group initiated the training within a few weeks after the beginning of the school year and another group began the intervention in the winter. Between these two groups, the measurement of the CPI performance changed and thus it was not possible to analyze the CPI data in the same statistical procedure.

Reward system. Upon the conclusion on each training session, each subject was provided with a reward game called RoboRacing. At the conclusion of each week of training, each participant was provided with an award. A variety of rewards were considered and set up for the participants; gift cards were the preferred items for middle school and high school students and the elementary students had choices from a variety of items in a prize box. After reaching the half-way point of the training, participants were involved in an activity that was discussed as part of the reward system during the initial interview. Examples of activities included free-time in the gym, playing on the Wii, and spending time with a favorite teacher or peer. After the completion of the training, the participants had a pizza party during their lunch time. Positive reinforcement was also provided throughout the intervention in the form of praise and encouragement by the Cogmed coach and training aide during coaching sessions. To assist in managing issues with fatigue and effort at the middle school level, crackers, drinks, and snacks were also available in the training room and were given either before or after the training, depending on time and students' needs at that time. To address prompt arrival issues with arriving on time to the training room, students who arrived at the designated time were able to write their name on a sheet; these were put in a drawing to be held at the end of each week for an additional reward.

Classroom training aide and monitoring of session. Each training session was monitored by a classroom aide who had been provided with training by the researcher and Cogmed Coach, in accordance with the information provided in the manual designed by the Cogmed designers. The training aide's role was to ensure that that the participants did not experience difficulty with the computers and to provide cues and reminders regarding the strategies that were discussed in the coaching session. Examples of strategies included taking a break after missing two items in a row, walking away from the computer for a few minutes, getting a drink of water, or starting with the most difficult activity first. A list of these strategies was posted by students' computers if they believed that it would be helpful; some individuals reported the list could be distracting at times. The aide was provided with a behavioral observation sheet to record behaviors that might be displayed by each participant when frustrated or overwhelmed. Data that was recorded included what activity the participant was completing when the behavior occurred, the duration of the activity, and what followed the behavior. This data were provided to the Cogmed Coach to help her become aware of how the student was responding to the challenges of the program (i.e., how does he/she manage frustration). The training aide also monitored the participants to ensure that the program was implemented with fidelity (e.g., such as not not allowing the students to use pencil and paper to assist in completing the tasks and to prevent students from distracting others).

Coaching sessions. The Cogmed Coach met with the participant once a week during an individual session to review his or her progress. Data collected by the Cogmed Training Web, such as each participant's training and exercise statistics as well as the day graphs, was reviewed each week. The Training Index calculated the difference in performance between the average of the first three sessions of training and the session with the highest performance. The participant, with the help of the coach, was also able to examine details of his or her own performance on each trial of each working memory exercise. Exercise graphs were also included to demonstrate each participant's average, day-to-day results. It began with his or her lowest level achieved during the session and went to the highest results he/she managed to achieve. Training day graphs were also examined; this allowed the coach and participant to examine the graph when an exercise was completed and observe the level of difficulty of the task. This graph was used to assist in determining whether the participant took any breaks, spent an unreasonable amount of time on an exercise, peaked during one part of the training, or dipped at another part. This information was also used to help in developing strategies to improve performance or manage frustration during the upcoming training sessions.

As part of the pilot, the coach and user also examined progress as measured by the Cogmed Progress Indicator (CPI). This score was used to provide information on how well training effects have transferred to non-trained tasks. It was measured in percentages, in which the baseline obtained will be zero percent and all subsequent measurement points were compared with the baseline. The coach and end user were able to track the progress and received a clear report of the training effects at the end of the training period.

Prior to meeting with the participant each week, the Cogmed Coach met with the training aide and researcher to review behavioral data collected from the week. This data were used to assist in developing strategies to help the participant address frequent errors, reduce frustrations, and address other issues that may be affecting performance. Using a structured interview format that was provided by Cogmed America (2011), each coaching session lasted approximately 10 to 15 minutes. As part of this session, the Cogmed Coach provided positive reinforcement and praise to the participant for continuing with the training program and for the progress he or she had made. The student also participated in a reinforcement schedule as previously described.

Wrap-up session at 5 weeks post-intervention. Five weeks after the conclusion of the training, and following the administration of the post-test assessments, the Cogmed Coach met with the participant for a wrap-up session. During this meeting, the Cogmed coach followed a template similar to the one developed by Cogmed (Cogmed America, 2011). At the conclusion of the training, a Cogmed Report was issued to the student; he or she was also given diploma designed by Cogmed (2011). As recommended in the Cogmed Coaching Manual (Cogmed America, 2011), the Cogmed Coach reviewed the pre- and post- rating scales developed by Cogmed, which is the DSM-IV evaluation forms that were to be completed by both parents and teachers as part of this research study (Cogmed America, 2011). Because of the difficulty in getting parent forms returned, data from the teachers were primarily reviewed by the coach. At this time, the coach again reviewed the participant's Index Improvement and his/her development on all exercises on the Cogmed TrainingWeb.

Follow-up session at 4 months post-intervention. Four months after the completion of the training, the Cogmed Coach and researcher made attempts to contact the family and teachers to conduct a follow-up interview, using the structured interview template designed by Cogmed (Cogmed America, 2011). Participants who completed the intervention in the winter session were still in the classrooms with the teachers who completed the pre-test forms. Because of advancement to the next grade, a different group of teachers was interviewed at the 4-month follow-up session. The interview was consistent in terms of observations of current behaviors across all raters, but the ability to discuss changes in students' behaviors were not able to be described at the 4-month follow-up for the second group of students, with the exception of the high school students whose special education teachers continued to follow the same caseload in the following school year. Questions that were asked included whether or not the participant benefited from the training and how the training helped in managing symptoms that are linked with inattention and other symptoms of ADHD.

Post-test assessments at 4 weeks and 4 months. Following the procedures described previously under the pre-test session, the researcher met each participant for three sessions. Similar to the pre-test procedures, the first session involved overseeing the students' completion of the Conners 3 (2009) Self-Report form. During the second session, the participant was administered subtests from the WJ-III NU Tests of Achievement, Form B (McGrew et al., 2007)(post-test at 4 weeks) and Form C (post-test at 4 months). The subtests were administered in the following order: Calculation, Math Fluency, and Applied Problems. Following the administration of the WJ III NU Test of Achievement (McGrew et al., 2007), the participant was also administered two subtests of the WJ III NU Tests of Cognitive Ability (McGrew et al., 2007), reported to measure Fluid Reasoning (G*f*).: Concept Formation and Analysis and Synthesis. During the third session, the research was administered subtests of the WRAML2 (Sheslow & Adams, 2003) in the order in which it was standardized. Each post-testing session followed the same protocol, again noting that a different form was used when administering the WJ III NU Tests of Achievement (McGrew et al., 2007).

Parents and teachers of the participants were given the BRIEF (Gioia et al., 2000), the Conners 3 Parent or Conners 3 Teacher Form (Conners, 2009), and the DSM-IV Rating Scale (Cogmed America, 2007). These results were completed by each rater and returned to the researcher and Cogmed Coach four weeks and 4 months after the completion of the Cogmed training.

Protection of Human Participants and Ethics Precautions.

Assent and consents. In order for the participant to participate in the research, a parent/guardian was required to sign the consent form. As part of the process, the researcher met with the guardian/parent(s) in person or reviewed the information over the phone, after sending the information to the parent in the mail. The following information was provided to the parents/guardians: overview of the study; review of the Cogmed RM working memory training, to include web resources found on www.cogmed.com and a summary of the assessment tools that were to be used to evaluate treatment effectiveness. The parents and participants were actively involved throughout the training period process as part of the coaching component and the data collection process incorporated in this study and established by the Cogmed procedures.

The parents and the participants were informed via the consent form that the records of this study will be kept private. Involvement in the program was voluntary and the parent or participant was able to withdraw at any time without consequences. Parents were informed that they could contact the researcher and Cogmed Coach at any time to address any concerns or questions they may have.

Risks and benefits.

Financial risks. There were no financial risks involved in the participation of the training program because the Cogmed RM working memory training was a service provided through the school district.

Treatment. In consultation with the participants' parents, teachers, and through information generated from the structured interview, and data collection, the researcher and coach assessed whether or not the participant was an appropriate candidate to complete the training. As outlined by the designers and trainers of the Cogmed program, three factors were found to be incompatible with the training: Severe conduct disorder; Severe Depression; and Severe Anxiety (Cogmed America, 2010). Previous research has indicated that children on medications (methylphenidate), as well as those children without medication can benefit equally from the program. Because the training needed to be implemented at a high weekly frequency, individuals who had a recent history of frequent absences were placed on a waiting list until they were able to attend school on a more regular basis.

Persons with photosensitive epilepsy were excluded from participating in the study, based on concerns that lights on the computer screen could trigger an epileptic seizure. Individuals found to have severe intellectual developmental disabilities, as defined by IDEA regulations, were not included in the study.

Because the training intervention is presented as a game-like software program, it did cause frustration and stress in participants as the activities became more challenging; this is evident from self-reports to the coaches. The coaching component provided by a trained Cogmed Coach was an important component in providing support and motivation to the participant as he or she progressed through the program. As part of the weekly coaching session, the participant was given strategies by the Cogmed Coach to assist in improving performance and managing frustration. These strategies were important tools that helped the participant cope not only with the specific challenges faced in completing the Cogmed training, but also, as techniques that that would be helpful in dealing with other challenges he or she may face in life. Learning to take a deep breath, taking a walk, or closing his or her eyes to visualize, are examples of techniques that were discussed to use when making similar errors two times in a row. Overall, the coaching sessions provided the participant with an opportunity to discuss his or her frustration while also being provided with positive reinforcement regarding the progress he or she has been making. This component of the treatment appeared to help reduce noncompliance in the training program as well as provide an ongoing assessment of how the participant is responding the intervention.

Regarding the participant's behaviors and needs during the intervention session, a training aide was present for all the sessions to ensure that each participant was managing his or her frustration effectively. The training aide was able to remind the participant of the strategies that were reviewed and to intervene if it appeared that he or she needed to take a short break during the training or use another strategy. Additionally, the Cogmed Coach, researcher, and aide consulted on a weekly basis to discuss the progress of the participants and noted any behavioral or emotional concerns displayed by any of the participants that may have required additional attention, in order to ensure the program continued to be implemented with fidelity.

As described previously, a reward system was another important component incorporated into the Cogmed training program. Additional reinforcement was also being provided in this research at the half-way mark and at the conclusion of the program. To assist in building internal motivation, the Cogmed Coach reviewed the participants' performances during the coaching meetings.

Ethnical obligations and assessments. In her role as a Nationally Certified School Psychologist, PA Certified School Psychologist, Diplomate of the American Board of School Neuropsychology, and Licensed Professional Counselor certified in the state of Pennsylvania, the researcher followed the guidelines and ethical guidelines outlined by the National Association of School Psychologists, American Psychological Association and National Board of Certified Counselors. This ethical obligation included protecting the rights and welfare of the participants. Every consideration was given to protect individual integrity and accommodate individual differences and to ensure knowledge in the validity and reliability of the instructions and techniques. Identifying information was removed in order to protect the privacy of the participants. Additionally, the researcher received extensive training in conducting the assessments included in this research through graduate training and post-graduate training to ensure that the tools were administered as standardized and interpreted accurately.

Subjectivity statement and control of bias. It is important to note that the researcher is employed by the district in which the research was conducted. Additionally, the researcher conducted the pre-test and post-test assessments as part of the data collection process of this study. In the role of the school psychologist for the district, the procedures and assessments described in this research are consistent with the role that she fills in her employment and thus, follows the same ethical guidelines in ensuring that the assessments were administered and scored as standardized. Consultation with professional colleagues remained an ongoing practice throughout the study. Additional safeguards to assist in controlling for bias was fostered through the use of Cogmed coaches and training aides who provided quality review of the implementation of the intervention and trained in the manner in which it was standardized. Data used in the analysis of the effectiveness of the intervention included the results gathered from computerized assessment tools implemented in a standardized practice established by the producers of the assessments (i.e. MAPS).

Data Analysis

Analysis of Variance (ANOVA). A one-way within participants Analysis of Variance (ANOVA) with repeated-measures was conducted using SPSS 21.0.0 (2012) to assess the effectiveness of the independent variable, a computerized working memory intervention, on several dependent variables, including various memory/learning constructs, fluid reasoning, and math achievement. Data analyzed included T-scores and standard scores derived from individually administered standardized assessments and behavioral surveys. Raw scores were derived from the ADHD checklists measuring the presence of ADHD symptoms. A one-way ANOVA repeated measures was selected as the statistical method to test the equality of means by using variances (Dugard, File, & Todman, 2012; Grim & Yarnold, 2000). Specifically in this study, three observations of each dependent variable was collected prior to the intervention, four weeks after the intervention, and four months after the completion of the intervention on each subject participating under the same conditions. Difference scores were calculated for each of the participants, comparing pretest with the four week posttest, the four week with the four month posttest and the pretest with the four month posttest. By selecting a one-way ANOVA with repeated measure design, the researcher was able to statistically assess through a standard univariate *F* within participants' test whether a difference is related to effect variance or error variance. A larger *F* value suggested that the differences between observations were greater than would be expected by chance or error alone (Grim & Yarnold, 2000; Turner & Thayer, 2001; Dugard, File, & Todman, 2012).

Assumptions. There were various assumptions that had to considered when utilizing an ANOVA and the *F*-test (Turner & Thayer, 2001; Dugard, File, & Todman, 2012; Grim & Yarnold, 2000). One assumption is that the observations were independent, because each observation was uncorrelated with another observation. If this assumption is violated, it can lead to misleading results and should not be trusted. This is particularly important in the repeated-measures design of this study because each subject contributed three scores on each dependent variable (Turner & Thayer, 2001).

Another assumption is that the observations were normally distributed, meaning that all of the measures of the central tendency of the observed scores were the same, to include the mean, the median, and the mode (Turner & Thayer, 2001). It is also assumed that the variances are the same, indicating that the spread of scores needs to be identical. This term is also known as the Homogeneity of Variances. If the population distribution is not normal, and the sample size is small, the *p* values would be considered invalid (Grim & Yarnold, 2000; Turner & Thayer, 2001; Dugard, File, & Todman, 2012).

One last assumption, called sphericity, occurs when the variance of the difference scores in the within-subject design is equal across all groups. In this case, the difference scores were calculated for each of the participants, comparing pretest with the 4 week posttest, the 4 week with the 4 month posttest and the pretest with the 4 month posttest. The assumption is that each of these sets of different scores is not statistically significant from one another. When the assumption is violated, there is an increased risk for Type 1 errors because the critical values in the F-table would be too small. Sphericity in this study was tested initially, using the Mauchy's Sphericity test. When the sphericity assumption was not met, procedures were used to correct the univariate results by making adjustments to the degrees of freedom in the denominator and numerator. The method used in this study to correct this bias was the Greenhouse-Geisser Epsilon, in which an adjustment factor that is based on the amount of variance heterogeneity was computed (i.e., how much the variances are unequal), making the F-critical somewhat larger

(Algina & Kesselman, 1991; Dugard, File, & Todman, 2012; Kesselman et al., 1980; SPSS, 2011;Turner & Thayer, 2001).

Advantages of a within-subject design. Advantages in using a within-subject design for this research study included having increased power and economy of scale. In terms of power, it allowed a greater opportunity for the researcher to detect a difference when one existed. One of the issues in conducting error variance when utilizing in between-group design is that natural differences can be expected between participants in treatment groups, potentially affecting the dependent variable. By using within-in subject design, the error variance is assessed by examining participants' characteristics on the same measure at different times; therefore, there is less 'noise' and a greater chance of detecting the true effects of the interventions (i.e. higher power) (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001). In other words, the within-subject repeated measure design allowed each participant to serve as his or her own control by finding the differences within each subject and then averaging the results (Dugard, File, & Todman, 2012). Regarding the economy of scale, using each subject as his or her own control also allowed the use of fewer participants to achieve a given level of power when compared with a between-group design.

Disadvantages of the within-subject design. One concern in using the within-subject design was "carryover effects," which threatens internal validity. Specifically, due to the length of the time of the research period there was increased risk that various external events could have influenced assessing the true effectiveness of the intervention.

Because there was no control group, it was not possible to know whether changes may have been related to the intervention or to other extraneous factors. Carryover effects essentially can create systematic variations that are separate from the independent variable (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001. This is particularly important to consider in the school setting when considering long-term research because differences can naturally occur, related to changes in curriculum and instruction as students make progress through the various marking periods and grade levels. Additionally, family background and home experiences could have also affected students' outcomes, depending on additional resources that were available to the participants during the research phase.

Two examples of undesirable systematic variations that need to be considered in this study are practice and fatigue effects (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001). Practice effect is a factor that is considered in the discussion because the participants are being exposed to the assessments during three different testing sessions. Testing sessions during this time period were approximately 12 to 13 weeks apart, thus possibly improving performance on the assessments due to prior exposure to the material. To alleviate this risk to a small degree, an alternative form of assessment was used in measuring math achievement; this will be described in greater detail later in the methods section.

A fatigue effect may have also occurred due to participants getting tired, being bored, or losing motivation to achieve their best performances on the assessments and intervention. When considering the issues of repeated measures, it is important to consider that practice effects may create a positive impact on the outcome measure but fatigue may have had a negative impact (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001).

Power analysis. A power analysis using the G*Power web-based calculator (Faul et al., 2007) determined that a sample size of 28 participants was needed in order to detect a medium effect size of d = .25 at .80 power, using within-participants ANOVA with alpha set at .05. Due to attrition factors, only 23 participants were able to complete the minimum number of 20 intervention sessions to include in the statistical analysis of this study, which yielded a power of .72.

Friedman test. The Friedman (1937) test, a non-parametric statistical test, was also calculated in order to address concerns related to the violations of the assumptions required for the ANOVA to be conducted. This statistic is used for one-way repeated measures of variance by ranks in order to provide additional data to detect differences in treatments by ranking the data.

Post-hoc tests. Paired-sample *t*-tests were used for post-hoc analysis of one-way repeated measures ANOVA to assess statistically significant differences. Pre-tests were compared with the 4-week post-test assessments and with the 4-month post-test assessments. The 4-week post-test assessment results were also compared with the 4-month post-test assessments.

Pairwise comparisons on the non-parametric data was performed through SPSS 21.0 (2012), using a Bonferroni post-hoc correction for multiple corrections.

Effect size. To measure the magnitude of the treatment effects of the working memory intervention, various types of statistical analysis was conducted to derive the effect size on the ANOVA's, Friedman test, and t-tests. The scale of magnitude provided by Cohen (1992) for partial eta square is listed as follows: .01=small, .06 for medium, and .16=large. For the *t*-tests, the Cohen's d was calculated for effect size with small =.2, medium =.5, and large=.8 (Lakens, 2013) For Cramer's V, also referred to as Cramer's Phi, the effect size used to measure the Chi-square of the Friedman statistic, the value of. 1 is considered a small effect size, .3 a medium effect, and .5 a large effect (Kotrlik & Williams, 2003; Vacha-Haase & Thompson, 2004).

Assumption Testing Results

Cogmed training index. An extreme outlier was removed from the data base to conduct a paired-sample t-test on the Cogmed Training Index to determine this analysis for a sample size of 22. The assumption of normality was found to be violated, using the Shapiro-Wilk's test (p=.012) on the paired-samples t-test used to measure the Cogmed Training Index.

Cogmed Progress Indicator (CPI). In an analysis using box-plot, outliers were found on the percentage of change on working memory tasks from baseline to the 10^{th} session; assessments at the $15{,}20^{th}$ and 25^{th} sessions were found to have no outliers. The

Shapiro-Wilk (p=.05) test was found to be normally distributed on each set of data. Only 14 of the 23 students were able to complete the assessment up to the 25th session but 21 students had data collected from baseline to the 20th intervention session. To assist in assessing whether or not significant differences were found using the change in percent derived from the computerized assessment on working memory, additional analysis were conducted. Results varied when including information from baseline to the 25th session, when compared with data from baseline to the 20th session. In order to increase the size of the participants in the analysis, tests were conducted on the students that reached 20 sessions. Twenty one students were able to participate in each of the three assessments. Outliers were not found when examining the participants change in percentage from baseline to the 10th, 15th, and 20th assessment session. As noted in the negative value in the mean, several students performed better on the baseline assessment than they did on the 10th session assessment. The data were found to be normally distributed for each of the assessment phases as assessed by the Shapiro-Wilk test ($p>.05$). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated $X^2(2) = 1.46$, p=.48.

Greenhouse-Geisser correction was applied to the following tasks of the CPI: math challenge for group one and two, and percent change on math challenge for group one and group two. Greenhouse-Geisser correction was also applied to the statistics measuring the following subtests of the WRAML-2: story memory, verbal learning, finger windows, design memory, number-letter subtest, picture memory, symbolic working memory, working memory, verbal memory, visual memory, and attention concentration. Greenhouse-Geisser correction was applied to the following math achievement tests: applied problems, math calculation, broad math and math calculation cluster. Greenhouse-Geisser was also applied to the following measurements on the behavioral/emotional checklists completed by teachers: Behavior Rating Index, Monitor, and the AHD hyperactivity/impulsivity scale.

Working memory tasks on the CPI. When looking specifically at the mean data generated at each point of assessment of the first group being assessed, two outliers were found on the computerized assessment during the 20th session, with one score significantly below the mean and one above the mean. Results of the Shapiro-Wilk (p =.05) test indicated that the data was normally distributed. A Friedman test was run to determine if there were differences in the performances across time, using a non-parametric approach. Mauchley's test of sphericity test indicated that the assumption of sphericity was not violated on the Working Memory assessment of the CPI when examining the data generated at baseline, session 10, session 15, and session 20 $X^2(5)=2.19$, $p=.82$ for the first group of students. In examining the mean data at each point of assessment on the second group being assessed on working memory on the CPI, no outliers were found on any of the assessments, using box-plot analysis on SPSS (2012). The results were also found to be normally distributed as assessed by Shapiro-Wilk. Mauchley's test of sphericity test indicated that the assumption of sphericity was not violated $X^2(5)=4.31$, $p=.51$.

Following directions on the CPI by group one. In examining the mean data on the first group being assessed on the following directions task, an outlier was found on the 10th session assessment, two on the 15th session assessment, and one on the 20th session assessment, as determined using box-plot analysis. The results were found to be normally distributed as assessed by Shapiro-Wilk. Mauchley's test of sphericity test indicated that the assumption of sphericity was not violated on the Following Directions assessment of the CPI when examining the data generated at baseline, session 10, session 15, and session 20 $X^2(5)=8.77$, $p=.12$ for the first group of students.

Following directions on the CPI by group two. In examining the mean data at each point of assessment on the second group being assessed on following directions, outliers were found on the computerized assessment. Two were found on the 10th session assessment and one was found on the 20th session. The results were found to be normally distributed, as assessed by Shapiro-Wilk. Mauchley's test of sphericity test indicated that the assumption of sphericity was not violated $X^2(5)=1.72$, $p=.89$.

Percent change on following directions tasks of CPI across time. As assessed using box-plot analysis on each of the CPI assessment session, no outliers were found when examining all four of the assessment periods (10th, 15th, 20, and 25th sessions) when determining data change on the following direction task. The results were found to be normally distributed using the Shapiro-Wilk test, with the exception of the percentage change from baseline to the 25th assessment session ($p=.01$). Twenty one students participated in the three assessment sessions, which occurred in session10, session 15, and session 20. No outliers were found when examining percentage of change across sessions using the Shapiro-Wilk test. Each of the three assessment phases was found to be normally distributed.

To analyze the results using a one-way repeated measures ANOVA, the Mauchly's Test of Sphericity was conducted on the three CPI assessment periods and found that sphericity had not been violated $X^2(2)=4.09$, $p=.13$.

To analyze the results using a one-way repeated measures ANOVA, the Mauchly's Test of Sphericity was conducted on the four CPI assessment periods and found that sphericity had been violated $X^2(5)=15.4$, $p=.01$; therefore, degrees of freedom were conducted, using Greenhouse-Geisser (ε=.65).

Math challenge tasks of CPI by group one. As assessed using box-plot analysis on each of the CPI assessment session on the math challenge task from group one of the participants, one outlier was found on the 15th session assessment. Only 10 of the 23 students completed this assessment from baseline to the 25th assessment session. The results were found to be normally distributed using the Shapiro-Wilk test on each of the assessment phases, except for the results on the 15th session assessment where $p=.05$. When the analyses was conducted without including the 25th assessment, which included only 14 of the 23 students, three outliers were observed on the 15th session assessment and one was found on the 20th assessment session. In addition, the measurements of the math challenge during the 15th session assessment (p=.004) and the 20th assessment session were found not be normally distributed (p=.03).

In order to conduct further assessments of the data, the Mauchly's test of sphericity was conducted and found that the assumption of sphericity had been violated $X^2(5)$ =12.18, p=.03; therefore, degrees of freedom were corrected, using Greenhouse-Geisser (ε=0.62).

Math challenge measurement of CPI by group two. Outliers were found on each of the four assessment periods for the second group of students on the math challenge tasks: two outliers were found on baseline: one on the 10th session assessment; one on the 15th session assessment, and three on the fourth session assessment. When including the 25th session assessment, two outliers were also found on that assessment. Using Shapiro-Wilk to assess for normality, the mean assessment score for the second group of participants was found not to be normally distributed on the 10th (p=.02) and 15th assessment session (p=.003) when examining each of the 5 assessment phases of the nine participants. The results were the same when examining the data on only four of the assessment sessions, which also included 9 students.

In order to conduct further assessments of the data on the math challenge tests, the Mauchly's test of sphericity was conducted and found that the assumption of sphericity had been violated $X^2(9)$ =19.68, p=.02; therefore, degrees of freedom were corrected, using Greenhouse-Geisser (ε=.53). Mauchly's test of sphericity was also conducted on the four assessment sessions and also found that the assumption of sphericity had been violated $X^2(5) = 18.29$, $p=.003$; therefore, degrees of freedom were corrected using Greenhouse-Geisser ($\varepsilon=.44$).

Percent change on math challenge tasks. No outliers were found when examining all four of the assessment periods in determining assessment change. The results were found to be normally distributed, using the Shapiro-Wilk test on the math challenge assessments. Thirteen students participated in the four sets of assessments. Mauchly's test of sphericity on baseline, 10^{th} session, 15^{th} session, 20^{th} session, and 25^{th} indicated that the assumption of sphericity had been violated when looking at percent change on the math challenge tasks $X^2(5) = 11.37$, $p=.05$; therefore, degrees of freedom were corrected using Greenhouse-Geisser ($\varepsilon=0.65$).

Using the box-plot analysis on the 10^{th}, 15, and 20^{th} assessment session on the math challenge tasks, no outliers were found. Using the Shapiro-Wilk test, each of the three assessment phases was found to be normally distributed.

Mauchly's test of sphericity on baseline, 10^{th} session, 15^{th} session, and 20^{th} session indicated that the assumption of sphericity had not been violated on the math challenge tasks $X^2(2) = .13$, $p=.94$.

WRAML-2 subtests. Mauchly's test of sphericity was not found to be violated on Verbal Working Memory $X^2(2) = 3.58$, $p=1.17$ and General Memory $X^2(2) = 4.62$, $p=.10$. Mauchly's test of sphericity indicated that the assumption of sphericity was violated on the following subtests and composites: Finger Windows $X^2(2)=10.18$, $p=.01$; Number Letter $X^2(2)$ $=6.61$, $p=.04$; Design Memory $X^2(2)=6.85$, $p=.03$; Picture Memory $X^2(2)=26.05$, $p=.01$; Symbolic Working Memory $X^2(2)=11.72$, $p=.04$;Working Memory $X^2(2)=11.72$, $p=.003$; Verbal Working Memory $X^2(2)=21.92$, $p=.01$; and Visual Memory $X^2(2)=6.99$, $p=.03$.

Story memory. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the pre-test assessment ($p= .088$), 4-week post-test ($p=.530$), and 4-month post- test assessment ($p=.111$) were normally distributed. No outliers were found. The mean scaled score of the story memory subtest was found to increase from pre-intervention (M=5.96, SD=2.75) to 4-weeks post intervention (M=7.26, SD=2.6) to 4-months post-intervention (M=7.83, SD=2.76). Mauchley's test indicated that the assumption of sphericity had been violated on the Story Memory subtest $X^2(2)=28.1$, $p=.000$; therefore, degrees of freedom were corrected using Greenhouse-Geisser ($\varepsilon=0.58$).

Verbal learning. There were no outliers in the data, as assessed by inspection of a boxplot. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the pre-test assessment ($p= .55$), 4-week post-test ($p=.29$), and 4-month post-test assessment ($p=.37$) were normally distributed. Mauchley's test indicating the assumption of sphericity had been violated on the Verbal Learning subtest, $X^2(2)=14.56$, $p=.001$; therefore, degrees of freedom were corrected using Greenhouse-Geisser ($\varepsilon=0.67$).

Finger windows. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the pre-test assessment (p=.19) and 4-month post-test assessments (p=.42) were normally distributed. The 4-week post-test assessment was not found to be normally distributed with p=.05. One outlier was noted with a student who made minimal progress between pre-test and the 4 week post-test assessment. As indicated previously, Mauchley's test indicated that the assumption of sphericity had been violated on the Finger Windows subtest $X^2(2)$=10.18, p=.006; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=0.72).

Number-letter subtest. Outliers were found on each of the three periods of assessments. The data was found to be normally distributed, however, for each group as assessed by the Shapiro-Wilk test. As indicated previously, Mauchley's test indicated that the assumption of sphericity had been violated on the Number Letter subtest $X^2(2)$ =6.61, p=.04; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=0.79).

Verbal working memory. Outliers were found on the pre-test and the 4 week post-test assessments on the verbal working memory subtest. Using the Shapiro-Wilk test, the performance on Verbal Working Memory was found to be normally distributed. Mauchly's test of sphericity was not found to be violated on Verbal Working Memory $X^2(2)$ =3.58, p=1.17.

Design memory. There were no outliers and the data were normally distributed for each group, as assessed by boxplot and Shapiro-Wilk test, respectively. Mauchly's test indicated that the assumption of sphericity had been violated on Design Memory$X^2(2)$ =6.88, p=.03; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=.78).

Picture memory. Outliers were found on the pretest 4 week post-test (3 below distribution with one being more than 3.0 box plots away) and 4 month post-test assessments (one outlier more than 1.5 box plot variance). Using the Shapiro-Wilk test, the performance on the picture memory subtest was found to be normally distributed on the pre-test assessment and the 4 month post-test assessment. The assumption of normal distribution was not accepted for the 4-week post-test assessment with p=.002. An examination of the assumption of sphericity using Mauchly's test found it to be violated on Picture Memory $X^2(2)$ = 26.05, p =.05; therefore, degrees of freedom were corrected, using Greenhouse-Geisser (ε=0.59).

Symbolic working memory. An outlier was found on the 4 week-post- test assessment. Although outliers were found, the Shapiro-Wilk test indicated that the results were normally distributed for each assessment period. The assumption of sphericity was found to be violated on Symbolic working memory, as measured by Mauchly's test of sphericity $X^2(2)$ = 6.50, p =.04;therefore, degrees of freedom were corrected, using Greenhouse-Geisser (ε=.79).

Working memory. Outliers were found on the pre-test analysis and the 4 week-post-test analysis. Further analysis using the Shapiro-Wilk test as part of the one-way repeated measure ANOVA indicated that the results were normally distributed on the 4-week post-test intervention period and 4-month intervention period. Results on the pre-test assessment was found to be statistically significant, thus the assumption of normal distribution was rejected when examining the data for the specific analysis. Mauchly's test indicated that the assumption of sphericity had been violated on Working Memory $X^2(2)$ =11.72, p=.003. To further assess sphericity, the degrees of freedom were corrected using Greenhouse-Geisser (ε=.70).

Verbal memory. Three outliers were found on the pre-test analysis (two were found lower than their peers and one was found to be higher). There were no outliers found when examining the data generated for the 4 week post-test assessment and the 4-month post-test assessment. Using the Shapiro-Wilk test as part of the one-way repeated measures ANOVA, the data collected indicated that the results were normally distributed on each of the three assessment periods. Mauchly's test of sphericity was found to be violated on Verbal Working Memory $X^2(2)$ =21.91, p=05. To further assess sphericity, the degrees of freedom were corrected, using Greenhouse-Geisser (ε=.61).

Visual memory. One outlier was found on the 4-month post-test assessment. There were no outliers found when examining the data generated for the 4 week post-test assessment and the 4-month post-test assessment. Using the Shapiro-Wilk test as part of the ANOVA repeated measures assessment, the data collected indicated that the results were normally distributed on each of the three assessment periods. Mauchly's test of sphericity was found to be violated on Visual Memory $X^2(2) = 6.99$, $p = .03$. To further assess sphericity, the degrees of freedom were corrected, using Greenhouse-Geisser ($\varepsilon = .78$).

Attention concentration. Outliers were found across each of the three assessment periods, with one person being the outlier on the pre-test and 4 month post test period and two people being outliers on the 4 week post-test and 4 month-post-test assessment period. One additional student was found to be an outlier higher than the group's mean on the 4-week post-test assessment period on the attention concentration composite.

Using the Shapiro-Wilk test the data collected indicated that the results were normally distributed on each of the three assessment periods. Mauchly's test of sphericity was found to be violated on the Attention Concentration Composite $X^2(2) = 7.54$, $p = .02$. To further assess sphericity, the degrees of freedom were corrected, using Greenhouse-Geisser ($\varepsilon = .77$).

General memory composite. One outlier was found on each of the three assessment periods with scores falling below the mean distribution of scores. Using the Shapiro-Wilk test the data collected indicated that the results were normally distributed on each of the three assessment periods. Mauchly's test of sphericity was found not to be violated on the General Memory Composite, $X^2(2) = 4.62$, $p = .10$.

Fluid reasoning assessments.

Analysis/synthesis. One outlier was found using the Box-plot analysis on the 4-week post intervention period, with a student performing higher than peers. The Shapiro-Wilk test indicated that the results of the analysis/synthesis subtest were normally distributed across each of the three assessment periods. Mauchly's test of sphericity was not found to be violated on the analysis/synthesis subtest $X^2(2)$ =2.42, p=.30.

Concept formation. No outliers were found. The Shapiro-Wilk test indicated that the results of the concept formation subtest were normally distributed across each of the three assessment periods. Mauchly's test of sphericity was not found to be violated on the concept formation subtest $X^2(2)$ =1.84, p=.40.

Fluid reasoning cluster. One outlier was found on the fluid reasoning cluster scores on the pre-test assessment. To further investigate the assumptions that underlie the use of the one-way repeated measures ANOVA, the results of the Shapiro-Wilk test was conducted and indicated that the fluid reasoning clusters were normally distributed across each of the three assessment periods. Mauchly's test of sphericity was not found to be violated on the analysis/synthesis subtest $X^2(2)$ =.31, p=.86.

Math achievement. Mauchly's test of sphericity indicated that the assumption of sphericity has not been violated on the following math achievement subtests and composite: Math Fluency $X^2(2)$ =5.80, p=.55, Applied Problems $X^2(2)$ =4.43, p=.11; and Brief Math $X^2(2)$=4.17, p=.13. Mauchly's test of sphericity found that the assumption of sphericity was violated on the Math Calculation subtest $X^2(2)$ =4.17, p= .009, Math Calculation Composite $X^2(2)$ =8.02, p=.02, and the Broad Math Composite, $X^2(2)$ =7.12, p=.03. Additional statistical analysis on the subtests and composite scores are described in following sections.

Math fluency. One outlier was found on the pre-test assessment on math fluency. The Shapiro-Wilk test indicated that the results of math fluency subtest were, however, normally distributed across each of the three assessment periods. To further investigate the ANOVA repeated measures analysis, the Mauchly's test of sphericity was conducted and indicated that the assumption of sphericity has not been violated on Math Fluency $X^2(2)$ =5.80, p=.06.

Math calculation. Analysis on the Math Calculation subtest found no outliers across the three time periods and that the scores were found to be normally distributed, as measured by the Shapiro-Wilk test. Mauchley's test indicated that the assumption of sphericity had been violated on the Math Calculation subtest: $X^2(2)$ =9.37, p= .01; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=.74).

Brief math. Using the Box-Plot analysis when examining outliers on the Brief Math cluster, one score was found to be an outlier; one participant performed higher than expected during the 4-week post-test session. To further assess the assumptions underlying the use of ANOVA repeated measures, the Shapiro-Wilk test was also conducted, including the outlier and indicated that the results were normally distributed in each of the three assessment periods. Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the Brief Math cluster $X^2(2)=4.17$, $p=.13$.

Math calculation cluster. No outliers were found during the three assessment periods on the Math Calculation Cluster. The Shapiro-Wilk test indicated that the results were also normally distributed.

Broad math. No outliers were found during the three assessment periods on the Broad Math Cluster. The Shapiro-Wilk test indicated that the results were also normally distributed (pre-test $p=.33$; 4-week post-test $p=.10$, post-test at 4 months, $p=.99$). Mauchley's test indicated that the assumption of sphericity has been violated on Broad Math achievement composite $X^2(2) =7.12$, $p=.03$; therefore, degrees of freedom were corrected using Greenhouse-Geisser ($\varepsilon=.78$).

Applied problems. No outliers were found during the three assessment periods on the applied problems subtests. The Shapiro-Wilk test indicated that the results were also normally distributed. Mauchly's test of sphericity was found not to be violated on Applied Problems $X^2(2) =4.43$, $p=.11$.

Math calculation cluster. Analysis using Box-Plot indicated that there were no outliers found during the three assessment periods on the Math Calculation Cluster. The Shapiro-Wilk test indicated that the results were also normally distributed. Preliminary analysis utilizing the Mauchly's test of sphericity found that the assumption of sphericity was violated on the Math Calculation Composite $X^2(2) = 8.02$, $p=.02$; therefore, the degrees of freedom was corrected using Greenhouse-Geisser (ε=.76).

BRIEF Teacher Rating Scale.

Inhibit scale. Use of the Box-Plot analysis when examining outliers on the inhibit scale indicated that one score was rated lower than the others on the post-test 4 month assessment. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the pre-test assessment ($p=.10$) was normally distributed. The 4-week post-test assessment ($p=.03$) and 4-month post-test results ($p=.03$) was not found to be normally distributed with $p=.05$. When analyzing the data utilizing the ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi2(2) = .28, p = .87$.

Shift scale. Four outliers were found on the 4-week post-test. In testing for normal distribution using the Shapiro-Wilk's test, it was found that none of the assessment periods was normally distributed: pre-test assessment (p=.01); post-test 4 weeks assessment (p=.01) and the 4-month post-test assessment (p=.002). To investigate the ANOVA repeated measures analysis on this set of data, the Mauchley's test of sphericity was conducted and indicated that the assumption of sphericity had not been violated on the Shift subtest of the BRIEF, $X^2(2) = 3.34$, $p=.19$.

Emotional control scale. One outlier was found on the 4-week post-test and one on the 4 month post-test assessment. In testing for normal distribution using the Shapiro-

Wilk's test, it was found that none of the assessment periods was normally distributed: pre-test assessment (p=.01); post-test 4 weeks assessment (p=.001) and the 4-month post-test assessment. To further investigate the ANOVA repeated measures analysis, the Mauchly's test of sphericity was conducted and indicated that the assumption of sphericity has been violated on the Emotional Control subtest $X^2(2)$ =6.63, p=.04; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=.07).

Behavior Rating Index (BRI). No outliers were found on each of the assessment periods measuring the BRI. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the pre-test assessment was normally distributed (p=.05). The 4-week post-test assessment was also found to be normally distributed (p=.20) but the 4-month post-test results (p=.04) was not found to be normally distributed. When analyzing the data utilizing the one-way repeated measures ANOVA, Mauchly's test of sphericity indicated that the assumption of sphericity had been violated on the Behavior Rating Index, $\chi 2(2) = 7.55, p= .02$; therefore, degrees of freedom were corrected, using Greenhouse-Geisser (ε=0.77).

Initiate. No outliers were found on each of the assessment periods. In testing for normal distribution using the Shapiro-Wilk's test (p >.05), it was found that the pre-test assessment and the 4-week post-test assessment were normally distributed. When analyzing the data utilizing the ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the Initiate subtest, $\chi2(2) = 1.04, p = .54$.

Working memory. One outlier was found on the 4-month post- test assessment on the teachers' ratings of the participants on the working memory scale. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the pre-test assessment (p=.18) and the 4-week post-test assessment (p-=.20) were normally distributed. The results of the 4-month post-test assessment were found not to be normally distributed (p=.02). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the working memory subtest, $\chi2\ (2) = 5.53, p = .06$.

Planning. One outlier was found on the pretest assessment and two on the 4 week post-test assessment. In testing for normal distribution using the Shapiro-Wilk's test, it was found that each of the assessments was normally distributed: the pre-test assessment (p=.38; 4-week post-test, p=.07) and the 4-mont post-test assessment (p-=.30). Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the planning subtest, $\chi2\ (2) = 3.85, p = .86$.

Organization. One outlier was found on the 4-week post- test assessment and two on the 4 month post-test assessment. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the data collected from each assessment phase were found not to be normally distributed: pre-test assessment p=.03; 4-week post-test, p=.003; and the 4-month post-test assessment. Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the planning subtest, $\chi2$ (2) = 3.57, p = .17.

Monitor. No outliers were found during each of the assessment periods. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the data collected from each assessment phase were found to be normally distributed: pre-test assessment p=.22; 4-week post-test, p=.73; and the 4-mont h post-test assessmen, p =.65. When analyzing the data, utilizing the one-way ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had been violated on the monitor scale, $\chi2$ (2) = 10.22, p = .01; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=0.72).

Metacognition. There were no outliers found across the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that each of the assessment phases in the study was found to be normally distributed: the pre-test assessment ,p=.46; 4-week post-test assessment, p=.19, and the 4-month post-test results, p=.26. When analyzing the data utilizing the ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated, $\chi2$ (2) = .5.41, p = .07.

Global executive control. One outlier was found on the 4-week post-test assessment. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the data collected from each assessment phase were normally distributed: pre-test assessment *p*=.15; 4-week post-test, p=.10; and the 4-month post-test assessment, *p*=.28. When analyzing the data utilizing the one-way ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the Global Executive Control subtest, $\chi2$ (2) = 2.27, *p* = .32.

Conners' teacher rating scale.

Inattention. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the assessments were normally distributed: pre-test assessment (*p*=.17); 4 week post-test assessment (*p*=.20); 4-month post-test assessment (*p*=.37). When analyzing the data utilizing the one-way ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the inattention scale, $\chi2$ (2) = 2.85, *p* = .24.

Hyperactivity/Impulsivity. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the assessments were not normally distributed on each of the assessment phases of the study: pre-test assessment *p*=.003; 4 –week post-test assessment, *p*=.01; and 4-month post-test assessment t, *p*=.001. When analyzing the data utilizing the one-way ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the impulsivity/hyperactivity scale, $\chi2$ (2) = 5.45, *p* = .07.

Learning problems/executive functioning. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that each of the assessments was normally distributed: pre-test assessment (p=.11); 4 week post-test assessment (p=.86); and the 4-month post-test assessment (p=.97). When analyzing the data utilizing the one-way ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the learning problems/executive functioning scale, $\chi 2$ (2) = 2.43, p = .30.

Learning problems. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that each of the assessments was normally distributed: pre-test assessment (p=.59); 4 –week-post-test assessment (p=.09), and the 4-month post-test assessment (p=.28). When analyzing the data utilizing the ANOVA repeated measures, Mauchly's test of sphericity indicated that the assumption of sphericity had not been violated on the learning problems scale, $\chi 2$ (2) = .78, p = .68.

Executive functioning. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that each of the assessments was normally distributed: pre-test assessment (p=.51); 4 –week-post-test assessment (p=.11); and the 4-month post-test assessment (p=.43). When analyzing the data utilizing the ANOVA repeated measures, Mauchly's test indicated that the assumption of sphericity had not been violated on the executive functioning scale, $\chi 2$ (2) = 1.54, p = .46.

ADHD inattentive scale. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that each of the assessments was normally distributed: pre-test assessment (p=.24); 4 –week-post-test assessment (p=.53); and the 4-month post-test assessment (p=.38). When analyzing the data utilizing the ANOVA repeated measures, Mauchly's test indicated that the assumption of sphericity had not been violated on the executive functioning scale, $\chi 2$ (2) = 3.56,p = .13.

ADHD hyperactivity scale. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the assessments was normally distributed on the pre-test assessment (p=.38). The 4-week post-test assessment (p=.004) and the 4-month post-test assessment (p=.001) were found not to be normally distributed. When analyzing the data utilizing the one-way ANOVA repeated measures, Mauchly's test indicated that the assumption of sphericity had been violated on the hyperactivity scale, $\chi 2$ (2) = 6.15, p = .05; therefore, degrees of freedom were corrected using Greenhouse-Geisser (ε=.80).

Conners' self-report.

Self-report on inattention. No outliers were noted across the three time periods. Using the Shapiro-Wilk test, the data collected indicated that the data were found to be normally distributed. Mauchly's Test of Sphericity was found to be violated on the Self-report inattention scale $X^2(2)$ =11.03, p=.004; therefore, degrees of freedom were conducted , using Greenhouse-Geisser (ε=.71).

Self-report on hyperactivity/impulsive. No outliers were found across the three time periods. The Shapiro-Wilk test indicated that the results were not normally distributed on the 1-month post- test (p=.004) and the 4-months posttest (p=.001). Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated on the hyperactivity/inattention scale $X^2(2)$ =4.53, p=.10.

ADHD predominantly inattention type. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that assessments were normally distributed. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated on the inattention type symptom scale $X^2(2)$ =3.74, p=.15.

ADHD predominantly hyperactivity/impulsivitytype. No outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk test, it was found that the assessments were normally distributed. Mauchly's Test of Sphericity indicated that the assumption of sphericity was violated $X^2(2)$ =69.16, p=.000; therefore, degrees of freedom were corrected using the Greenhouse-Geisser (ε=.51).

Teachers' DSM-IV-TR checklists. Because of the difficulty in returning the form from the parents of each participant across each of the testing phases, the statistical analyses were not completed on the parents' rating scales. Using the Box-Plot analysis, no outliers were found on any of the three assessment phases. In testing for normal distribution using the Shapiro-Wilk's test, it was found that the assessments were normally distributed on the 4-week post-test assessment (p=.17). The pre-test assessment data of the participants (p=.02) and the 4-month post-test assessment (p=.03) were not found to be normally distributed. When analyzing the data utilizing the one-way ANOVA repeated measures, Mauchly's test indicated that the assumption of sphericity had not been violated on the DSM-IV –TR teacher scale, $\chi 2(2) = 2.06, p = .36$.

Chapter 4: RESULTS

Results

Cogmed Training Index

Research question one: Do the participants show statistically significant improvement on the trained tasks over the intervention training period when implemented in the school day, as measured by index improvement scores collected by the training software program?

A paired-samples t-test was used to determine if there was a statistically significant mean difference between the participant's score at the beginning of the intervention program, when compared with his or her maximum training index score. Although the assumption of normality was found to be violated, the paired samples t-test was continued because the paired-samples t-test is typically considered robust, and non-normality typically does not affect Type 1 errors. A statistically significant increase was found when comparing the participant's maximum level of training performance to the baseline training score, t (21) =6.28, p =.011, d=1.34.

Cogmed Progress Indictor (CPI)

Research question Two: Do the participants show statistically significant improvement over the intervention period on untrained tasks, as measured by the Cogmed Processing Index (CPI) collected by the training software program?

To measure progress on the untrained tasks, the percent of change from baseline performance to each of the computer-generated assessments administered at the beginning of the 10^{th}, 15^{th}, 20^{th}, and 25^{th} session was calculated.

Working memory tasks on the CPI. A related samples Friedman analysis of variance that was conducted on the CPI measurement of working memory for the first group of assessed students found no statistically significant differences among the test sessions $X^2(3)=3.67$, $p=.30$ $\varphi c=.32$,Multiple comparisons were not performed because the overall test retained the null hypothesis of no difference. A one-way, repeated measures ANOVA repeated measures statistic revealed no statistically significant difference between the measurements of the first group $F\,(3, 30)=1.36$, $p=.27$, partial $\eta 2=.12$.

Statistically significant differences were not found when assessing changes across time using one-way, repeated measures ANOVAs on the data generated at baseline, session 10, session15, and session 20 for the second group of students $F(3,24)=.81$, $p=.50$ partial $\eta 2=.09$.

Percent change on working memory tasks of CPI across intervention. A one-way repeated measures ANOVA indicated no statistically significant differences across time on the percent of change on the working memory task $F(2,40)=1.81$, $p=.18$, partial $\eta 2=.08$.

Following directions task on the CPI. Results of one-way, repeated measures ANOVA yielded no statistically significant differences among the measurements of the first group $F(3, 33) =.06$, $p=.98$, partial $\eta 2=.01$.

A Friedman test was run to determine if there were differences in the performances across time using a non-parametric approach for the second group. The CPI measurement of following directions for the second group of assessed students found no statistically significant differences among the test sessions $X^2(3)=5.48$, $p=.14$, $\varphi c =.45$. Multiple comparisons were not performed. Statistically significant differences were found when assessing changes across time using one-way, repeated measures ANOVA of the data generated at baseline, session 10, session15, and session 20, $F(3,24)=4.6$, $p=.01$ partial $\eta^2=.37$.

Percent change on following directions tasks of CPI across time. A Friedman test was conducted on the three groups of assessments, excluding the 25th assessment session ($N=21$). The percent change on the following direction task for the nineteen participants found no statistically significant differences among the test sessions $X^2(2) =.99$, $p=.61$, $\varphi c =.15$. Multiple comparisons were not performed because the overall test retained the null hypothesis of no difference. Results of the one-way, repeated measures ANOVA did not find a statistically significant change on the percent change across the 10th, 15th, and 20th session on the following directions task $F(2,36)=.32$, $p=.73$, partial $\eta^2=.02$.

A Friedman test was also administered on all four of the assessment sessions measuring percent increase on the following directions task on CPI to assess median differences. The percent change on the following direction task for the seventeen participants found no statistically significant differences among the test sessions $X^2(3) =.20$, $p=.98$, $\varphi c =.06$. Multiple comparisons were not performed because the overall test retained the null hypothesis of no difference. Results of the one-way, repeated measures ANOVA for the measures of percentage change across the interventions on the following directions task was found not to be statistically significant $F(13,33) =.06$, $p=.94$, partial $\eta^2=.01$.

Math challenge tasks of CPI. A Friedman test was conducted on first group's first four assessments, excluding the 25th assessment session, in order to have more participants in the statistical analysis. No statistically significant differences were found when comparing the mean score of the four math challenge assessments in the first group of participants in the study $X^2(3)=.96$, $p=.81$, $\varphi c =.16$. Multiple comparisons were not performed because no significant differences were found.

A Greenhouse-Geisser corrected one-way repeated measure ANOVA on the first group of students participating in the math challenge tasks of the CPI indicated no statistically significant differences across time on the percent of change on the math challenge task $F(2,44)=.93$, $p=.41$, partial $\eta 2=.07$.

A Friedman test was conducted on the second group's five sessions of assessments. No statistically significant differences were found when comparing the mean score of the five math challenge assessments in the second group of participants in the study $X^2(4,N=9)=3.46$, $p=.48$, $\varphi c=.31$.

Results of the Greenhouse-Geisser corrected one-way, repeated measures ANOVA on the second group of students participating in the math challenge tasks of the CPI across all 5 assessment periods indicated that there was no statistically significant difference across time on the percent of change on the following directions task $F(2,44)=.55$, $p=.59$, partial $\eta^2=.06$. Post-hoc analyses were not conducted.

Results of the one-way repeated measure ANOVA on the second group of students participating in the math challenge tasks of the CPI across all 4 assessment periods indicated that there were no statistically significant differences across time on the percent of change on the following directs task $F(2,44)=.75$, $p=.44$, partial $\eta 2=.85$. Post-hoc analyses were not conducted because the null hypothesis was retained.

Percent change on math challenge tasks. A Friedman test was administered on all four of the assessment sessions measuring percentage increase on the math challenge tests on CPI. The percent change on the math challenge task for the seventeen participants found no statistically significant differences among the test sessions $X^2(3) =.20$, $p=.98$, $\varphi c =.08$. Multiple comparisons were not performed because the overall test retained the null hypothesis of no difference. Results of the Greenhouse-Geisser corrected one-way, repeated measure ANOVA from baseline to the 25th session found no statistically significant differences across time on the percent of change on the math challenge task F (2,44)=.56, p=.57, partial $\eta 2$=.03.

A Friedman test was conducted on the three groups of assessments, excluding the 25th assessment session, in order to have more participants in the statistical analysis (N=21). The percent change on the math challenge task for twenty one participants found no statistically significant differences among the test sessions $X^2(2) =.99$, $p=.61$ $\varphi c =.15$. Multiple comparisons were not performed. Results of the one-way, repeated measures ANOVA from baseline to the 20th session found no statistically significant differences across time on the percentage of change on the math challenge task F (2,40)=.89, p=.42, partial η^2=.04, thus post-hoc analysis were not conducted.

Statistical Analyses of Individualized Assessments

One-way repeated measures ANOVAs were conducted to compare the effect of the working memory on the students' performances on various tests measuring various memory and learning tasks, fluid reasoning, and math achievement.

Wide Range Assessment of Memory and Learning-Second Edition (WRAML-2). Research question three. Does the training result in near-transfer and far-transfer effects on different tasks of memory and learning, as measured by the WRAML2 at 4 weeks and 4 months following the conclusion of the training?

To assist in addressing the research question regarding near and transfer effects of the working memory intervention program on other cognitive tasks, subtests from the WRAML-2 were individually administered to participants in this study to establish a baseline of performance, with follow-up sessions being conducted four weeks after the conclusion of the intervention and 4-months after the completion of the training.

Story memory. A Greenhouse-Geisser corrected one-way repeated measures ANOVA found significant differences among the scaled scores across the experimental period F (2, 44) =13.75, p=.001, partial η^2=0.38. A paired sample t-test was used to determine whether there was a statistically significant change in scores between the story memory post-test assessment at 4-weeks, when compared with the pre-test assessment of story memory t(22)=3.89, p=.001, d= .37. A paired sample t-test was also used to measure change between the pre-test assessment and 4-month post- test assessment (M= 7.82, SD=2.76), t(22)=3.8, p=.001, d=.68. A paired sample t-test was also conducted to measure significant changes between the post-tests assessments, t(22)=2.61, p=.02, d=.21.

V*erbal *learning. A Greenhouse-Geisser corrected one-way, repeated measures ANOVA found statistically significant differences among the scaled scores across the experimental period *F* (2,44)=6.86, *p* =.01, partial η^2=.24. Results of a paired-sample t-test found a statistically significant improvement between the pre-test assessment to the 4-weeks post-test assessment, *t* (22) =2.36, *p*= .03, *d*=.37. Results were also compared, using the paired-sample t-test to compare post-test results collected 4-months after the intervention to the pre-test assessment, *t* (22) = 2.84, *p*=.01, *d*=.67. A paired sample t-test was also conducted to measure significant changes between the post-tests assessments on the verbal learning subtests *t* (22) =2.24,*p*=.04, *d*=.05.

Finger windows. Because of the observed outlier and concern with normal distribution of the data on the four-week posttest assessment, the non-parametric Friedman test was initiated to determine if there were differences on the finger-windows results in relation to the working memory intervention. Significant differences were found at the different assessment periods χ2(2) = 28.64, *p* =.000, *φc* =.79. The Friedman test showing a statistically significant differences in scores from pre-test (Median =6.0) to the 4-week post intervention (Median=10.0) (*p*=.0005) and pre-test to the four-month post-test of the intervention (Median=9.00)(*p*<.002) were found. A statistically significant difference was not found between the two post-test assessment periods.

Because the one-way repeated measures ANOVA is considered fairly robust, the assumptions of the repeated measures were also further investigated despite the outliers and concern with normal distribution on the four-week post-test assessments. A Greenhouse-Geisser corrected one-way, repeated measures ANOVA analysis found statistically significant differences among the scaled scores across the experimental period *F* (2,44)=26.49, p=.000, partial η^2=.55. Results of the paired-sample t-test found a statistically significant improvement from the baseline (*M*=5.52, SD=2.52) assessment to the four-week post-test assessment (*M*=9.91, SD=2.52), *t* (22)=5.97, *p*=.00, *d*=-1.74. A paired-sample t-test found a statistically significant improvement when comparing the 4-month post-test (M=9.04, SD=2.70) assessment to the baseline assessment, *t* (22) =4.84, *p*=.00, *d*= 1.35. Paired t-test comparing performance between post-tests found statistically significant changes *t* (22) =2.21, *p*=.04, *d*=.33.

Number-letter subtest. Because of the observed outliers, the non-parametric Friedman test was initiated to determine if there were differences on the Number Letter subtest in relation to the working memory intervention. Statistically significant differences were found at the different assessment periods $\chi 2$ (2) = 6.38, *p* = .04. Φc = .37. Pairwise comparisons were performed using a Bonferroni post-hoc correction for multiple comparisons. No statistically significant difference was found between each of the assessment periods: pre-test (Median=8.0) and post-test assessment at 1 month (Median=9.0) (*p*=.17); pre-test and post-test assessment at 4 months (Median =9.0) (*p*=.20), and post-test 1 month to 4 month post-test assessment (*p*=1.00) on the adjusted level of significance.

A Greenhouse-Geisser corrected one-way, repeated measures ANOVA found statistically significant differences among the scaled scores across the experimental period, *F* (2,44) =5.37, *p*=.01, partial $\eta 2$=.19. Results of the paired-sample-t-test found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, *t* (22) =2.48, *p*=.02, *d*=.49. Results comparing the 4-month post-test assessment to the pre-test assessment was also found to demonstrate a statistically significant improvement, *t*(22)=2.83, *p*=.01, *d*=.46 Paired-sample t-test did not find a statistically significant difference between post-tests assessment *t*(22)=-.59, *p*=.57, *d*=.08.

Verbal working memory. Because outliers were found, the non-parametric Friedman test was run to determine if there were differences in the verbal working memory scores across assessment periods. The Verbal Working Memory score was found to be statistically, significantly different at the various assessment points in relation to the working memory intervention $\chi 2$ (2) =12.583, *p*=.002, φc =.52. Pairwise comparisons were performed with a Bonferroni post hoc test. Post hoc analysis revealed statistically significant difference between the pre-test (Median=7) to the post-test four week (Median=8) (*p*=.01). Statistically significant differences were not found between the pre-test assessment and the four-month post-test assessment (Median= 8) (*p*=.14) and between the 4 week post intervention assessment and the 4-month post intervention session (*p*=.81).

A one-way repeated measures ANOVA found statistically significant differences among the scaled scores across all three time periods F (2, 44) =8.63, p=.001, partial η^2=0.28.

A paired-sample-t-test on the verbal working memory subtest found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, t(22)=3.96, p=.001, d=.63. Results comparing the 4-month post-test assessment to the pre-test assessment did not find a statistically significant improvement on the performance in verbal working memory t (22) =2.58, p=.18, d=.47. Paired-sample t-test comparing the 4-month post-intervention session to the 4 weeks post-intervention session were not found to be statistically significant t (22)=1.27, p=.22, d=.16.

Design memory. A Greenhouse-Geisser corrected one-way, repeated measures ANOVA did not find statistically significant differences among the scaled scores across the experimental period F (2,44)= 1.8, p=.18, partial $\eta 2$=.08. Results of the paired-sample-t-test on the design memory subtest did not find a statistically significant improvement from the baseline assessment to the four-week post-test assessment, t (22) =1.21, p=.24, d=.16. Results comparing the 4-month post-test assessment on design memory to the pre-test assessment was not found to be statistically significant on the performance in design memory t(22)=1.56, p=.13, d=.11. Results comparing the 4-month post-test assessment on design memory to the 1-month post-test assessment was not found to be statistically significant on the performance in design memory $t(22)=.86$, $p=.4$, $d=.04$.

Picture memory. A Friedman test was run to determine if there were any statistically significant differences in scores across the three assessment periods. Results were found to be statistically significant at the different time periods $\chi2(2)=15.051$, $p=.001$, $\varphi c=.58$. Pairwise comparisons were performed with a Bonferroni post-hoc correction for multiple comparisons. Post-hoc analysis did not find the results to be statistically significantly different between the pre-test assessment (Median=11.0) and 4 week posttest assessment (Median=12.0) ($p=.554$). Results were found to be statistically, significantly different between the pre-test assessment and 4-month (Median=12) ($p=.01$). No statistically significant differences were found between the 4 week post-test intervention and the 4-month posttest assessment ($p=.23$).

Results of Greenhouse-Geisser corrected one-way repeated measures ANOVA did find statistically significant differences among the scaled scores across the experimental period F (2,44)=41.83, $p=.01$, partial $\eta2=32$. Results of the paired-sample-t-test on the picture memory subtest found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=2.54$, $p=.02$, $d=.44$. Results comparing the 4-month post-test assessment to the pre-test assessment were also found to demonstrate a statistically significant improvement on the performance in picture memory, $t(22)=3.83$, $p=.001$, $d=.6$. A statistically significant increase was found when comparing the results from the 4-week follow-up assessment to the 4-month follow-up assessment *t* (22)=3.03, *p*=.01, *d*=.19.

Symbolic working memory. A Friedman test was run to determine if there were differences in the performance on the symbolic working memory subtest in relation to the implementation of the working memory intervention. Pairwise comparisons were performed with a Bonferroni post-hoc correction for multiple comparisons. The results were found to be statistically significant at different points during the experimental period $\chi 2$ (2) =33.71, *p*=.000, φc =86. Post hoc analysis found statistically significant differences on the symbolic working memory test from pre-test to the 4 week post-test assessment and from the pre-test to the 4 month post-test intervention period. No statistically significant difference was found between the 4-week post- test assessment and the 4-month post-test assessment.

A Greenhouse-Geisser corrected one-way, repeated measures ANOVA found a statistically significant differences among the scaled scores across the experimental period *F* (2,44)=34.4, *p*= .05, partial $\eta 2$=.610. Results of the paired-sample-t-test on the symbolic working memory subtest found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, *t*(22)=6.51, *p*=.00, *d*=-1.64. Results comparing the 4-month post-test assessment to the pre-test assessment were also found to demonstrate a statistically significant improvement on the performance on symbolic working memory, $t(22)=6.27$, $p=.00$, $d=-1.51$. A statistically significant difference was not found between the two post-test assessments $t(22)=-.94$, $p=.36$, $d=.14$.

Working memory. Because outliers were found, a Friedman test was run to determine if there were differences on the working memory scaled scores across the assessment periods. The scaled scores of the Working Memory index was found to be statistically significant at the different time points $\chi 2$ (2) =23.71, $p=.000$, φc =.72. Pairwise comparisons were performed with a Bonferroni post-hoc correction for multiple comparisons. Post hoc analysis revealed statistically significant differences in the working memory scaled scores from pre-test assessment to post-test 4 weeks intervention, and from pre-test to post-test 4 months intervention . No statistically significant differences were found between the 4 week post-test assessment and the 4 month post-test assessment.

A Greenhouse-Geisser corrected one-way, repeated measures ANOVA found statistically significant differences among the scaled scores across the experimental period F (2, 44) =9.07, $p=.002$, partial $\eta^2=.29$. The Bonferroni adjustment was used on post-hoc analysis of the data. It was found that Post-hoc analysis using the Bonferroni adjustment indicated that scaled scores increased from the pre-intervention session (M=79.48, SD=11.12) to 4 week post-test session (M=92.22, SD=21.45) at a level of statistical significance. A statistically significant difference was found when comparing performance at baseline with the results at the 4-month follow-up assessment (M=93.57, SD=12.23). A statistically significant different was not found between the 4-week post intervention results and 4 month- post intervention results.

Results of the paired-sample-t-test on the working memory subtest found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, *t*(22)=2.81, *p*=.01, *d*=.75.Results comparing the 4-month post-test assessment to the pre-test assessment was also found to demonstrate a statistically significant improvement on the performance on working memory, *t*(22)=5.99, *p*=.000, *d*=1.21. A significant difference was not found between the two post-test assessments *t*(22)=.36, *p*=.72, *d*= .08.

Verbal memory. A Friedman test was run to determine if there were differences in verbal memory composite scaled scores in relation to the working memory intervention. The Verbal Memory scaled scores were found to be statistically significantly different at the various assessment periods $\chi2(2)$ =25.05, *p*=.000, *φc* =.74. Pairwise comparisons were performed with a Bonferroni correction for multiple comparisons. Post hoc analysis found statistically significant differences between pretest assessment and the 4-week post-test assessment and the pre-test and 4-month post-test assessment. There were no statistically significant differences found between the 4-week post-test assessment and the 4-month post-test assessment.

Results of analysis on Greenhouse-Geisser corrected one-way, repeated measures ANOVA did find statistically significant differences among the scaled scores across the experimental period *F* (2,44),*p*=18.64, *p*=.05, partial *η2*=0.46. Results of the paired-sample-t-test on the verbal memory composite found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=4.93$, $p=.000$, $d=.52$.

Results comparing the 4-month post-test assessment to the pre-test assessment was also found to demonstrate a statistically significant improvement on the performance on verbal memory composite, $t(22)=4.51$, $p=0.00$, $d=.81$. A statistically significant differences was also found when comparing differences between the two post-interventions assessments $t(22)=2.98$, $p=.01$, $d= .32$.

Visual memory. Because outliers were found, the Friedman test was run to determine if there were differences across the three assessment periods. The mean of the Visual memory scaled scores were found to be statistically significant at the different assessment periods $\chi2(2) =8.58$, $p=.01$, $\varphi c=.43$. Pairwise comparisons were performed with a Bonferroni post-hoc correction for multiple comparisons. Post hoc analysis revealed statistically significant differences from the pre-test to the 4 month post-test assessment. No statistically significant differences were found between the pre-test assessment to the 4 week post-test assessment and between the 4 week post-test and 4 month post-test assessment.

A Greenhouse-Geisser corrected one-way, repeated measures ANOVA found statistically significant differences among the scaled scores across the experimental period $F\ (2,44),p=8.07$, $p=.003$, partial $\eta^2=0.27$. Results of the paired-sample-t-test on visual memory found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=2.98$, $p=.01$, $d=.34$. Results comparing the 4-month post-test assessment to the pre-test assessment was also found to demonstrate a statistically significant improvement on the performance on visual memory, $t(22)=3.17$, $p=.004$, $d=.43$. No significant difference was found between the two post-intervention assessments, $t(22)=1,31$, $p=.2$, $d=.12$.

Attention concentration. Because outliers were found, a Friedman test was run to determine if there were differences in the attention concentration mean in response to the working memory intervention. The Attention Concentration mean scaled scores were found to be statistically significant at different points of the experimental period $\chi 2(2) =27.61$, $p=.00$, $\varphi c =78$. Pairwise comparisons were also performed with a Bonferroni post-hoc correction for multiple comparisons. Post hoc analysis revealed statistically significant differences on the scaled scores of Attention Concentration from pre-test intervention to the 4 week post-test intervention, and from the pre-test intervention assessment to the 4 month post-test assessment No statistically significant difference was found between the post-test 4 week intervention assessment and the 4-month intervention assessment.

Despite the presence of outliers, a Greenhouse-Geisser corrected one-way, repeated measures ANOVA was also conducted because ANOVA is fairly robust to deviations from normality. Results of the Greenhouse-Geisser corrected one-way, repeated measures ANOVA found statistically significant differences among the scaled scores across the experimental period F (2,44*),p*=22.96, *p*=.005, partial η^2=0.51.

Results of the paired-sample-t-test on the attention-concentration composite found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, *t*(22)=5.26, *p*=.000, *d*=1.21. Results comparing the 4-month post-test assessment to the pre-test assessment were also found to demonstrate a statistically significant improvement on the performance on the attention-concentration composite, *t*(22)=5.16, *p*=.000, *d*=99. A statistically significant difference was not found between the two post-interventions sessions *t*(22)=1.80, *p*=.9, *d*= .23.

General memory composite. A Friedman test was run to determine if there were differences in the total mean of the General Memory composite across time. The mean scaled scores of the General Memory composite was statistically significantly different at the various time points in relation to the timing linked with the working memory intervention $\chi 2(2) = 20.17$, *p* =.000, *φc* =.66. Pairwise comparisons were performed with a Bonferroni post-hoc correction for multiple comparisons. Post hoc analysis revealed statistically significant differences in the General Memory composite from pre- to post-intervention four week post-intervention assessment and at the 4-month follow-up assessment post-intervention, but at not four week post- and 4-month post.

Despite the presence of outliers, a one-way repeated measures ANOVA was also conducted because ANOVA is fairly robust to deviations from normality. Results of analysis on test of within-subject effects found statistically significant differences among the scaled scores across all three time periods F (2,44)=4.61, p=.02, partial η^2=.17.

Results of the paired-sample-t-test on the general memory composite found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, t(22)=3.88, p=.001, d=.78. Results comparing the 4-month post-test assessment to the pre-test assessment were found not to demonstrate a statistically significant improvement on the performance on the general memory composite, t(22)=1.22, p=.24, d=.35 The results were not found to be statistically, significantly different between the post-interventions assessments t(22)=1.6, p=.12, d=.43

Fluid reasoning assessments. Research question 4. Does the training improve far-transfer effects in the area of fluid intelligence, as measured by standardized assessments at 4 weeks and 4 months after the completion of the training?

Analysis/Synthesis. Because an outlier was found, the non-parametric test Friedman test was run to determine if there were differences in the analysis/synthesis subtest during the experimental period. The standard scores of the Analysis/Synthesis subtest were statistically different at the different time points during the experimental period $\chi2(2)$=13.23, p=.00, φc = .54. Pairwise comparisons were performed with a Bonferroni post-hoc correction for multiple comparisons. Post hoc analysis revealed differences in the Analysis/Synthesis subtest scores from the pre-test to the 1 month post-test assessment and to the pre-test to the 4 month post-test assessment . No statistically significant difference was found between the 1 month post-test assessment and the 4-month post-test assessment.

A one-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences on the mean scaled scores of fluid reasoning skills, as elicited from a working memory intervention. Results found statistically significant differences among the scaled scores across all three time periods F (2,44)=8.36*,* p=.001, partial η^2=.28. Results of the paired-sample-t-test on the analysis/synthesis found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, t(22)=4.29, p=.000, d=.85. Results comparing the four-month post-test assessment with the pre-test assessment on analysis synthesis was also found to be statistically significantly different t(22)=3.02, p=.01, d=.77. No statistically significant differences were found between the 4-week post intervention assessment and the post 4-month post intervention assessment t(22)=.22, p=.83, d=.04.

Concept formation**.** A one-way, repeated measures ANOVA was conducted to determine whether there was statistically significant improvement on the mean scaled scores of the concept formation subtest, a fluid reasoning tasks, as elicited from a working memory intervention. Statistically significant differences among the scaled scores across all time periods were found F (2,44)=22.13*,* p=.000, partial η^2=0.50.

Results of the paired-sample-t-test on the concept formation subtest found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=4.4$, $p=.000$, $d=.09$. Results comparing the 4-month post-test assessment with the pre-test assessment on concept formation was also found to be statistically significantly different $t(22)=6.55$, $p=.000$, $d=1.27$. No significant differences were found between the 4-week and 4-month post intervention sessions $t(22)=1.51$, $p=.15$, $d=.24$.

Fluid reasoning cluster. Because an outlier was found, a Friedman test was run, in addition to the ANOVA repeated measures, to assist in assessing the degree to which the outlier may have influenced the interpretation of the impact that the working memory intervention had on the results of the fluid reasoning assessment. The score on the fluid reasoning cluster was found to be statistically different at the various assessment points of the investigation, $\chi2(2) =24.67$, $p=.00$, $\varphi c=.73$. Pairwise comparisons were performed, using a Bonferroni correction for multiple comparisons. Post hoc analysis revealed statistically significant differences on the mean of the scaled scores of the fluid reasoning cluster for the participants, from pre-assessment intervention to the 4 week post-intervention assessment, and from pre- to the 4 month post-intervention test No statistically significant differences were found between the 4 week post-test assessment and the 4 month post-test assessment.

A one-way repeated measures ANOVA was conducted to determine whether there were statistically significant differences on the mean scaled scores of fluid reasoning skills, as elicited from a working memory intervention. Results of one-way repeated measures ANOVA found statistically significant differences among the scaled scores across all three time periods $F\ (2,44)=24.76,\ p=.000$, partial $\eta^2=.53$. Results of the paired-sample-t-test on the fluid reasoning cluster found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=5.37$, $p=.000$, $d=.09$. Results comparing the 4-month post-test assessment to the pre-test assessment on the fluid reasoning composite was also found to be statistically significantly $t(22)=6.4$, $p=.000$, $d=-1.15$. No statistically significant differences were found between the 4-week post intervention assessment and the post 4-month post intervention assessment $t(22)=.96$, $p=.35$, $d=.14$.

Math achievement. Research question 5. Does the training result in far-transfer effects in the area of math, as measured by standardized achievement test at 4 weeks and 4 months after the conclusion of the training?

Math fluency. To further assess the impact that the outlier had on the math fluency results, the nonparametric Friedman test was also run to determine if there were mean differences on the math fluency scaled score in response to the working memory intervention. Math fluency was statistically significantly different at different points of the study, $\chi2(2) = 6.77$, $p=.03$,$\varphi = .38$. Pairwise comparisons were performed with a

Bonferroni post-hoc correction for multiple comparisons. Post hoc analysis revealed statistically significant differences in math fluency from the pre-test to the 4 week post-test assessment; however, statistically significant differences were not found between the pre-test assessment the four month follow- up or between the two post-test assessments.

Using the one-way repeated measures ANOVA, statistically significant increases were found in the mean score on the math fluency subtests $F(2,44)=3.38$, $p=.04$,partial $\eta 2=.13$ when examining data across time. Results of the paired-sample-t-test on the math fluency found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=-3.39$, $p=.003$, $d=-.46$. Results comparing the 4-month post-test assessment to the pre-test assessment on math fluency did not find a statistically significant change $t(22)=-1.37$, $p=.186$, $d=-.29$. No statistically significant differences were found between the 4-week post intervention assessment and the post 4-month post intervention assessment $t(22)=-.94$, $p=.36$, $d=.16$.

Applied problems. A Friedman test was conducted to evaluate the differences in medians for applied problems across time. Twenty-three participants were scored at three different time periods. The test was not significant, $X^2(2, N=23)=4.43$, $p=.11$, $\varphi c=.31$.

Results of the Greenhouse-Geisser corrected one-way, repeated measures ANOVA found statistically significant differences among the scaled scores across all three time periods, $F(2,44)=23.63$, p=.000, partial $\eta^2=0.52$. Results of the paired-sample-t-test on the applied problems subtest found a statistically significant improvement from the baseline assessment to the four-week post-test assessment, $t(22)=-3.99$, $p=.001$, $d=.78$. Results comparing the 4-month post-test assessment to the pre-test assessment on applied problems did find a statistically significant change, $t(22)= 6$, $p=.00$, $d=-1.25$ .A statistically significant difference was found between the 4-week post intervention assessment and the post 4-month post intervention assessment, $t(22)=3.35$, $p=.003$, $d=-.48$.

Math calculation subtest. The results suggest that the working memory intervention did not elicit statistically significant changes in math calculation scores across time using the Greenhouse-Geisser corrected, one-way repeated measures ANOVA, F (2,44)= 18.07, $p=.28$, partial $\eta^2=.06$. Results of the paired-sample-t-test on the math calculation subtest did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=-.75$, $p=.464$, $d=.13$. Results comparing the 4-month post-test assessment to the pre-test assessment on math calculation also did not find a statistically significant change $t(22)=-1.32$, $p=.2$, $d=.31$ A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment, $t(22)=1.27$, $p=.22$, $d=.16$.

Brief math. Because an outlier was found that presents a challenge to the assumptions underlying the use of ANOVA repeated measures, the nonparametric test Friedman test was run to investigate if there were differences on the Brief Math cluster results throughout the phases of the study, $\chi2(2) =15.163$, $p=.001$, $\varphi c =.57$. Pairwise comparisons were performed with a Bonferroni-post hoc correction for multiple comparisons. The Brief Math cluster results were statistically, significantly different during the investigation of the far transfer effects of the working memory intervention. Post hoc analysis indicated that there was no statistically significant difference between the pre-test assessment and the 1 month post-test assessment. A statistically significant difference was found between the pre-test assessment results and the 4-month post assessment and also between the post-assessment at 1 month to the 4-month post assessment.

Results of analysis on one-way repeated measures ANOVA found statistically significant differences among the scaled scores across time $F\ (2,44)=19.81$, $p=.00$, partial $\eta^2=0.47$. Results of the paired-sample-t-test on the brief math cluster did find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=2.76$, $p=.01$, $d=.49$. Results comparing the 4-month post-test assessment to the pre-test assessment on the brief math cluster also found a statistically significant change, $t\ (22)=6.20$, $p=.000$, $d=1.01$. A statistically significant difference was also found between the 4-week post intervention assessment and the post 4-month post intervention assessment, $t\ (22)=3.92$, $p=.001$, $d=.93$.

Broad math. The results of the Greenhouse-Geisser corrected, one-way repeated measures ANOVA suggest that the working memory intervention elicited statistically significant changes on broad math achievement over time, $F\ (2,44)=18.07$, $p=.000$, partial $\eta^{2=}$0.45, with the mean of the standard scores continuing to increase from pre-intervention to the 4 months post-intervention. Results of the paired-sample-t-test on the broad math cluster did find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=3.52$, $p=.002$, $d=.54$. Results comparing the 4-month post-test assessment to the pre-test assessment on the broad math cluster also found a statistically significant change, $t\ (22) =4.94$, $p=.000$, $d=.34$. A statistically significant difference was also found between the 4-week post intervention assessment and the post 4-month post intervention assessment $t\ (22)=3.37$, $p=.003$, $d=.16$.

Math calculation cluster. The results suggest that working memory intervention did elicit statistically significant changes on the scaled scores on math calculation skills cluster over time, as measured by the Greenhouse-Geisser corrected one-way, repeated measures ANOVA, $F\ (2,44)=5.22$, $p=.02$, partial $\eta 2^{=}$1.92. Results of the paired-sample-t-test on the math calculation cluster did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=1.86$, $p=.08$, $d=.31$. Results comparing the 4-month post-test assessment to the pre-test assessment on applied problems also did not find a statistically significant change, $t(22)=2.83$, $p=.01$, $d=.49$ A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment $t(22)=1.59$, $p=.13$, $d=.16$.

Statistical Analyses of Executive Functioning Ratings

Research question 6. Does the program improve executive functioning skills, as measured by rating scale, as measured at 4 weeks and at 4 months after the completion of the training?

Behavior Rating Inventory of Executive Functioning-Teacher Rating Scale.

Inhibit scale. Because an outlier was found that presents a challenge to the assumptions underlying the use of one-way repeated measures ANOVA, the nonparametric Friedman test was run to investigate if there were differences on the teachers' rating scale on the mean inhibit T-score across time. The results of the inhibit score was not found to be statistically significantly different $\chi 2(2) = 5.361$, $p=.07$, $\varphi c=.34$. Multiple comparisons were not performed because no significant differences were observed.

Statistically significant changes in the mean score of the inhibit scale were found when examining the data across time F (2,44)=3.34, $p=.05$,partial $\eta 2=.18$. Results of the paired-sample-t-test on the inhibit scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.00$, $p=1.0$, $d=.00$. Results comparing the pre-test assessment with the 4 month-post-test assessment on inhibition did find a statistically significant change, $t(22)=2.17$, $p=.04$, $d=.56$ A statistically significant difference was also found between the 4-week post intervention assessment and the post 4-month post intervention assessment, $t(22)=2.34$, $p=.03$, $d=.05$.

Shift scale. Because an outlier was found that presents a challenge to the assumptions underlying the use of ANOVA repeated measures, a nonparametric Friedman test was run to investigate if there were differences on the teachers' rating scale on the shift score across time. The results of the shift score was not found to be statistically significantly different, $\chi2(2) =.76$, p=.69, $\varphi c =.13$. Multiple comparisons were not performed because the overall test retained the null hypothesis.

Results of the one-way repeated measures ANOVA indicate that statistically significant differences were not found in the mean score of the shift ratings by the teachers across the research period $F\ (2,44)=1.14$, $p=.33$ partial $\eta^{2=}.05$ Results of the paired-sample-t-test on the shift scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=1.13$, $p=.27$, $d=.32$. Results comparing the pre-test assessment with the 4 month- post-test assessment on the shift scale also did not find a statistically significant change, $t(22)=1.26$, $p=.22$, $d=.37$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment $t(22)=.22$, $p=.83$, $d=.05$.

Emotional control scale. Because outliers were found, the Friedman test was run to investigate if there were significant differences on the teachers' rating scale on the emotional control rating across time. The results of the emotional control scale was not found to be statistically significantly different $\chi2(2) = 3.08$, p=.21,. φc =.26 Multiple comparisons were not performed because the overall test retained the null hypothesis of no differences.

Results of analysis on test of within-subject effects did not find statistically significant differences among the scaled scores across the experimental period, F (2,44)=1.581, p=.22, partial η^2=.07. Results of the paired-sample-t-test on the emotional control scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, t(22)=.79, p=.44, d=.24. Results comparing the pre-test assessment to the 4 month- post-test assessment on the emotional control scale also did not find a statistically significant change, t(22)=1.62, p=.12, d=.48. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t(22)=1.25, p=.22, d=.24.

Behavior Rating Index (BRI). Because the results were not found to be normally distributed in each assessment phase, the Friedman test was run to investigate if there were differences on the teachers' rating scale on the BRI score across time. The results of the Behavior Rating Index was found to be statistically significantly different, $\chi2(2) = 6.1$, p=.05, φc =.36. Post hoc analysis did not reveal statistically significant differences among the assessment periods: pre-test assessment to 4-week post-test assessment (p=.17); pre-test assessment to 4-month post-test assessment (*p*=.12) and 4-week post-test assessment to 4 month post- test assessment (*p*=1.00).

A Greenhouse-Geisser corrected one-way repeated measures ANOVA found no statistically significant differences among the scaled scores across the experimental period, $F\ (2,44)=2.51$, $p=.11$, partial $\eta^2=.11$. Results of the paired-sample-t-test on the BRI of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.51$, $p=.62$, $d=.14$. Results comparing the pre-test assessment to the 4 month- post-test assessment on the BRI did find a statistically significant change, $t(22)=2.04$, $p=.05$, $d=.6$. A statistically significant difference was found between the 4-week post intervention assessment and the post 4-month post intervention assessment $t\ (22)=2.29$, $p=.03$, $d=.47$.

Initiate. Because the results were not found to be normally distributed in each assessment phase, the non-parametric Friedman test was run. The results of the teachers' ratings of the participants on the initiate scale was not found to be statistically different in relation to the working memory intervention, $\chi2(2)=1.44$, $p=.49$, $\varphi c=.17$. Post hoc analysis was not performed. When analyzing the data utilizing the one-way repeated measures ANOVA, significant changes in the mean score of the was not found when examining the data across time $F\ (2,44)=.85$, $p=.43$,partial $\eta^2=.04$. Results of the paired-sample-t-test on the initiate scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=1.11$, *p*=.28, *d*=.28. Results comparing the pre-test assessment with the 4 month- post-test assessment on the initiate scale also did not find a statistically significant change, *t*(22)=1.02, *p*=.32, *d*=.24. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment *t* (22)=.26, *p*=.8, *d*=.06.

Working memory. Because the results were not found to be normally distributed in each assessment phase, the Friedman test was run to investigate if there were differences on the teachers' rating scale on the working memory score across time. The results were found not to be statistically different in response to the working memory intervention, $\chi 2(2) = 3.28$, *p*=.19, $\varphi c = .27$.A non-parametric post hoc analysis was not performed because no statistically significant differences were observed.

When analyzing the data, utilizing the one-way repeated measures ANOVA, statistically significant changes in the mean score was found when examining the data across time $F(2, 44)=3.89$, *p*=.03,partial η^2=.15. Results of the paired-sample-t-test on the working memory scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, *t*(22)=1.4, *p*=.18, *d*=.34. Results comparing the pre-test assessment to the 4 month- post-test assessment on the working memory scale did find a statistically significant change, *t*(22)=2.7, *p*=.01, *d*=.61. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)=1.55, p=.14, d=.3.

Planning. Because the results were not found to be normally distributed in each assessment phase, the Friedman test was run to investigate if there were differences on the teachers' rating scale on the planning score across time. The results was not found to be statistically different in relation to the working memory intervention, $\chi2$ (2) =.47, p=.79, φc =.10.Post hoc analysis was not performed because the overall test retained the null hypothesis of no differences.

When analyzing the data utilizing the one-way repeated measures ANOVA, statistically significant changes in the mean score was not found when examining the data across time F (2, 44) =.46, p=.63, partial η^2=.02. Results of the paired-sample-t-test on the planning scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, t(22)=.54, p=.6, d=.15. Results comparing the pre-test assessment with the 4 month- post-test assessment on the planning scale also did not find a statistically significant change, t(22)=.91, p=.38, d=.22. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)=.43, p=.67, d=.08.

Organization. Because the scores were not found to be normally distributed, the Friedman test was run to investigate if there were differences on the teachers' rating scale on the organization scale of the BRIEF across time. The results was not found to be statistically different in relation to the working memory intervention, $\chi2(2)$ =23.5, p=.07, φc =.71. Post hoc analysis was not performed.

When analyzing the data utilizing the one-way repeated measures ANOVA, statistically significant changes in the mean score was not found when examining the data across time F (2, 44) =2.35 p=.11, partial η^2=.1. Results of the paired-sample-t-test on the organization scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, t(22)=.37, p=.72, d=.09. Results comparing the pre-test assessment to the 4 month- post-test assessment on the organization scale was found to have a statistically significant change, t(22)=2.43, p=.02, d=.52. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)=1.43, p=.17, d=.41.

Monitor. A Greenhouse-Geisser corrected one-way repeated measures ANOVA did not find statistically significant differences among the scaled scores across the experimental period F (2,44) =176.45, p=95, partial η^2=.37. Results of the paired-sample-t-test on the monitor scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, t(22)=.39, p=.7, d=.11. Results comparing the pre-test assessment to the 4 month- post-test assessment on the monitor scale was not found to have a statistically significant difference, t(22)=.79, p=.44, d=.23. A statistically significant difference was found between the 4-week post intervention assessment and the post 4-month post intervention assessment *t* (22)=2.19, *p*=.04, *d*=.37.

Metacognition. Statistically significant changes in the mean score of the metacognition rating scale was not found when examining the data across time on the metacognition scale, as assessed by the one-way repeated measures ANOVA, *F (*2, 44)=.57, *p*=.57, partial η^2=.03. Results of the paired-sample-t-test on the metacognition scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, *t*(22)=.55, *p*=.6, *d*=.15. Results comparing the pre-test assessment with the 4 month- post-test assessment on the metacognition scale also was not found to have a statistically significant difference, *t*(22)=1.03, *p*=.31, *d*=.25. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment *t* (22)= .55, *p*=.59, *d*=.11.

Global executive control (GEC). When analyzing the data, utilizing the one-way repeated measures ANOVA, statistically significant changes in the mean score were found when examining the data across time *F (*2, 44) =4.44 *p*=.02, partial η^2=.17. Results of the paired-sample-t-test on the GEC scale of the BRIEF did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, *t*(22)=.55, *p*=.59, *d*=.15. Results comparing the pre-test assessment with the 4 month-post-test assessment on the GEC scale also was not found to have a statistically significant difference, $t(22)=1.85$, $p=.08$, $d=.48$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= 1.81, $p=.09$, $d=.36$.

Statistical Analyses of Behavioral Symptoms of ADHD

Research question 7. Does the program reduce the frequency of inattention and hyperactivity symptoms in the classroom and home, as rated by teachers and parents, as measured at 4 weeks and at 4 months using standardized tools after the completion of the intervention?

Conners' teachers' rating scale.

Inattention. A one-way repeated measures ANOVA did not find statistically significant differences among the scaled scores on the inattention scale on the Conners' across the experimental period F (2, 44) =.32, $p=.73$, partial $\eta^2=.01$. Results of the paired-sample-t-test on the inattention scale of the Conners' Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.69$, $p=.50$, $d=.18$. Results comparing the pre-test assessment with the 4 month- post-test assessment on the inattention scale also were not found to have a statistically significant difference, $t(22)=.58$, $p=.57$, $d=.15$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= 1, $p=.92$, $d=.02$.

Hyperactivity/Impulsivity. Because the results were not found to be normally distributed, the Friedman test was run to investigate if there were differences on the teachers' rating scale on the hyperactivity/impulsivity scale of the Conners' Teachers Report across time. The results were not found to be statistically different $\chi 2$ (2) =1.01, p=.60, φc =.15. Post hoc analysis was not performed because the overall test retained the null hypothesis of no differences.

A one-way repeated measures ANOVA within-subject effects did not find statistically significant differences among the T-scores across the experimental period F (2, 44) =.35, p=.71, partial η^2=0.02. Results of the paired-sample-t-test on the hyperactivity/impulsivity scale of the Conners' Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, t(22)=.54, p=.6, d=.14. Results comparing the pre-test assessment to the 4 month- post-test assessment on the hyperactivity/impulsivity scale also were not found to have a statistically significant difference, t(22)=.69, p=.49, d=.18. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .26, p=.8, d=.05.

Learning problems/ executive functioning. A one-way repeated measures ANOVA did not find statistically significant differences among the scaled scores across the experimental period F (2, 44) =.58, p=.58, partial $\eta 2$=0.03. Results of the paired-sample-t-test on the learning problems/executive functioning scale of the Conners'

Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.39$, $p=.7$, $d=.1$. Results comparing the pre-test assessment to the 4 month- post-test assessment on the learning problems/executive function also were not found to have a statistically significant difference, $t(22)=.98$, $p=.34$, $d=.23$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .8, $p=.43$, $d=.15$.

Learning problems. Results of one-way repeated measures ANOVA did not find statistically significant differences among the scaled scores across the experimental period F (2, 44) =14.22, $p=.23$, partial $\eta^2=.01$. Results of the paired-sample-t-test on the learning problems scale of the Conners' Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.63$, $p=.53$, $d=.13$. Results comparing the pre-test assessment to the 4 month- post-test assessment on the learning problems scale was not found to have a statistically significant difference, $t(22)=.27$, $p=.79$, $d=.05$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .43, $p=.67$, $d=.07$.

Executive functioning. Results of analysis on test of within-subject effects did not find statistically significant differences among the scaled scores across the experimental period F (2, 44) =.69, $p=.51$, partial $\eta 2=.03$. Results of the paired-sample-t-test on the executive functioning scale of the Conners' Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.4$, $p=.7$, $d=.09$. Results comparing the pre-test assessment to the 4 month- post-test assessment on the executive functioning scale were not found to have a statistically significant difference, $t(22)=.69$, $p=.5$, $d=.16$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= 1.35, $p=.19$, $d=.25$.

ADHD inattentive scale. Results of analysis on test of within-subject effects did not find statistically significant differences among the scaled scores across the experimental period $F(2, 44)=.54$, $p=.59$, partial $\eta^2=.02$. Results of the paired-sample-t-test on the ADHD inattentive scale of the Conners' Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.48$, $p=.64$, $d=.11$. Results comparing the pre-test assessment to the 4 month- post-test assessment were not found to have a statistically significant difference, $t(22)=.91$, $p=.38$, $d=.24$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .48, $p=.64$, $d=.13$.

ADHD hyperactivity/impulsivity scale. Because of the concern with normal distribution of the data, the non-parametric Friedman test was initiated to determine if there were differences on the teachers' ratings on the presentation of ADHD hyperactivity/impulsivity symptoms on the participants. Statistically significant differences were not found at the different assessment periods $\chi2$ (2) = .62, *p* =.73, φc =.12. Multiple comparisons were not performed because the overall test retained the null hypothesis of no differences.

A Greenhouse-Geisser one-way repeated measures ANOVA found no statistically significant differences among the scaled scores across the experimental period on the teachers' rating on this scale *F* (2,44)=.25, *p*=.72, partial η^2=0.01. Results of the paired-sample-t-test on the ADHD hyperactivity/impulsivity scale of the Conners' Teachers Rating Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, *t*(22)=.54, *p*=.6, *d*=.13. Results comparing the pre-test assessment to the 4 month- post-test assessment were not found to have a statistically significant difference, *t*(22)=.56, *p*=.58, *d*=.14. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment *t* (22)= .11, *p*=.91, *d*=.02.

Conner's 3 self-report. Participants in this study completed the Conner's Self-Report prior to participating in the intervention, 4 weeks after the intervention, and 4 months after the intervention. Measurements to be examined included the participants' self-reports on inattentive behaviors and hyperactivity/impulsive behaviors.

***Self-report on inattention*.** Results of the ANOVA repeated measure test found no statistically significant differences in the inattention behaviors across time *F (*2,44)

=.459, p=.57, partial $\eta^{2=}$02. Results of the paired-sample-t-test on the inattentive scale of the Conners' Self-report Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=1.31$, $p=.21$, $d=.16$. Results comparing the pre-test assessment to the 4 month- post-test assessment were not found to have a statistically significant difference, $t(22)=.77$, $p=.45$, $d=.16$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .4, $p=.69$, $d=.01$.

Self-report on hyperactivity/impulsive. A Friedman test was conducted on the three assessments across the time period. No statistically significant differences were found at the different assessment periods $\chi2(2) = 4.26$, $p = .12$, $\varphi c=.30$. Multiple comparisons were not conducted. Results of analysis on test of within-subject effects did not find statistically significant differences among the total mean T-score scores on the inattention scale $F(2,44)=2.84$, $p=.07$, partial $\eta^2=.11$. Results of the paired-sample-t-test on the hyperactivity/impulsivity scale of the Conners' Self-report Scale did find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=2.5$, $p=.02$, $d=.37$. Results comparing the pre-test assessment with the 4 month- post-test assessment were not found to have a statistically significant difference, $t(22)=1.89$, $p=.07$, $d=.41$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .26, $p=.8$, $d=.05$.

ADHD predominantly inattention type symptom scale on Conners' Self-report. Results of one-way repeated measures ANOVA did not find statistically significant differences among the total mean T-score scores on the inattention symptom scale $F(2,44)=1.03$, $p=.36$, partial $\eta^2=.05$. Results of the paired-sample-t-test on the ADHD Inattentive scale of the Conners' Self-report Scale did find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.6$, $p=.55$, $d=.15$. Results comparing the pre-test assessment with the 4 month- post-test assessment were not found to have a statistically significant difference, $t(22)=1.25$, $p=.23$, $d=.33$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= 1.03, $p=.32$, $d=.20$.

ADHD predominantly hyperactivity/impulsivity type on Conner's Self-report. Results of analysis on test of within-subject effects did not find statistically significant differences among the total mean T-score scores on the Hyperactivity/Impulsivity Symptom Scale $F(2, 44)=2.58$, $p=.12$, partial η2=.11. Results of the paired-sample-t-test on the ADHD hyperactivity/impulsivity scale of the Conners' Self-report Scale did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, $t(22)=.83$, $p=.41$, $d=.47$. Results comparing the pre-test assessment with the 4 month- post-test assessment were not found to have a statistically significant difference, $t(22)=1.56$, $p=.13$, $d=.44$. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment t (22)= .83, p=.41, d=.03.

Teachers' DSM-IV-TR checklist. The DSM-IV-TR checklist, a rating scale used as part of the protocol designed by Cogmed (2011), was administered to the participants' teachers and parents prior to the intervention, 4-weeks after the intervention and 4-months after the completion of the intervention. Because of the difficulty in retrieving the forms from the parents of each participant across each of the testing phases, the statistical analyses were not completed on the parents' rating scales. Because of the concern with normal distribution of the data, the non-parametric Friedman test was initiated to determine if there were differences on the teacher rating on the presentation of ADHD hyperactivity symptoms as measured by the DSM-IV-TR checklist on the participants. Pairwise comparisons were performed using a Bonferroni correction for multiple comparisons. Statistically significant differences were found at the different assessment periods $\chi2(2) = 6.42$, p =.04, φc =.37. Post hoc analysis did not reveal statistically significant difference between the pre-test *(M*edian=17) to the post-test 4 week *(M*edian=17). A statistically significant decrease was found between the pre-test assessment and the 4-month post-test assessment *(M*edian= 12) (p=.05). No statistically significant difference was found between the post test administered at 1 month and the 4-month post-test assessment and between the 4 week post intervention assessment and the 4-month post intervention session.

A one-way repeated measures ANOVA found a statistically significant differences among the scaled scores across the experimental period F (2, 44) =4.41, *p*=.02, partial η^2=.17. Results of the paired-sample-on the DSM-IV checklist did not find a statistically significant change from the baseline assessment to the four-week post-test assessment, *t*(22)=1.71, *p*=.10, *d*=.41. Results comparing the pre-test assessment to the 4 month- post-test assessment were not found to have a statistically significant difference, *t*(22)=2.74, *p*=.01, *d*=.41. A statistically significant difference was not found between the 4-week post intervention assessment and the post 4-month post intervention assessment *t* (22)= 1.31, *p*=.2, *d*=.29.

Chapter 5: DISCUSSION

This study was conducted to contribute to the research on interventions implemented within in the school setting to address the neuropsychological weaknesses found in individuals with ADHD and math disabilities. The impact of a computerized working memory intervention in improving performance on various memory and learning tasks, fluid reasoning, and math achievement tasks was investigated. Behavioral rating forms were also administered to assess observations of specific behaviors across time. Although there is a growing body of evidence supporting the benefits of computerized interventions to improve performance on trained tasks, there has been little research examining its effectiveness on near and far transfer effects on various cognitive constructs and math achievement. Related studies have occurred in the home setting, but this study is one of the first of its kind to investigate the effectiveness of a working memory training program implemented in a public school setting in the United States with individuals receiving special education services. Additionally, this research contributed to the field of computerized interventions with school-aged children by examining the long-term effectiveness of the training by analyzing assessment data collected at four weeks and at four months after the completion of the intervention. This chapter discusses the meaning of the results and the limitations of the study, and examines the implications of findings for practice, policy and future research.

Summary of Overall Findings

Overall, the results support previous research indicating that transfer effects do occur on untrained tasks of memory and learning (Thorell et al., 2009). The generalizability of the training on the various cognitive tasks assessed in this study must be considered because it possesses a theoretical challenge, based on the understanding that various cognitive processes have distinct neural and cognitive underpinnings (Curtis & D'Esposito, 2003; Holmes, 2009) Because of the complexity involved in defining and measuring cognitive functions, it remains unclear how the training affected the specific cognitive functions assessed. Previous research has suggested that the areas of the brain linked with working memory are activated, regardless of the type of stimuli being held in working memory, thus contributing to the improvement of other types of cognitive tasks. It has also been reported that improvement on tasks not directly linked to training can be explained through the understanding that plasticity of the neural systems underlying each cognitive component can be enhanced by the intensive training (Curtis & D'Esposito, 2003; Hautzel et al., 2002; Klingberg, 1998). As reported by Holmes et al., (2009), it was also suggested that the training may not necessarily increase WM capacity, but rather the intensity and duration of the intervention program may a) increase WM strategies that are utilized to compensate for weaknesses in basic cognitive processes, or b) may be more directly related to improving the voluntary control of attention.

In further examining the robust findings on the tasks linked with attention/concentration tasks, it is important to consider more closely the impact the intervention had in improving processes directly linked with attention. It is difficult to differentiate attention from working memory with the realization that attention is necessary in order for memory to be put into a form to be reinstated later (Posner & Rothbart, 2007). As addressed in the literature review, there are different theories on attention and working memory and on the relationship between the different processes. Within each model, there are also various systems and processes that are delineated and integrated together to explain attention systems and working memory processes. Executive attention is one term that has been referenced as central to young people's ability to regulate their emotions and their cognitions and thus influence performance in the curriculum (Posner & Rothbart, 2007). It can be hypothesized that the intensive training the participants received from the computerized intervention facilitated improvement in executive attention, which allowed them to improve in the other cognitive tasks, including fluid reasoning and working memory. The question could thus be raised about whether the training improves what has been described as working memory or if it primarily improves attentional capacity, which contributes to the improvement in various cognitive tasks. In examining the types of tasks implemented on the computerized training program, the activities are primarily visual-spatial in nature, appearing to tap skills that improve attention and ability control (Holmes & Gathercole, 2013; Kane & Engle, 2003). In reviewing previous research, attentional skills have been found to correlate strongly with future learning and thus, these training gains in math could also be attributed to the improved attention/concentration performance (Gathercole et al., 2004; Jarvis & Gathercole, 2003).

Because attention and working memory have become increasingly more recognizable as hallmark features of individuals with ADHD and learning disabilities, computerized working memory training as an intervention option warrants further exploration in the field of education. It is suggested to continue to investigate whether or not training gains could transfer to a larger-scale within the school system, with controlled randomized trials to better understand the value it can have in improving the outcomes of struggling students. All working memory programs are not alike nor are they equivalent as indicated in the literature review; thus it is valuable to examine the current research on each model.

In summarizing the data collection on the behavioral observations reported by teachers on ADHD symptoms and Executive Functioning skills, the results did not find any significant changes on the standardized tool used to measure the severity of symptoms of individuals with ADHD. The teachers' results gathered from examining the raw data of the DSM-IV checklist indicate that the participants' displays of ADHD symptoms did decrease in severity when assessed several months following the completion of the intervention. Another interesting finding generated from the behavioral checklists was found specifically when examining the impact of the training on a measurement of Executive Function. It was found that the participants' Working Memory performances, as rated by teachers, were consistent with the findings derived from the individualized assessments, as evidenced by significant decreases in working memory impairment when examined 4-weeks and 4-months following the completion of the intervention. Collectively, it was also found that the students did show an overall decrease in executive functioning impairment, based on the compiled data on the BRIEF'S Global Executive Scale (Gioaia et al., 2000). Overall, the data derived from the checklists suggest that although the participants continued to demonstrate the symptoms of ADHD, they did show a decrease in overall symptoms when measured by observable data, and they also demonstrated improvement on tasks requiring a range of executive functioning skills and Working Memory.

The results of this study do hold promise that a computerized working memory intervention may not only improve performance on tasks that are directly trained by the intervention, but they also may transfer to skills considered similar, or near, to the task being trained. Improvement was also observed on tasks that were not directly practiced within the training program, but could be linked in some capacity to memory and learning. One of the primary questions that remains when considering the individuals' assessments and teachers' rating of behavior is whether gains may be attributed to the combination of training and coaching or if improvement can be attributed to training program or coaching processes in isolation. A variety of limitations exist in this study; these need to be considered before the findings can be further generalized to the larger population. The following section addresses the specific limitations observed in this study more specifically; it also addresses some additional factors that need to be considering when interpreting the results of this study.

Limitations

There are several limitations in this study that need to be considered prior to conducting future research and making decisions on educational programming. One of the primary variables to consider is that the sample in this study was selected for convenience and thus may not accurately represent the larger population, particularly because the members of the sample were from a primarily rural district with a fairly homogeneous population in terms of race and socioeconomic status. The participants in this study were selected from a group of individuals who met the specific criteria being explored in this study; they were identified with ADHD and were experiencing significant math difficulties. Because one of the goals of this study was to look for transferability of the training to the public school setting, selecting students to participate in the training during a school day within an authentic environment was an important variable. Providing it within this district was also important not only because it allowed the researcher to examine the implementation of the program in a setting where it will be most effective and efficient to meet the needs of struggling learners, but also because it provided a community with a resource that would not be available to them outside of the school setting due to the fact of its being rural and at a socioeconomic disadvantage. In general, families may find it to be a hardship to pursue the training individually because there are no local providers and this training is costly. Additionally, examining the implementation of the intervention within a controlled and easily monitored environment provided the coaches and training aides with an opportunity to ensure that the program was being implemented with integrity and fidelity, an important component in the regulations regarding the implementation of research based interventions.

Expanding the research to include individuals from other districts was not practical because of the challenges of conducting the wide range of individual assessments administered in this study, of training the staff to oversee the program, and of ensuring that there was buy-in from the top-down to ensure the interventions were administered with integrity. Additionally, because the administration of these assessments was lengthy, it would have been difficult to include more individuals within the sample due to the critical nature of time in ensuring that the assessments were administered at very specific times before and after the completion of the intervention program. With these factors in mind, it may be beneficial to expand the research to include a larger pool of participants with a research team able to implement the procedures in an educational environment within a timely manner. Implementing it within the school setting presented several challenges, which will be discussed in further detail, but it also provided many benefits. One of the strengths of conducting the research within the school is that it allowed the interventions to be implemented as prescribed because the coaches and aides were available to monitor the participants and provide the coaching on a regular basis, in person. This appears to encourage more successful outcomes, when compared with other providers who must consult and provide coaching over the phone or travel to facilities within research settings in order to evaluate training effectiveness.   Although there were some benefits to utilizing a convenience sample in for the purpose of this study, there are additional limitations that need to be considered from a research perspective.

One limitation of this study is that the derived sample was small and thus the results cannot be appropriately generalized to the larger population. Although a control group was included in the proposal of this study, this was not possible; the limited number of subjects available to meet the criteria of the study made it impossible to have both an experimental group and a control group. It was discovered that despite the use of specific criteria to select students, there was still some heterogeneity of cognitive and achievement needs noted among the students. This can be observed when examining the range of scores derived from the assessment results on specific subtests leading to additional statistical analysis to interpret the data. A question could also be raised about whether or not the range in scores on various assessments administered in this study may reflect the population of students, with these co-occurring disabilities in in any school district across the country.

One factor that may have contributed to the variability in cognitive profiles among individuals with disabilities in this study is that there continues to be debate in the field of disability about how to identify individuals with disabilities. As addressed previously in the literature review, there are still questions raised regarding the neuropsychology of math, although it does appear that there are many processes involved in math and that the integration of neuropsychological processes are unique to the type of math being conducted. Attempting to find homogeneity when conducting research on interventions targeting cognitive processes is complicated when considering that there is still much that needs to be learned about math. One option is to use a "kitchen sink" intervention approach, as described by one research team when discussing the Cogmed program because the combination of task increases the likelihood of training related improvement and larger transfer effect (Morrison & Chein, 2011). A disadvantage is that it is difficult to determine tasks that underlie subsequent neuropsychological improvement, including which WM processes are involved (Morrison & Chein, 2011).

Another limitation of the research design is that the parents, participants, coaches, aides, and teachers were not blinded and thus were aware that the goal of the training was to improve working memory and attention. It was imperative as part of the training protocol and coaching guidance for the participants and coaches to be aware of the importance of their commitment and effort in the process. Additionally, parents and teachers were aware of the goals found on the working memory intervention program and conducted their own reviews of the research found on the website to gain more knowledge. In reviewing the findings of the research, the data collected on the behavioral checklists are those that must be subjected to scrutiny because bias could have been influenced their ratings. Factors that could have affected this bias include whether or not they believe in training that addresses neuropsychological factors or even if they believe that the time committed to the training was as valuable as time spent with a teacher, receiving additional support. In a time when teachers are concerned about their employment and cyber schooling is gaining in popularity, any suggestions of technology being used in lieu of time spent with a "live person" can be concerning.

An additional limitation acknowledged by the researcher in this study is that she is also the individual who administered the individualized instruments to the participants. To assist in avoiding bias, the protocols were identified with codes. The names of the individuals were not reviewed because they were referred to by their gender, date of birth, grade, and identifying numbers in the data base and on the protocols and records. The assessment tools were administered as standardized, and considering the fact that the researcher in this study is a school psychologist, she adhered to the guidelines required in the profession. It would be ideal for future research to have assessors who are not directly involved in the analysis and interpretation of the data to assist in reducing concern about experimenter bias.

Another limitation in the research is that there were a few students who were not able to complete the training within the required time period and thus had to complete the training session at another time period. The training was established to take approximately 35 to 45 minutes per session. Some individuals took longer to complete specific tasks, which led to them extend their time to almost an hour at times. The aides and the coaches made the decisions during these times to continue the sessions when they had time available. Once consultation was made with the technical department overseeing the computerized interventions, sessions were shortened for two of the individuals. It should also be noted that adding the CPI contributed to the session length, which is important to consider when examining the time constraints already present in the school day. When planning future implementation of the training in the school setting, attention needs to be given in balancing the time required to meet the recommended daily training time, yet also considering the time constraints of conducting interventions within an already packed school day.

One additional critique to be raised is that the control of medication was not part of the design of this study. Almost half of the participants reported that they were on medication for ADHD for the duration of the training. Several of them reported, however, that they did not take their medication regularly for a variety of reasons, including the fact that they did not like the side effects; they forgot, or their parents couldn't get refills in a timely manner because of insurance issues or lack of funds to pay for them. Of the individuals not taking medication, five students reported that they took the medication when they were younger, but did not continue because of side effects such as weight loss. Two of the individuals reported that their parents did not believe in the use of medication to address ADHD. Because one of the purposes of this study is to examine the implementation of a computerized working memory program in an authentic school environment, the pattern of medication usage by the participants appears to represent the patterns found in the everyday classroom. Further research examining the interface between medication and the training, however, is warranted.

To assist in addressing a limitation in this study of not having a large enough sample for a control group, a repeated measures design was implemented. A factor that is necessary to examine when utilizing a within-subject design is possible threats to internal validity of the results because of various “carryover effects.” Specifically, due to the length of the time of the research period there was increased risk that various external events could have influenced assessing the true effectiveness of the intervention. It was not possible to know whether changes may have been related to the intervention or to other extraneous factors because there was no control group. Carryover effects essentially can create systematic variations separate from the independent variable (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001). Because the involvement of the participants in this study did expand for a period of over 6 months, other factors that could have affected the results include developmental growth of the participants, revisions in the curriculum, and classroom expectations changing, because teachers require more mature behaviors in the classroom as the year progresses. Additionally, the stress present in the school setting at different times of the year experienced both by teachers and by students may be important to consider, particularly when examining the results on the behavioral checklists. Because the district administers universal screeners for particular grades three times a year and also provides the state assessments to students in the spring, there was continual pressure on the teachers. The stress of ensuring that their students were prepared for the high stakes tests appeared to become further exacerbated with the growing concern in linking teachers' evaluations to students' performances.

It is particularly worrisome for staff concerned about individuals receiving special education services that these individuals are making the progress required of them. Combining the fact that the individuals in this study were those who also identified with ADHD, it is likely that teachers' concerns were raised even further because their behavioral and attentional difficulties presented additional challenges in how to best meet their specific learning needs. Additionally, family backgrounds and home experiences could have also affected students' outcomes, depending on additional resources available to the participants during the research phase.

Practice and fatigue effects are two specific examples of undesirable systemic variations that need to be considered when considering the duration of the research. (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001). Practice effects could have influenced outcomes because of the repeated exposure to specific assessments as part of a repeated measure design. Testing sessions during this time period were approximately 12 to 13 weeks apart, thus there is the possibility that there were some measurements more highly influenced by multiple exposures to the testing material. This could have led to an error in analysis because an assumption could have been made that the improvement was related to the training instead of attributing the gain to repeated exposure to a particular set of questions.

A fatigue effect may have also occurred because subjects were getting tired, bored, or losing motivation to achieve their best on the assessments and intervention. When considering the issues of repeated measures, it is important to consider the fact that practice effects may create a positive impact on the outcome measure but fatigue may have had a negative impact (Dugard, File, & Todman, 2012; Kesselman et al., 1980; Turner & Thayer, 2001).

In summary, there are a variety of limitations that need to be considered when interpreting the data, particularly due to the use of a small sample without a control group. Although the results cannot be generalized to the larger population, the study was helpful in raising additional research questions on computerized intervention and the impact that specific variables may have had on the ability to measure transfer effects directly. The significant role that coaching could have played on the outcomes is one variable that is also worthy to consider in future research.

This study could be viewed not only as an examination of a specific intervention, but also as a contribution to field of educational neuroscience because the research took into consideration the literature derived from education and neuroscience. Historically, the fields have operated in two separate realms, with a few individuals in- between connecting the two in order to inform practice in the educational setting. With the advances in the fields of neuroscience and technology, there is an incredible wealth of knowledge about the science learning that could guide educators as they are commit to the use of researched based interventions to improve the outcomes of all students. It is essential for the two fields to collaborate so that there will be increased opportunities for schools to provide interventions and programs that may truly address their students' specific learning needs.

Findings and Interpretation

Working Memory as a Primary Deficit

Before presenting a discussion related to the research questions in this study, it is valuable to consider whether or not baseline data supports previous research theorizing that working memory is a primary deficit in children with ADHD. The Functional Working Model of ADHD (Kofler et al., 2008), which is based on Baddeley's model of working memory (2007), theorizes that working memory is the core, causal cognitive process responsible for ADHD, and that behavioral inhibition is considered a by- product of working memory deficits. Additionally, weaknesses in working memory are presumed to account for secondary features such as hyperactivity, inattention, and impulsivity (Kofler et al., 2008). Because this study examined the use of an intervention with special education students with co-occurring ADHD and math difficulties, the assumption generated from the review of the literature is that working memory deficits may also be contributing to struggles in learning, particularly in math (Bull & Johnston, 1997; Hooper, Swartz, Wakely, deKruf, & Montgomery, 2002; Lyon, Fletcher, & Barnes, 2003;

Swanson & Beebe-Frankenberger, 2004). If educators recognize that the learning difficulties experienced by individuals with ADHD may not be solely related to behavioral challenges in the classroom, but may also be linked with neuropsychological weaknesses, they may be better able to explore more appropriate interventions and strategies to improve the outcomes of these struggling students. This study demonstrated that there were results on measures of cognitive tasks that stood out as particularly deficient when compared with results from the normative population; these include those measured by the following assessments: Finger-Window subtest, a visuo-spatial memory task measured on the attention/concentration composite; Symbolic Working Memory, a visuo-spatial subtest of the Working Memory Composite; Number-Letter, a verbal memory measure of the attention/concentration composite; and Verbal Working Memory, a subtest used to compose the Working Memory Index. Scores were also found to be within the Low and Below Average range on all composite scores of the WRAML-2(Sheslow & Adams, 2003) with the exception of visual memory, which was found in the average range.

The results collected at baseline on individually administered standardized assessments support previous research indicating that individuals with ADHD and math difficulties do demonstrate significantly lower performance on tasks linked with working memory, when compared with the normative population. In this study, the participants demonstrated weaknesses in both verbal and visual-spatial cognitive processes linked with attention and working memory. In acknowledging that there are many questions regarding the significance that verbal working memory and visual-spatial working memory has on particular components of math learning, it is beyond the scope of this research to examine these factors in detail. The following paragraphs are structured, based on each of the research questions proposed in this study to examine specifically whether the working memory intervention was an effective intervention in improving performance on tasks similar to those that were trained, as well as to examine the transference to untrained tasks linked with memory, fluid reasoning, and math achievement.

Index improvement score. Based on the understanding that schools across the nation are struggling to determine how best to meet the academic needs of individuals with disabilities, the first research question investigated in this study relates to whether or not individuals with co-occurring ADHD and math difficulties would make significant progress on the intervention's trained tasks.   First, the researcher examined the participants' overall progress on the trained tasks from the computerized training program, as measured by index improvement scores calculated by the training software program. The results on the Cogmed Training Index supported previous research, in which, participants demonstrated significant gains when comparing their baseline performance with their overall training improvement index (Klingberg et al., 2002)

Although the gains found on the Cogmed training index are consistent with previous research, the results are significant because the participants are individuals identified for special education services, with histories of failing to make academic progress despite exposure to research based interventions. It is hoped that the findings of this study may prompt further investigation and development of computerized or cognitive based interventions that could significantly improve the outcomes for individuals with disabilities. This is an important goal in education in consideration of the fact that many of the individuals identified for special education have been viewed as "treatment resistant" because an effective intervention has not been found. A potential area for further research is the addition of a computerized working memory training program with specialized direct instruction to 'boost' or maximize instructional strategies that previously have yielded slow or minimal increases in academic performance. The following section will discuss findings related to the questions on transference of skills to various untrained tasks, and their implications for practice and further research.

Cogmed Progress Indicator (CPI). Several questions were raised in this study regarding whether or not the cognitive processes trained in the computerized training program would lead to the transference of the training effects to various other cognitive tasks. Tasks that were examined included those perceived to be similar to the trained tasks, as well as those that are considered far-transfer effects because they were not directly trained within the intervention. Examples of far-transfer effects include those that are linked to memory, fluid reasoning, and math achievement. To examine transfer effects, two approaches were utilized in this study, including the examination of the Cogmed Progress Indicator (CPI), a computerized assessment measurement developed by the test designers and piloted in this study, and the administration of individualized assessment instruments. Research question two specifically examined whether or not transfer effects would be found as a result of the intervention, as evaluated by the CPI in specific areas that were not directly practiced within the intervention. The specific tasks measured by the CPI included working memory, following directions, and math. Significant differences generally were not found on the scales measuring the CPI. There are several factors that need to be considered, however, when interpreting these findings. One particular issue relates to the motivation of the participants during the CPI assessments, particularly because the individuals realized that they were completing "tests." They had complained to the training aide that "these tests" impacted their overall time engaged in the intervention for that day. An examination of the mean percentage of change of the working memory performance across time revealed that the participants' performances steadily increased, based on correct items, particularly at the 15^{th} and 20^{th} intervention sessions. The median data, however, did not indicate any significant differences in the analysis of training effects on the untrained tasks. When reviewing the results of the math challenge test on the CPI, little variability in the total mean score across time was observed, particularly with the second group. The math challenge assessments showed that the first group of participants did demonstrate growth, although the results were not found to be significantly different. The results derived from the math challenge assessments were not particularly surprising because these students have engaged in struggles with math and continue to fall below grade level in math.

Additionally, the math test on the CPI was timed, thus presenting additional challenges to students who are likely working on accuracy as a priority over speed as part of their educational programming.

When examining the use of the data generated from the CPI in assessing transfer effects to non-trained tasks, the results remain inconclusive, due to various issues in its implementation. Because of the changes in the calibrations of CPI measurement between group one and group two, the sample size to assess the CPI was reduced to an even smaller sample size. The results generated from piloting the CPI on a small group of individuals showed that the participants did not make any statistically significant improvements during the intervention phase of the treatment, with the exception of group in the category of following directions. It is understood that this study served to pilot the Cogmed Progress Indicator (CPI) and that the researchers of the Cogmed program continue to investigate and refine the use of this assessment tool in measuring transfer effects.

Transfer effects on standardized memory and learning tasks. Probably one of the most frequently asked questions proposed in the literature when examining computerized working memory interventions, is whether or not the skills practiced will transfer to other memory and learning tasks that are not directly trained within the intervention. Research question 3 specifically asks, “Does the training result in near-transfer and far-transfer effects on different tasks of memory and learning as measured by the WRAML2 at four weeks and four months following the conclusion of the training?" Placed in the context of previous findings on computerized training on cognitive processes, this study makes a unique contribution because a wide range of standardized tasks were administered to assess various skills linked with memory and learning. An especially important component of this research is that it isolated skills defined as attention/concentration tasks from those that are more closely defined as working memory through the administration of the WRAML2 (Sheslow & Adams, 2003). Another benefit in using this specific assessment battery is that it was possible to delineate visuo-spatial memory tasks from verbal memory tasks because one criticism noted in the research is that there is a failure to recognize the differences in the various forms of memory. Another unique aspect of this research is that it also examined follow-up training outcomes four months after the completion of the intervention on these particular types of tasks. This is particularly important for school districts because they must consider issues of time commitment and finance when making determinations of those interventions and curriculums that will deliver the most effective, efficient, and robust results. Overall, the results support the hypothesis and previous research that participants will demonstrate significant increases on various memory and learning tasks, as measured on the WRAML2 four-weeks following the training. Specifically, significant increases were found on the core subtests used to derive the verbal memory, visual memory and attention/concentration composites. Significant increases were also found on the indices measuring working memory and general memory. Design memory was the one subtest in which significant changes were not found.

Another important question raised in the research on computerized working memory intervention is whether improvements derived from the training are short-lived or if the results can be maintained or even improved over an extended period of time. Within this study, not all measurements found to be clinically significant a few weeks after the interventions sustained the same level of improvement four months following the intervention, when compared with baseline. To assist in illustrating this point, the compilation of scaled scores on the General Memory Index collected as part of the 4-month post-intervention assessment did not maintain the significant improvement found 4-weeks after the intervention. Further analysis would be necessary to pinpoint factors that could have contributed to the maintenance of transfer effects on specific cognitive tasks while other gains faded with time. One thought is that the use of strategies the participants learned as part of their experiences with the training and coaching may have allowed them to continue to rehearse these specific tasks in their everyday lives. In addition, there may be tasks that were more easily strengthened but others may have needed continual training. Practice effect is another issue when considering improvement in performance; this will be discussed in more detail in subsequent paragraphs.

In contrast to findings gathered on some of the math achievement tests to be discussed further, significant gains on various memory and learning tasks of the

WRAML2 were typically not found between the 4-week post intervention assessment and the 4-month intervention assessment (Sheslow & Adams, 2003). In reviewing mean and median scores, many of the subtests showed a decrease in scores from the 4-week to the 4-month post-intervention session. By the same token, it is also worthy to note that many of the scores on the subtests did not return to the scores collected at baseline which was evaluated approximately 6 months prior to the 4-month post-intervention assessment. Further analysis of the specific cognitive skills that were able to be maintained at the 4-month follow-up assessment will be discussed in the following paragraphs.

Attention/concentration composite. In breaking down the results on each of the composite scores and corresponding subtests, the Attention/Concentration composite is an area of particular interest as the specific subtests used to derive this measure include those that are typically attributed as deficits in individuals with ADHD and math difficulties because of the link they have with attentional capacity and/or short-term memory depending on the conceptual model (Fuchs et al., 2005; Fuchs et al., 2006; Preston et al., 2009; Rughubar et al., 2009). As noted earlier, the two subtests used to derive the attention/concentration composite, Number-Letters and Finger-Windows, were found to be lower than expected for the normative population. The Finger-Windows subtest was found to yield the lowest mean and median scaled score derived in the study with Symbolic working memory, following second in the lowest scores derived from the participants' pre-test assessments. Both of these subtests require the participants to remember and/or manipulate visuo-spatial information, which also represent a significant deficit noted in the research for individuals with math disabilities. In summary, the results were quite robust when examining transfer effects on attentional capacity.

One weakness noted in previous research is that cognitive tasks have been loosely defined and researchers often failed to examine both visuo-spatial and verbal tasks within the same study. This study provided an opportunity to examine whether or not differences in transfer effects exist between those domains as a result of the computerized working memory intervention. Results on the tasks linked with visuo-spatial skills were found to be maintained four months following the intervention, as measured by the Finger-Windows subtest, as assessed by both parametric and non-parametric measures. The results on the number-letter subtest, a subtest that mirrors a digit-span forward test including the addition of memorizing letters as part of the verbal sequence, yielded similar results. The results on the Number-Letter subtest of the WRAML-2 (Sheslow & Adams, 2003) yielded significant improvement in performance when comparing base-line performance with each post-test assessment. In contrast to the results generated from the finger-windows subtests, no significant differences in median data were found across time on this test. Although the results in the current research demonstrate a positive trend on the verbal span task when examining data, it may be beneficial for future research to examine if individuals with more significant deficits in their short-term storage, or attentional capacities of verbal information, would benefit from the standard intervention protocol of this training program. Additional thoughts regarding the factors that may affect treatment effects will be discussed in more detail later in this chapter when exploring the impact of coaching and strategy development.

In relation to improvement on the subtests, an important question raised is whether or not the similarity of the assessment tasks to the actual training task influenced the degree to which significant differences were observed and maintained. The research does support the idea that near-transfer effects are improved as a result of the intervention. There are few studies, however, that are able to support statistically significant improvement on far-transfer effects as a result of the computerized working memory training. The finger-windows subtest in this study resembles tasks that are practiced in the computerized training, whereas the number-letter subtests are less similar. The finger windows subtest relies on the participant observing and memorizing visual-spatial sequences and replicating the exact sequence of a non-verbal task. This particular activity more directly represents tasks on the Cogmed training program, whereas there were not any directly trained tasks in which students were asked to, verbally , repeat sequences that were heard, which is the requirement for the number-letter subtest. In other words, the Finger Windows is an example of near-transfer effects because the task is very similar to some of the training activities, whereas the Number-Letter subtest requires a verbal response; the training employs a tactile response, utilizing a degree of visual-spatial responses. An argument can be made that the Number-Letter subtest, which strongly resembles a forward span digit-span task, with the only difference being the requirement of a verbal instead of non-verbal response. Because mean gains were found at the follow-up assessment on both types of visuo-spatial and verbal tasks, the overall findings suggest that the training was valuable in building attention/concentration skills. Additionally, these tasks are reflective of near-transfer training even when an added component of verbal output was required as part of the one assessment and not in the intervention. When raising the issue of practice effects on these tasks, it is valuable to consider the technical manual on theWRAML-2 (Sheslow & Adams, 2003), in which it was indicated that of all the subtests on the battery, the smallest increase for practice effects was found on the tasks linked with the Attention Concentration composite. The results on the attention/concentration tasks do support the hypothesis that the training does lead to the improvement in tasks that are similar to the trained tasks.

Working memory composite. As discussed previously, it is important to be cautious in comparing and contrasting results from one study to another because the cognitive process being described may be assigned various names even if the task represents similar skills or assigned similar names but actually loads on different cognitive processes. In this study, which involves examining the data from the WRAML-2 (Sheslow & Adams, 2003) as defined by the test designers, the symbolic working memory and verbal working memory represent the components defined as working memory tasks based on the degree to which the participants are expected to go beyond holding sequences of information in memory to also manipulating verbal or visual-spatial information into a specific category and/or order. This contrasts with the procedures involved in attention/concentration subtests in which individuals must hold information in their minds and then repeat them in the order in which it was presented to them with the sequences getting longer as they progress through the assessment. When comparing this study to previous research, one must consider that tasks similar to those measured on the attention/concentration composite of the WRAML2, such as digit-span tasks, have frequently been described as a working memory task in other studies. Others could contend, however, that the added component of some subtests, such as the digit-span subtest of the WISC-IV (Wechsler, 2004), does represent the additional manipulation of data when they are expected to repeat the sequences in reverse order. Merely placing data in the reverse order in which the digits are presented, however, has been debated in the research, of not tapping the more complex process of holding and manipulating information in a particular manner associated with working memory (Rapport et al., 2008).

Overall, the results compiled do support the hypothesis that the cognitive skills trained in the computerized working memory training did transfer to working memory tasks that were not directly trained in the intervention. Gains were also maintained when assessed 4-months following the intervention. In interpreting the data, it is valuable to decipher differences discovered between the verbal and visual-spatial working memory subtests to get a fuller understanding of training effects.

Symbolic working memory, which has been viewed both as a measure of the executive working memory and of the visual-spatial working memory, yielded significant improvement when assessed a few weeks after the assessment and maintained significance when reassessed at the 4-month follow-up assessment. These results are consistent with previous research that examined gains on tasks that have been defined as visual-spatial working memory (Dahlin et al., 2013; Holmes et al., 2009, Klingberg et al., 2002; 2005) For example, Dahlin et al. (2013) found the most improved performance on the working memory measures on the Span Board forward and back at the 7 month follow-up assessment, when compared with baseline in the experimental group (both boys and girls) and boys only. As reported previously in the literature review, these findings are important because of the relationship visuo-spatial working memory has in a person's ability to develop math skills (Swanson 2006).

Similar to the research conducted by Holmes et al. (2009), measurements of verbal working memory was found to increase significantly when assessed a few weeks after the intervention, but did not maintain its level of significance several months after the intervention. The investigation by Dahlin et al. (2013) of computerized working memory training on individuals with ADHD and math difficulties differed because it did not find any significant improvement on tasks that they defined as verbal working memory five weeks after the intervention. Significant changes were also not observed at the 7-month follow-up in their investigation.

The results support previous research demonstrating that the training does lead to improvement on processes linked with the central executive function, which most closely resembles the subtests of the WRAML-2 (Sheslow & Adams,2003) used to derive the working memory composite (Dahlin et al.,2013). Because these tasks do not closely represent the training activities to the same degree as the attention/concentration tasks, positive outcomes on this assessment could be described as resembling a far-transfer effect. This could be debatable, however, as some of the less complex entry items of these assessments resemble aspects of the training tasks and provide the examinee with an opportunity to practice the activity before proceeding to the more complex activities. This study also supports the idea that training seemed to have a more significant impact on tasks related to visual-spatial working memory than to verbal-working memory when considering the long-term outcome measurements (Dahlin et al., 2013; Holmes et al., 2009). One important factor that appears to contribute to this finding is that some of the interventions tap verbal working memory because the participants are to focus and memorize sequences, but instead of responding verbally to the tasks, they must rely on other forms of output to register the response to the computerized system calculating their progress. This contrasts with the assessments measuring verbal working memory tasks in which they are provided the verbal information and must respond verbally without any additional tools to provide their responses.

In referring to the conceptual framework, Baddeley's Model of Memory (2007), it is valuable to examine the degree to which the participants are tapping into the cognitive processes that align with the phonological loop and those linked with the visuo-spatial aspects of memory. It may be difficult to get a clear understanding of the degree to which the intervention allows the participants to train their verbal working memories because the intervention appears primarily to tap visuo-spatial tasks. To assist in explaining improvement that was observed on the verbal working memory tasks, the participants may have utilized internal speech to rehearse the verbal/auditory data in the phonological loop and then integrated the cognitive processes with their visual and motor skills to respond to the tasks physically. When considering the strategies that could have been used by the participants to optimize their performances, it is important to recognize that the participants in this study are likely to represent those individuals who are delayed or weak in the development of this internalization process. They are also likely to struggle in finding alternative interventions and strategies to help them learn new materials. This is the area in which the coaching component is an important part of this process in helping to integrate the skills learned through the intervention and coaching process to the academic setting and in everyday life activities. The overall finding on the measures of the working memory index, particularly when examining the long-term training effects, is promising, especially when considering that children with math difficulties demonstrate persistent weaknesses in verbal working memory processing (Passolunghi & Siegel, 2004).

Verbal memory. The assessment of verbal memory tasks was perceived as an important skill to measure in this study because of the significant role these processes have in learning in the classroom. Additionally, deficits in verbal memory have been attributed to the struggles experienced by individuals with ADHD in learning, particularly in the difficulties experienced by individuals with ADHD and math calculation (Semurd-Clinkeman, Pliszka, & Liotti, 2008). Verbal memory tasks are valuable to examine when evaluating for far-transfer effects because of the significance they hold in their everyday learning experiences. The story memory subtest, for example, assesses auditory memory of extended, meaningful verbal material, which is linked with listening to conversations or classroom instruction, as well as to reading text (Adams & Reynolds, 2009). The verbal learning subtest is also beneficial to assess auditory memory of meaningful verbal information that is without context (Adams & Reynolds, 2009). One important factor that needs to be considered in examining the results of the story memory is that participants were exposed to the stories several times as a result of utilizing a repeated measures design, thus gains could be attributed to repeated exposure of the stories. When considering the positive gains on the story memory subtest by the four-month follow-up, the participants were provided with the opportunity to hear information within a context that could have had similarities to events within their lives. Helping individuals with learning difficulties to link new information with prior knowledge is a strategy frequently implemented within the school setting. In this case, it could be suggested that these individuals may have improved their ability to integrate the cognitive processes necessary to sustain attention by the four-month post-test assessment to listen to the story and store the information long enough to report it back immediately after the conclusion of the story.

In regard to the improvement found at the four-week post-test assessment on the verbal learning tasks, it seems that this task would be very difficult for the participants in this study, particularly if they have not been successful in learning arbitrary and less meaningful information in their academic coursework. When assessed several months after the completion of the intervention, the participants continue to improve significantly in their ability to increase the number of words they recalled from the long list of words read to them, reflecting findings similar to the research on adolescents with extremely low birth rates conducted by Lohaugen et al., (2011). One explanation that may be considered in examining the far-transfer effects to verbal learning, the one component of the intervention that may have affected the outcomes in such tasks is that the individuals may have improved the attentional levels necessary to engage actively in learning. Lack of engagement in individuals with ADHD is particularly evident when they are provided with tasks that may be uninteresting, too easy, or too difficult, acknowledging that these are the issues that they appear to have the most difficulty in overcoming in their everyday life experiences.

Visual memory. When assessing transfer effects of the computerized working memory intervention to the assessment, it is initially important to consider that the participants' performances were found to be within the Average range on this composite.

In other words, visual memory was not found to be an area of need when examining overall performances of these individuals. In further examining the data, visual memory may actually represent a relative strength for several of these individuals; they could have possibly used strategies that involved visual memory in their attempts to learn complex information.

The data generated from the subtests used to derive the visual memory composite, Picture Memory, was one subtest that was not found to be significantly different at the 4-week post-intervention session when examining the non-parametric data; however, it was found to be significant at the 4-month post-intervention assessment. It is the researcher's impression that the Picture Memory subtest is one in which practice effects due to multiple administration of an instrument may have had an impact on performance scores because the participants may have been able to rely on other sources of memory linked with prior experience and meaningful events to help them recall pictures of scenes.

The design memory subtest was one of the subtests in which there were no significant differences observed when comparing the multiple measures. This subtest required the individuals to memorize arbitrary lines and figures that possessed no assigned value to previous experiences or emotional triggering linked with meaningful events. In reviewing the technical manual from the WRAML-2, it was indicated, however, that practice effects were notable on the Design Memory subtest when compared with the other results, showing almost 2 scaled score point gains (Sheslow & Adams, 2003). It appears that the additional opportunities to practice the Design Memory subtest did not make a significant difference in their performance. Their performance was found to be within the average range, and thus, the group as a whole may have reached their optimal performance. Although the scenes in the Picture Memory subtest were initially novel to the participants and required them to recall changes in the scenes, the images themselves were not arbitrary or isolated, but rather part of a familiar context in which an emotional or cognitive value could have been more easily assigned to the task. The rationale of linking prior knowledge to context in the academic setting is based on the understanding that some individuals require that meaningful context to attend to the material and memorize the information.

The improvement on the visual memory composite, which appeared to be primarily linked with the significant gains on the Picture Memory subtest, does need to be interpreted with caution because the improvement may be due to frequent administrations of the assessment. It is also important to add that the tasks assessed by the subtests do not reflect any direct tasks trained by the intervention. Although there are cognitive processes such as attending to the design tasks and visual rehearsal of the tasks that could have improved as a by-product of the training, the tasks of the intervention appeared to have less detail than required in this assessment because the participants tended to practice tasks that were more visual-spatial in nature and less detailed oriented. In summary, the results appear to be inconclusive because improvement in the scores may be a result of practice effects, particularly in the area of picture memory. When examining the results on the design memory task, the research does not suggest that the intervention may have any direct training effects on specific aspects of visual memory, especially when considering that the individuals in this study were not found to have any significant weaknesses in this area, when compared with the normative population.

Training effects and fluid reasoning. Another research question proposed within this study is, "Does the training improve far-transfer effects in the area of fluid intelligence as measured by standardized assessments at 4 weeks and 4 months after the completion of the training?" As discussed previously in the literature review, there is research suggesting that a relationship exists between working memory and fluid reasoning. This study is one of the few to investigate directly whether or not significant improvements can be found in fluid reasoning tasks as a result of transfer effects of the WM training. Yuan (2007) conducted his dissertation research examining this question. Significant treatment effects were not observed in this study; however, it was suggested that more sufficient time may be required between the implementation of the training and the post-intervention assessments to observe improvement in fluid reasoning tasks, considering that Yuan (2007) only assessed transfer effects immediately after the intervention. In the present study, significant increases were found when examining the mean and median of the subtests on each of the two fluid reasoning tasks provided to the participants. Although a significant difference was not found between the two post-intervention sessions, the results remained fairly stable, suggesting that the participants were able to maintain the treatment effects across time. Slight increases continued to be found at the 4-month post-intervention session on the Concept Formation subtest. Results on the overall Fluid Reasoning Composite yielded similar results, with the level of mean and median improvement being significant when compared to baseline data.

Consideration should be given to understanding that some of the scores derived at the 4-week and 4-month assessment period would fall within the level of confidence of the standardized tool. Although these scores may fall within the 95% confidence level, the results do demonstrate improvement at a statistically significant level. One observation is that the participants' standard scores were approaching more solid Average range scores when examining their overall mean and median score at the post-intervention assessment. This was particularly noticeable on the Concept Formation subtest where the pre-test assessment mean was 90.09 and the mean at the 4-month follow-up period was 106.65, demonstrating a difference slightly over one standard deviation. Results of the fluid reasoning composite also demonstrated a significant difference approaching one standard deviation.

In contrast to the findings that the participants' demonstrated working memory and attention deficits prior to beginning of the intervention, the students did not present as having significant deficits in the area of fluid reasoning, with the mean and median scores falling within the range of low average and average. More research may be beneficial in further examining the relationship of fluid reasoning and working memory in individuals with ADHD and math disabilities in order to explore whether there is a pattern of weaknesses within this subgroup of individuals or whether they tend to be more heterogeneous with a variety of patterns of strengths and needs. The interpretation of these results needs to be interpreted cautiously because of the small sample size and lack of a control group.

One factor requiring attention when examining the fluid reasoning results is that the improvement may be related more closely to the students learning how to block various internal and external distractors in order to complete tasks placed on them. In other words, improvements on the fluid reasoning tasks may be related to their improvements in focus and ability to attend. Previously, these individuals were prone to experience issues with attention and memory impeding their ability to tap into the more advanced skills required to solve complex problems such as those required in fluid reasoning. As discussed throughout the research, it is difficult to isolate cognitive processing skills and to differentiate the sources of learning difficulties. Because the students in this study were not found to be significantly low in the area of fluid reasoning, it would be beneficial to assess further, the training effects on fluid reasoning by conducting additional research on individuals with weak fluid reasoning skills, in addition to assessing further, the relationship of fluid reasoning with working memory in individuals with math disabilities and ADHD.

Transfer effects in math. Based on the research demonstrating that working memory is a process significantly involved in math learning, one of the primary research objectives of this study was to examine whether or not the computerized training program contributed to improvement in math achievement. Results were found to vary, depending on the specific skill being assessed. Standard scores were found to continue to improve across time on the Applied Problems subtest. Math fluency was found to improve significantly from baseline to the 4-week post-test intervention, but was not maintained at the same level of significance by the 4-month follow-up period. The mean standard score did, however, stay above the baseline mean. There were no significant improvements found when looking more specifically at the math calculation scores. Results on the math calculation cluster, however, which included combining the results of the math calculation and math fluency subtests, did yield significant improvement when comparing baseline data to the 4-month post-intervention assessment session. This suggests that when a cluster of skills were combined together, improvement was more substantial after being provided with sufficiently more time to become engaged in the math curriculum and apply the skills gained through the interventions to their learning. When assessed after only a few weeks after the intervention, there was a relatively short time for them to synthesize their skills with their current learning to make significant gains.

The data from the brief math cluster, which consisted of the applied problems and calculation subtests, varied, depending if mean or median data were observed. Similar to the findings on the math calculations cluster, significant differences were observed within a few weeks after the training, when compared with the baseline data 4-months after the intervention, when examining the median scores. One interesting observation in the study is that in the area of math, significant improvement was discovered when comparing results at the 4-week post intervention session to the 4-month intervention session. This contrasts with many of the memory and learning tasks in which there tended to be a decrease, even if only slightly, from the assessment administered a few weeks after the intervention to the second post-test. An important variable in this study is that the students were receiving math support to some degree, as designed in their individual education plan. The hypothesis is that their math improvement was boosted by the cognitive gains achieved through involvement in the intervention. The role of the coaching process is another factor that needs to be considered when explaining math improvement.

An additional area that needs to be reviewed when examining the data in math, as well as other standardized measurements presented in research, is that the assessments did yield a confidence interval, indicating that there was a 95% chance that scores would fall within a certain range if the test were to be administered again at a later time. When examining the confidence intervals of the participants on the math cluster, their initial baseline median standard scores fell within the borderline range (standard score under 80). Four months following the completion of the intervention, their performances increased to the upper end of the low average range on an alternative form math achievement test. Significant differences were also observed between each of the three testing sessions with the participants' scores improving across time. Results were also similar when examining the scores on the Broad Math cluster, which consisted of the cluster of the applied problems, calculation, and math fluency subtests. Because the scores could also have decreased or remained fairly consistent when considering the confidence interval of assessment, the findings did support a positive upward trend that was statically significant; they did not remain similar to the initial score or decrease to the lower end of the confidence intervals. These findings do support that transfer effects were observed in math, although the lack of a control group minimizes the significance of this finding because the students were also receiving specially designed math instruction as individuals with disabilities. One important question that needs to be further researched is whether the gains can be due to the combination of the training intervention with the math curriculum or whether similar results could be found with individuals receiving only the math curriculum. Prior findings suggesting that individuals with disabilities often struggle to make significant gains in their educational programming indicate that there is a strong possibility that incorporating the working memory intervention program with the math curriculum may have "boosted" the cognitive processes necessary to ignite their math learning.

Computerized working memory interventions are fairly new to the field of education; thus, there is relatively minimal research investigating the training effect that this training has had on academic performance. The results of this particular study were consistent with research by Holmes et al. (2009) in which individuals were found to make significant gains on math skills six months following the completion of the intervention. Training gains that were found in the area of math provide support that it may worthy to review the use of computerized working memory training as an educational intervention, particularly with those individuals who have participated in researched based interventions for significant periods of time and have made minimal or slow progress. Such individuals can include those within the special education program or those who have been participating in a Response to Intervention Process.

Behavioral observations of ADHD symptoms and executive functioning tasks. Several behavioral emotional checklists were administered to teachers and parents at each of the three assessment sessions to answer the research question regarding whether or not the intervention could reduce the frequency of inattentive symptoms and behaviors linked with the diagnosis of ADHD. These checklists included the Conners-3 (Conners, 2009) and the DSM-IV-TR (Cogmed America, 2007), a form that was completed as part of the training protocol. Participants were also provided with a self-report to complete on both the Conners-3 (Conners, 2009) and the DSM-IV-TR checklist (Cogmed America, 2007). The BRIEF (Gioia et al., 2000) was also administered to parents and teachers to further assess whether or not the interventions had an impact on various executive functioning tasks at 4-weeks and 4-months post intervention. Because parents did not consistently return the forms in a timely manner after the three assessment sessions, the interpretation of the behavioral checklists focused on the teachers' ratings.

The data collected to assist in assessing transfer effects of the training to the improvement of behaviors are particularly important for educators as they attempt to address the concerns of students with ADHD and behavioral concerns who are continually struggling in the classroom, despite being provided with accommodations such as frequent prompts, extended time on tests, and participation in a small-group setting during instruction. Although difficulty with attention is often considered by educators as primarily a behavioral concern, there is significant evidence to indicate that attention is closely related to learning. Research has supported the idea that there is a relatively strong relationship between attention and working memory that impacts academic performance. For example, studies have found specifically that students with higher scores for inattention were also found to be particularly vulnerable to significantly lower performance on academic tasks such as math (Raghubar et al., 2009). Because the individuals in this study are those that have been identified with ADHD and are experiencing math difficulties, they may be especially at risk for experiencing poor outcomes due to the additional difficulties they experience with weaknesses in their executive functioning skills. Difficulty with areas such as planning and organization, initiating tasks, and working memory can exacerbate their learning problems and behaviors in the classroom. Because attention and executive functioning skills are inextricable, it is valuable to examine both the symptoms of ADHD, as measured by the DSM-IV-TR and more comprehensively by the Conners-3, and executive functioning, as measured by the BRIEF, to gain a better understanding of the impact that the computerized interventions may have had in the display of the participants' behaviors as rated by their teachers.

Data generated from the Conners-3's (2009) teacher's report and from self-reports were consistent in yielding no significant differences. These results contrast with previous research related to the CogmedWM training by Holmes et al. (2009) and Klingberg and colleagues (2005), in which the intervention was reported to have a role in decreasing the rating of the presentation of inattention and hyperactivity symptoms (Holmes et al, 2009; Klingberg et al., 2005). The findings of this study were consistent with more recent research conducted by Gray et al. (2012), in which behavioral ratings on the IOWA Conners' scale (Pelham et al., 1989) were not found to be significantly different on the behavioral symptoms of inattention or academic improvement achievement, as rated by teachers. Significant differences were found between the pretest and the 4 month post-test on the number of inattention and hyperactivity behaviors rated by teachers when the raw data was combined. This suggests that the presentation of specific criteria used to identify ADHD were not as prevalent as they had been when assessed prior to the intervention.

Results of the BRIEF (Gioia et al., 2000) found positive improvement on the Working Memory scale as well as the Global Executive Scale composite at both the 4-week post intervention session and at the 4-month follow-up assessment. There were several scales on the BRIEF(Gioia et al., 2000) , in which improvement was not observed within the month following the conclusion of the intervention, but was observed when comparing the 4-month post-test assessment to baseline data. Specifically, improvement was found on the Inhibit, BRI, and Organization scales. These scales also were found to improve significantly from the 4-week post-test assessment to the 4-month post-test assessment. It can thus be suggested that immediate changes in inhibition may not have been observed directly during the intervention period, but gains would become more noticeable several months after the completions of the computerized training program. These findings support aspects of previous research conducted by Beck et al., (2010), in which the teachers' ratings on working memory and plan/organize scales were also found to improve when examining data at the 4-month follow-up. In contrast, Beck et al. (2010) also found improvement on the Initiate scale, which was not significantly different in this study. When examining the results of the monitor scale, significant improvement was found only when comparing the results from the 4-week post-test assessment to the 4-month post-test assessment. No significant difference was found from the 4-month post-test assessment to baseline because the ratings were found to worsen slightly at the 4-week post-test assessment.

The results found on the teachers' ratings on the BRIEF (Gioia et al., 2000) do support the idea that the computerized training program may have played a role in improving specific executive functions that have been linked as primary deficits in individuals with ADHD. When examining data generated from the rating scales used in this study, there are additional factors that should be examined that may have influenced the teachers' ratings of the students participating in the intervention. The following section reviews various dynamics that could have influenced how behaviors were rated.

Factors affecting teachers' observations and rating scales. There are several factors that are worthy to note when examining the outcomes of the behavioral checklists. One particular factor is that the teachers' observations of students' behaviors may have been impacted by issues related to the excessive demands placed upon them, leading essentially to a negative school climate. Teachers reported feeling overwhelmed during this school year, particularly with changes in the teacher evaluation system in which their students' performances on standardized assessments could affect teacher ratings. Additionally, there was concern about pending changes taking place in the curriculum, due to the requirements in meeting the Common Core standards. Adding to the new demands, teachers were faced with changes in the assessment of their students and expressed some concern about students participating in computerized interventions instead of receiving additional homework support in a resource period. Because of these issues, there may have been some negative attitudes affecting the ratings. In other words, bias against the participants' involvement in the computerized working memory training program needs to be considered, particularly because the teachers were aware of the training program. It is plausible that there may have been resentment because they were further frustrated by a system that gives them less autonomy in how they structure their lessons and meet the needs of their students. In this particular case, the teachers were not able to have students go to the resource room on certain days due to the level of compliance expected for students in the training program.

Another factor is whether or not the participants had the opportunity to transfer the training they received as part of the working memory training program to their everyday life experiences. It is not likely that there would be a sudden and expected change in behaviors that could be instantly observed by the participants' teachers within the few weeks following the intervention. Changes in the various skills being monitored by the rating scales would likely change gradually over time and may not be noticeably significant for teachers because they are busily managing a multiplicity of tasks during their school day. It may be beneficial to look more closely at long-term follow-up data to assess whether additional time is needed for the participants to practice and rehearse skills or strategies they may have acquired through their involvement in the working memory training program.

When interpreting the limited variability observed across time on the teachers' rating scales, it is also valuable to examine specific variables in the school setting that could affect behavioral improvement and academic performance. For example, the formation of relationships and social status are extremely influencing factors in shaping young people's behaviors in the classroom and also impact teachers' attitude, expectations, and behaviors towards the overall class. Because many of the social norms and patterns of the classroom have been already established upon the conclusion of the intervention, it may be difficult for the participants in this study to alter their habits and behaviors to the degree that it would be noticeable by teachers. In considering these dynamics, it is often the worsening and more severe behaviors that are given more direct attention by staff. An additional variable that may be beneficial to consider is that overall, participants' behaviors did not worsen, which in itself is valuable information when recognizing the difficulties individuals with dual-disabilities experience as the academic expectations increase throughout the school year.

In considering the role of bias on rating scales, the teachers were provided with information about the participants engaging in a computerized training program designed to improve memory, but the continual interest in learning about the program by the staff was mixed. There were a few who spoke to the coaches about the program and sought to gain more knowledge about the training, but others did not seem to be particularly aware of what the participants were doing when they were in the computer room. It is thus difficult to rule-out teacher bias in how they rated their students' behaviors because they were aware of the training goals. One of the strengths of this study is that due to issues related to subjectivity in utilizing rating scales, individualized and objective assessments were also administered to measure transfer effects of the training to specific cognitive tasks instead of only considering findings on rating scales. One area that was found to be consistent in the collection of rating scale data and individualized assessments is that the working memory improvements found on the BRIEF (Gioia et al., 2000) coincided with the observations collected on the WRAML2 (Sheslow & Adams, 2003) on which working memory skills and attention were found to improve.

Additional Factors Affecting Outcomes

Implications regarding practice effects. One primary factor that needs to considered when examining the results of the individual assessment is whether or not the positive findings are related to true cognitive improvement as a result of the intervention or if improvement may be due to the students' participation in the repeated administrations of the subtests to measure progress across time. It can be assumed that several of the subtests measuring the cognitive processes linked with attention, fluid reasoning, and working memory entail administering multiple sequential tasks that would be difficult to memorize and recall beyond the first several seconds of administration, when considering the nature of specific cognitive processes. Specifically, these tasks were designed to provide a measurement of individuals' ability to retain or retrieve tasks beyond a relatively short period, with items becoming more complex and difficult to retrieve beyond the first few minutes of administration. As indicated in the technical manual of the WRAML-2, for example, it was indicated that practice effects on such tests used to derive the Attention-Concentration composite and Symbolic working memory were found to have negligible effects from repeated practice (Sheslow & Adams, 2003). Thus, the implication is that administering specific tasks linked with the attention and working memory subtests several times, over a period of months is unlikely to yield significant gains due to repeated exposures to the actual assessment.

Future researchers considering the utilization of a repeated measures design to investigate computerized working memory training may find it valuable to implement a procedure similar to that followed by Lohaugen and colleagues (2011) in which a separate group of individuals were administered the multiple assessments, but did not participate in the interventions. The results of their study found no significant differences between baseline and the 6-week follow-up results in the non-trained control group. Similar to the findings reported on some of the memory and attention tasks of the WRAML2, the authors noted that their results supported previous research examining practice effects of the WAIS-III, in which there was little improvement seen on the working memory tasks after repeated administrations of the instrument (Basso et al., 2002;Spreen & Strauss, 2006). Some tasks that are unique to the assessments and that may be more memorable across time, such as picture memory and story memory, do need to be discussed as assessments that may have been easier for subjects to recall across time. It is imperative to discuss the role of practice effects with such tasks, prior to interpreting the findings as evidence of treatment effects.

An important consideration when raising the issue of practice effects in this study is that it may be difficult to differentiate what could be considered practice effects of the assessments from improvements related to the training intervention. In other words, the training intervention in itself is based on rigorous practice that aligns with tasks measured by the assessment tool. To decipher the role of practice effects on repeated administrations of standardized tools, it may be valuable to consider that the reliability studies conducted during the development of the instruments have suggested that standard scores on the assessments across time remain fairly stable, with some of the instruments being administered within only a few weeks to months between testing sessions during the standardization phase of the instruments. This is comparable to the research in this study in which the duration between administration consisted of periods of time, with 3 months between the pre-test and the 4-week post-test and a 4-month time period between the post-test assessments. It is also important to consider the very nature of practice effects within the context of intense rehearsal of very specific skills have been found to increase performance when, historically, it has been believed that cognitive processes are fixed and thus not able to improve. In this new field of computerized cognitive interventions, it is the very nature of the program to repeatedly practice cognitive tasks that do closely align with the tasks that are being assessed by neuropsychological measures. In other words, practice effects, within a different context from that of spoiled assessment results, is actually an important underlying assumption linked to explaining the value of the cognitive training program. The term, practice effects, refers to participants improving on assessments because they were administered the testing instrument within a specific time frame; in this study, however, improvement on assessments may be linked to the actual, repeated, intensive practice of specific skill sets through the intervention process. This is particularly the case when considering that assessments measuring working memory and attention entail answers that would be difficult to retain much further in time after the administration of each test item. This is not to say that improvement on the assessments should be considered only as a result of the training, but that it can be difficult to decipher whether the improvement on specific tasks described earlier may be related to repeated exposure to the intervention tasks or to the assessment measurement.

Strategy development. One of the questions raised in previous research on the computerized training program is whether or not the gains achieved by participants may be attributed more specifically to the participants' developing improved strategies to learn and retain information rather than increasing working memory capacity or building other cognitive skills. Supporting the thoughts that improvement in outcome data may be related to strategy development was gathered from the interviews conducted by the coaches, particularly at the 4-week follow-up.

One particular high school student, who was found to be an outlier on the Cogmed training index due to demonstrating significantly higher gains than the other participants in this study, reported that he specifically focused on developing new strategies to help him improve his score; these included closing his eyes and repeating the picture or item in his head. He also indicated that he was easily frustrated during the beginning of the intervention process, but through coaching and experience, he learned to take a deep breath and to "just do my best." In summarizing the qualitative data generated from the participants, several participants shared similar experiences of learning to "hold onto the information" in their minds. One student described it as learning to shut out or "close the door on other information to get in" so he could focus on the task on the computer. Several students described their brains as "becoming tired" as they described the mental strategies they used to help improve their performance.

Based on the students' responses, the question could be raised about whether the training program itself improved their overall performance on the trained tasks or whether the results were positive because they also learned important strategies in the process of how to memorize new information (Holmes et al., 2009). Whether or not participation in the program improved their cognitive processes or the strategies or combination of both led to their overall improvement, the qualitative feedback is important in demonstrating that one of the struggles that individuals with ADHD have is consistently demonstrating the skills necessary to learn new information. As described previously in the review of the literature, individuals with ADHD possess a variety of executive functioning deficits that affect their abilities to focus, but also how to plan and implement studying strategies. The coaching and computerized exercises allowed them access to the intensive training needed to engage the neuropsychological processes necessary to learn and retain new information. These are skills that other learners are able to apply intuitively in their studies; however, students with ADHD often appeared scattered and have difficulty integrating the skills necessary to be efficient learners.

Benefits of coaching. There are other important components of the process that need to be considered as factors that may have contributed to the gains that were made by the students although they are not directly related to the intervention itself. One particular component is the ongoing coaching opportunities that were provided to each student by a caring and consistent adult. Although the coaching is not necessarily considered a reward of the program, it did provide positive reinforcement to the students throughout the intervention process and as part of the follow-up procedures. The participants were given undivided time with an adult, who not only reviewed the data generated from the intervention, but also provided specific strategies to improve performance that could be transferred to learning and studying their academic material. Additionally, the encouragement and overall support they received may have had positive effects in fostering confidence and assisting the students in sustaining effort when their previous tendencies could have been to give up. Knowing that a caring adult was monitoring their progress and "rooting for them" may have, in itself, helped the individuals to sustain their efforts. Many individuals with the dual difficulty of managing ADHD symptoms and their academic difficulties are likely to have experienced consistent frustration throughout the years and continue to be in need of that regular reinforcement to try their best. Future research may want to investigate further the significance of coaching in this intervention process, including whether it has an influence on ongoing motivation and on self-confidence during the completion of these very difficult tasks. It is valuable to consider the benefits of the coaching process through a review of the data generated from the resiliency research, which indicated that individuals with even the most difficult life experiences can improve their chances through the consistent support of a caring adult (Brendtro &Larson, 2006).

An additional area that was indirectly and directly targeted through the coaching process was the development of executive skills. For example, an important executive skill that the coaching process encouraged was the development of goal-directed persistence, a skill that engages students on how to make and achieve goals in the long-term. Although the focus was on what strategies could be used to improve short-term performance, the individuals were coached on the importance of perseverance on the training tasks in order to achieve long-term goals (Dawson & Guare, 2012). Another executive skill that was trained through the intervention process, including the coaching component, is metacognition. Specifically, each of the students was involved in considering the barriers that may have influenced their performances on the previous intervention session and in their everyday work. Themes that were noted during the coaching process regarding the training sessions included fatigue, boredom, and frustration. In the coaching session, the coach assisted the students in coming up with ways to overcome these difficulties or work through them in a manner that would help them do their best and to apply these strategies not only during the intervention, but also to other areas in their everyday lives. Students then reviewed the strategies with the coach and looked at the data to determine if their strategies were beneficial (Dawson & Guare, 2012).

There were likely additional executive functioning skills that were also trained either directly or indirectly by participating in the coaching process. Additional research on the relationship that coaching had in addressing deficits in executive functioning is an area of research that would be beneficial to investigate in the future. The role of coaching in this study should not be underestimated; in review, the students were likely to have had more intensive and frequent coaching, when compared with previous studies, because of the benefit of receiving the services within the school setting. It is likely that the coaching had some degree of influence on treatment effects even if it was only to serve as a source of motivation for the students.

External rewards. As discovered through previous pilots of the computerized program in the middle school setting, it was indicated that many of the students required additional and more meaningful rewards to encourage them to work through the difficult testing sessions and to keep them coming back for the next session. An additional component that appeared to play a significant role in the training was the selection, consistency, and intensity of the extrinsic rewards selected for the participants. The high school students seemed to be particularly motivated by receiving gift cards to a local gas station/convenience store, with several of the participants stating that they appreciated it to help put gas in their cars. Elementary students appeared to be motivated by objects that were tangible at that moment. It was also reported by the coaches and the aides that reminding students of external reinforces helped reduce their complaints and their resistance to begin another intervention session. The gains found in the training should not be viewed as resulting from the external motivation to participate in the training itself, but the gifts did serve the purpose of ensuring that they worked their hardest and stayed motivated to come back and keep on trying.

Recommendations for the Field

In a nation where there is increased pressure to ensure that all children are making adequate yearly progress and are demonstrating skills that meet the standards necessary for them to enter the work force or post-secondary training, it is imperative to continue to research interventions that may prove to increase academic performance and reduce the behavioral concerns of individuals, such as those in this study, who have been described as "treatment resistant". Although the subjects in this study were those who had already been identified for special education, it is recommended both for regular education and for special education professionals to review the neuroscience research on learning disabilities to assist in understanding the impetus for examining the training of neuropsychological processes. With the growing emphasis on utilizing a response to the intervention process as a means to provide individuals with additional support prior to referring them for a special education evaluation, it is especially important for intervention specialists to be aware of the ongoing research on computerized working memory training to assist in determining whether this may prove to be an intervention option to boost academic performance. Research on interventions that specifically targets the neuropsychological process is relatively new to the field of education; thus, it is also valuable for those involved in the decision making process and the purchasing of curricula, educational programs, and intervention materials, to become familiar on the translational research between neuroscience and education. This is necessary in order to recognize whether emerging programs reporting to improve specific learning processes are legitimate and grounded in solid research or whether their findings have yet to be proven. This raises an important issue, however, because it is likely that many stakeholders in education may not be aware of the knowledge that has been gained in the field of neuroscience to explain the learning processes involved in reading, writing, and math. They could be at risk of employing instructional practices and using expensive materials that do not appropriately address the developmental needs of many of the students in the classroom. This is particularly a concern when working with struggling learners who may have specific cognitive deficits that contribute to their inefficiency in learning. By not considering the neurodiversity that exists among learners, educators could clearly miss opportunities to make significant changes in young people's lives.

In considering that the bridge between the fields of education and neuroscience is just beginning to form, it is recommended for both neuroscientists and educators to collaborate in the analysis of research investigating interventions that target cognitive processes in order to ensure that both fields understand the factors that may affect struggling students' ability to learn. It is possible through these conversations for the fields to meld more effectively, to develop educational programs and interventions that improve the outcomes even of those individuals who have failed to make progress, despite receiving a variety of research based interventions for a significant amount of time. One of the strengths of this research, as well as others on computerized working memory training is that it provides additional translational research through the examination of cognitive underpinning, linked with learning, and also whether or not specific targeted interventions may improve neuropsychological processes and academic skills of struggling students. Stakeholders in the field of education could particularly benefit in increasing their knowledge base on applied neuroscience in order to ensure that schools are implementing developmentally appropriate educational practices. It is essential, therefore, for educational leaders to engage the various stakeholders in the dissemination of the discoveries that have been made in neuroscience to specific individuals who have the ability to utilize this knowledge to ensure that the strategies, interventions, and curricula that are being implemented in the schools align with the research.

Probably the most important group of stakeholders who need to be aware of the research connecting the fields of neuroscience and education are teachers. One of the most powerful concepts that teachers need to understand is that the brain is malleable and not fixed, as many educators were once trained to believe. In reviewing the research on the plasticity of the brain and the discovery that improving the negative effects of certain variables, such as poverty and stress, can improve specific cognitive processes that directly impact school performance, teachers may feel more empowered about their irrefutable role in shaping young children's current and future neuropsychological development.

In order for teachers to feel supported in adjusting their teaching philosophies and approaches to children, based on the research generated from the field of neuroscience, it is imperative for other personnel in the educational system to be informed of this data as well, to ensure continuity and consistency in the instructional practices implemented within the school day. Although teachers have the most direct and daily contact with students, administrators hold the keys to what teachers are able to provide to their students in the classroom. Administrators do want to ensure that the teachers they supervise have available to them research based interventions that will enable them to help their students reach their fullest potential. They are also the individuals who not only oversees the day to day functioning of the school building, but also serve as one the primary decision makers in selecting curriculum. It is, therefore, essential for them to be aware of the most current research in the neuropsychology of learning to help them make informed choices about the strategies and interventions that are the most efficient and effective in meeting the needs of all students. This includes those who are struggling in the regular education system as well as those identified to receive special education services. Additionally, administrators, from superintendents to building principals, are at the front-line when schools are criticized for not meeting the expectations assigned to them; they are also the ones who are responsible to interpret and implement the standards and mandates developed by the Departments of Education. With the increased interest in understanding more about the brain through the Brain Initiative as proposed by President Obama in April of 2013 (Szalavitz,2013), it is probable that there will be increased expectations placed upon educational entities to utilize the data generated from brain research. It is thus essential for administrators to increase their knowledge base about what is currently known about neuroscience as it relates to children and young adults and to participate in ongoing professional development to stay informed of the emerging research.

In addition to administrators who are assigned the responsibility to ensure that their students are receiving appropriate instruction, curriculum designers are also responsible to keep informed about the research because the materials they publish will be scrutinized by a wide range of stakeholders, particularly because of the significant expense taxpayers put forth to enable schools to purchase these programs. Curriculum designers need to be considered in reducing the chasm between neuroscience and education to ensure that students are reaching their fullest potential, or at the minimum, meeting grade level expectations. An example of how neuroscience has informed curriculum designers is in the area of reading; the literature has contributed to a wide range of resources that emphasizes the five pillars of reading, facilitating the differentiation of instruction to meet the specific needs of students struggling in various aspects of reading (National Institute of Health, 2000). Currently, there has been increasing attention in the area of math by curriculum designers because they are examining the differences around the world, particularly in countries found to be more successful in teaching advanced math at the higher grade levels. It can be expected that as more is understood about brain functioning in math, there will be ongoing research on how to best meet the needs of struggling math students.

Another group of stakeholders who play an extremely important role in the shaping of education are the institutions of higher education who are responsible for the training of future teachers. In understanding that the curriculum in teacher education programs are packed full in order for their students to meet pre-requisites, prior to beginning their student teaching, it is imperative for increased attention towards instructing these individuals on the neuropsychological processes involved in learning and in recognizing the factors that could be contributing to learning difficulty. It is especially important to assist future teachers in developing a strong repertoire of interventions and strategies to use with children in their classrooms, with the realization that people are neurodiverse and that not all children learn the same way.

This last decade has brought a whirlwind of discovery on the brain's incredible ability to grow during young people's development when it was once thought their skills were fixed. It may be valuable to consider a public policy initiative linked with the BRAIN initiative to encourage further research specifically focusing on the linking of neuroscience with education. This data must be disseminated to stakeholders involved in the education of children, including parents, in order to ensure that each child is given his or her best shot to reach his or her optimal skill level. A public initiative encouraging the sharing of this knowledge may help prevent schools and communities that are typically leery and suspicious of "another new trend" in education from lagging behind in implementing recommended practices. Considering the current contention in the nation regarding the implementation of core standards, it is important to be cautious in making drastic changes in practice to avoid any misperceptions that any changes in the educational processes are political in nature versus being based on sound scientific research. Implementing a goal in which neuroscience data are provided to all individuals responsible for the education of young children may increase the chance of positive systemic change to guide practice. Another issue that also arises in education relates to the delineation among federal, state, and local authority when examining public school programming, monitoring, and funding. As groups challenge who has the authority to change educational practices, issues also emerge surrounding the costs of research and the difficulty in finding the necessary funds and time to meet the initiative of creating a larger body of research that considers neuroscience research and the implementation of interventions within the educational setting. Many factors need to be considered when schools are asked to consider a change in perspective; thus, more discussion is needed in determining how best to intertwine the fields of education and neuroscience as part of the underlying thread in everyday school practice.

Future Research

There are a wide variety of opportunities to conduct future research on computerized working memory interventions and the impact these may have in improving outcomes within a variety of populations. One particular aspect that would be valuable to investigate is the coaching process in itself. An area that has been gaining attention is the role of the coaching processes in improving executive functioning skills in school aged students. It would be beneficial to examine further, the degree to which the coaching process influences students' outcomes when combined with a computerized working memory program. One thought is to involve students in completing a coaching feedback form to assist in determining the value that part of the process contributed to the outcomes of the individuals (Dawson & Guare, 2012). Dawson and Guare (2012) have a sample of a coach feedback form that may be beneficial for use when examining specific behaviors observed in children with executive functioning deficits. One of the specific factors to consider is whether the relationship itself between the coach and the student played a role in sustaining motivation and using strategies throughout the intervention process. One component that may be valuable to include in future research would be to document coaching effectiveness on the improvement of specific executive skills by comparing individuals participating in the coaching process alone with those involved in both the computerized working memory training program and a highly structured coaching model. It would also be valuable to assess the role of motivation , the influence of coaching and the value of other tools and opportunities in the progress of student education.

Given the small sample size in this study, it was not feasible to conduct further analysis of the data in determining whether the outcomes varied, depending on the subtype of ADHD. It may be beneficial for future researchers to examine the degree to which the intervention affects outcomes for individuals with inattention concerns only, when compared with those with both inattention and hyperactivity/impulsivity symptoms. Future studies could involve exploring whether individuals with more severe learning and behavioral concerns demonstrate outcomes proportionally different from individuals with fewer concerns. One of the difficulties, however, in conducting this type of research is that although the individuals may meet the criteria for a specific subtype of ADHD, comorbidity with other disabilities and concerns (e.g. learning disabilities, conduct disorders, oppositional defiant disorder, low language skills, anxiety, and depression), contribute to the difficulty in finding comparable control groups (Dahlin,2012;Nigg, 2006). To go into greater depth in order to understand the relationship that the severity of symptoms has on effectiveness of the training program would likely require more narrowed criteria in selecting participants, such as focusing on a specific math disability or neuropsychological process to measure, in order to reduce the likelihood of Type 1 and Type 2 errors.

Another proposed idea for future research is to consider further the relationship that medication could have on the outcomes of individuals participating in a computerized training program, particularly if the assumption is made that medication may be more frequently used by individuals with more severe symptoms. One question that may be beneficial to consider in this research is whether individuals on medication are currently functioning at their optimal level in their behavior, learning, and/or focus.

An alternative thought, however, is whether the combination of medication and computerized working memory training helps individuals reach their optimal levels of performance, when compared with medication alone. Although the use of medication is an extremely important variable that needs to be considered when conducting research on individuals, there are ethical concerns that are likely to affect the ability to control fully for the use of medicine in young people in the United States. Ethical concerns, particularly when treating children, could be raised if expectations are placed on individuals regarding their use of medication during their participation in a study.

The role of gender in assessing treatment effects is another variable that has been raised in previous research. Dahlin (2012) questioned whether neuropsychological differences exist between the genders when examining treatment effects for students struggling in math. It may be valuable to consider in such an exploration whether gender is a variable that could influence the outcomes or if differences between the genders may have more to do with how schools identify individuals with disabilities and address their needs.

Several questions could also be raised when attempting to interpret the findings generated on the verbal working memory tasks. One is that as technology advances, there may be increased opportunities to allow participants to use voice activation to produce verbal output instead of relying primarily on tactile responses to respond to verbal information. Second, to examine the degree to which the training intervention taps verbal working memory tasks, it may be beneficial to investigate whether or not there may be positive outcomes if participants were provided with booster sessions that focused more directly on verbal working memory tasks. This may be beneficial in deciphering whether the difficulty in maintaining long-term outcomes on the verbal working memory tasks can be attributed to the training activities and protocol, when compared with the other trained tasks or whether it may be more directly related to the difficulty in remediating verbal working memory in individuals with ADHD and/or math difficulties.

As discussed throughout the research on cognitive processes, it is difficult to isolate skills and to differentiate the sources of some cognitive difficulties. Because the students in this study were not found to be significantly low in the area of fluid reasoning, another area that would be beneficial to consider is to assess training effects on fluid reasoning, specifically with individuals screened and found to have weak fluid reasoning skills. Additionally, it would be valuable to explore more deeply the relationship of fluid reasoning with working memory in individuals with math disabilities and ADHD.

Utilizing a repeated measure design in this study contributed to the difficulty in analyzing data because of the role that practice effects could have had in improving performance on certain tasks across time. A more appropriate manner to measure long-term training effects on specific cognitive tasks and achievement would be through the use of alternative forms that were standardized to ensure they were valid and reliable instruments that tested the same skills. Because there are a limited number of specific assessment batteries and tools that offers a wide range of assessment with alternative forms, one option is to consider implementing a procedure similar to that followed by Lohaugen and colleagues (2011). In their study, a separate group of individuals were administered the multiple assessments, but did not participate in the interventions.

Although the working memory training may have contributed to gains in specific cognitive processes, it is still important for individuals to continue to participate in direct instruction in math, with the thought that the training intervention may provide a "boost" to their learning. Future research may want to examine whether individuals with the working memory training could make more significant gains with an intensive research based academic intervention program such as in reading or math, compared with another group of individuals without the computerized working memory intervention but with the researched math intervention. It is important to look at gains achieved several months to a year following the intervention to determine if the addition of the computerized working memory intervention improved the outcomes because the hypothesis is that the training assists in further developing the cognitive skills linked with learning. This training will help improve their ability to attain and retain the material taught through the educational program. Because research on the far-transfer effects of computerized working memory programs on academic performance is only beginning, one must consider that there are many communities struggling to find resources to help vulnerable populations. By attempting to meet the needs of individuals in the school setting, it helps to even the playing field because some computerized training programs were more likely pursued by families with the financial resources to provide this intervention through a private provider. Although the school setting does offer some significant advantages in providing computerized interventions for struggling learners, there are significant barriers that need to be considered. Schools are practical and want to know the direct relationship that interventions have in increasing performance scores on high-stakes test; therefore, the examination of far-transfer effects on academic performance should be a priority in this field of research in order that it may be accepted more widely as an accepted intervention in the school setting.

Researcher's Reflections

In reflecting on the process that led to the final product of this study, there are various factors that would have been revised if it were proposed to the researcher to replicate this study. When developing the proposal, the researcher would have heeded the advice of others in implementing fewer assessments as part of the repeated measure design, recognizing that additional research can be implemented in the future to further test hypotheses. This is especially valuable advice when considering that this was not a project in which there was a team of researchers working collaboratively to answer several hypotheses. The work load was often arduous, when considering the limited amount of time that was available to administer individualized assessments in three different sessions at three different times of the school year for each group of participants while also adhering to the duration between the intervention and administration of the assessment. One of the strengths of such a rigorous schedule was the difficulty in linking performance with certain participants because their protocols were identified with codes and the number of individualized assessments completed on any given day led to difficulty in putting one person's face with a particular response pattern. Although the opportunity to collect qualitative data of a person's performance on an assessment is significantly important when conducting individualized psychoeducational evaluation, the purpose of this study was to collect quantitative data across time on individuals' performance on standardized assessments and to put in place various safeguards to assist in avoiding experimenter bias.

Another factor that requires reflection relates to the actual design of the study. There could have been some benefit in reducing the size of the sample in order to commit time and attention to focusing on only a few individuals utilizing a single subject design. This would have provided the opportunity to collect both qualitative and basic statistical data in order to examine some of the questions raised about variables such as motivation, the reward systems, and coaching process. Because one of the primary objectives of this study was to examine transfer effects, an attempt was made to collect a larger sample group to increase the opportunity of testing whether or not the intervention could be beneficial to a particular subgroup of individuals who are struggling significantly both behaviorally and academically within the school setting. The study did involve the use of a convenience sample and because there were not enough participants to establish a wait-list, or control group, the ability to generalize the findings to others needs to be considered cautiously. It was likely too ambitious to hope for a larger sample size when there was only one researcher responsible for the administration and scoring of all assessment materials. It was beneficial, however, to have experienced coaches and training aides overseeing the day to day practices of the intervention, including those who did the actual coaching of the students. This also helped to reduce the risk of experimenter bias.

The researcher was unsure of the direction that the assessment data would take when answering the hypotheses presented towards the beginning of the study. Although the researcher was aware of the findings of the research, the questions regarding transferability of skills was particularly interesting because of being in the position to assist school personnel in finding research based interventions for individuals failing to make progress. Additionally, the issue of students identified with special education failing to make progress in the curriculum was one that was bothersome because efforts were being made to try to improve the outcomes of these individuals, to ensure that they were not another group of individuals failing several grades and then quitting school as soon as they were no longer at compulsory age for school attendance.

In addressing the question of how the researcher changed because of this study, one of the primary thoughts that came to mind was in recognizing the amount of perseverance, patience, confidence, and support that is needed in order to complete meaningful research. It was daunting at times to consider the amount of time and attention that was required to complete every aspect of a research study to ensure that the procedures were precisely implemented as proposed. Although the proposal process was lengthy and extremely detail- oriented, it was worth the effort because this document served as a blueprint throughout the entire process. There were highs and lows throughout the research process because there were times when small changes had to be made, such as the need to change a time to assess a student because to a scheduled talent show or benchmark assessment, but other times it was exciting to look at the data when trying to answer the research questions.

One of the more frustrating aspects of the research was in facing roadblocks with colleagues who had legitimate concerns about how to utilize individuals' time effectively in the school day. It was a conundrum when considering that students who are struggling need many supports in a wide range of areas, especially when it seems that there is not enough time in a day to meet all of their learning needs. In examining the daily debates that occur between and among school professionals, particularly in the era of response to intervention when choices have to be made about when to provide interventions, it brings up the need for research, such as that examined within this study, to help provide educators with the data necessary to make wise choices in how best to address students' needs.

In the final stages of analyzing the data and interpreting the findings, it became evident that although the time and commitment involved in completing the study was surprisingly intense, it was awe inspiring to consider that there are committed researchers all over the world, working arduously every day to complete the tedious nature of research with the overall objective of providing evidence to support or refute findings that essentially will help humankind live better lives. The fields of education and neuroscience are currently in a promising position to build a relationship that may serve to unlock some of the mysteries of the human brain linked with learning and also discovering the key that may open the door for individuals who have consistently struggled. It is hoped that the findings of this study may serve to guide additional research that will allow further exploration in how to meet the needs of struggling students.

Summary and Conclusion

It is fairly evident that there is a significant need to find interventions and strategies to dramatically improve the prognosis of individuals with ADHD and co-existing learning disabilities and ADHD. In a nation where there is increased pressure to ensure that all children are making adequate yearly progress and demonstrating skills that meet the standards necessary for them to enter the work force or post-secondary training, it is imperative to continue to research interventions that may prove to address the needs of those sometimes described as "treatment resistant." This quasi-experimental, repeated-measures study was initiated to investigate the training effects of a computerized working memory intervention, implemented within the school setting, with individuals identified for special education with co-occurring concerns in math and ADHD. In reviewing the findings in this study, the preliminary results appear promising because both near- and far-transfer effects were found on various memory tasks, with the most robust results found in the areas of attention/concentration and working memory. Additional data also found that math achievement also improved when examining long-term outcomes, and improvements were also observed on rating scales measuring executive functioning skills and working memory. Although a repeated-measures approach was utilized to reduce the limitations linked with not having a control group and having small sample size, these results are to be interpreted cautiously and cannot be generalized to the broader population of individuals. It is thus recommended to continue investigation of this intervention in the school setting, to assess if the results can be replicated in improving attention and working memory tasks, as well as achievement, in individuals with co-occurring ADHD and learning disabilities.

This study provided only one example of a group of individuals that are not making the gains expected of them; it is imperative, therefore, to also examine the impact this training may have on individuals with other learning concerns. It may also be beneficial to assess the effectiveness of the computerized working memory training in individuals with learning disorders that do not meet the criteria of ADHD classification; it may help in illustrating more clearly the relationship that the intervention has in improving the neuropsychological processes linked with reading and math. Because it is not appropriate to remove specially designed intervention services to children with disabilities, it is suggested to look specifically at whether computerized working memory interventions can boost interventions already provided to individuals through their educational programming; this idea is based on the hypothesis that it is the interface between the intervention and researched based academic interventions that contributed to the transfer effects observed in math performance.

In conclusion, there are many more questions that need to be considered as schools enter this new frontier of integrating the fields of neuroscience and education. Training educators in neuroscience can help build a better conceptual understanding on how the brain learns and what factors may help or hinder an individual's ability to achieve in school. Although there are skeptics who may be hesitant to examine the neuroscience research when exploring intervention options, it is very likely that the fields will collide at some point in the near future. It is essential for stakeholders to be aware of the research on computerized training as the trend towards computerized interventions continues to grow. Knowing that there is significant cost linked with the integration of technology and education, it is also wise for educational leaders to be well-versed in interpreting the findings in order to ensure that the interventions and programs that are being considered are grounded in research. It is with great hope that although there were limitations in this study that would affect generalizability, the research could serve as a springboard for additional questions and research in the field of educational neuroscience. Given the fact that the subjects in this study represent a very small subsection of the many individuals struggling academically across the country, it is imperative for neuroscientists and educators to recognize that through the building of a bridge between the fields, they can potentially provide these individuals with an increased opportunity to find the tools that can ignite their learning and improve their chances for a more successful future. Recognizing that this study was initiated when there were relatively few studies examining the use of computerized training, and even fewer examining the training of cognitive processes linked with learning instead of directly teaching achievement, it is clear that it is just at the launching point in the journey to new discoveries in educational neuroscience.

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APPENDICES

Appendix A

Parental Consent Form for Participation in

Study

Big Spring School District
45 Mount Rock Road
Newville, PA 17241

Date: August, 2012

RE: Informed Consent to Participate in a Research Study
Dear Parent or Guardian,
My name is Angela Heishman and I am employed at the Big Spring School District as a certified school psychologist and I am also a doctoral graduate student in the Graduate School of Education and Human Development at George Washington University. I am inviting your child to take part in a research study. This letter is to tell you about the study. Your child's participation is voluntary and is ultimately based on your decision to grant permission if you would like him/her to participate. If you decide to have your child participate, you will be asked to sign the permission forms at the end of this letter and will be given a copy to keep.

The purpose of this research
As part of my dissertation, I am conducting a study to examine the effects of a computerized working memory program for students who have been identified with a disability as defined by IDEA. Students who will participate in the program are those individuals with weak academic skills and who may have a history of concerns with inattention, impulsivity, and/or hyperactivity.

The administrators at the Big Spring School District are fully aware of this project and have allowed me to conduct this research. My Dissertation Chairman, Carol Kochhar-Bryant, Senior Executive Dean at George Washington University, will be supervising this dissertation study.

Why your child is being asked to participate?
Your child has been referred after reviewing the records of students identified with a disability and meeting the criteria established by the study. Additionally, due to the nature of your child's schedule and in consultation with his/her teacher(s), he/she will be able to participate in the intervention as part of his/her schedule during the school day.

It is important to note that whether you accept or decline to have your child participate in this research, it will not affect your child's school services or academic standing.

What you and your child will be asked to do?
I am requesting permission to assess your child by administering a series of tests prior to the training and following the training. I will meet with your child for several sessions before the working memory training starts and also during two sessions after he or she completes the training (approximately 4 weeks after the training and 4-months after the training). Your child will be administered individualized assessments to evaluate his or her current level of achievement (i.e. math performance) and various cognitive processes. Should your child meet criteria and parent permission is further granted, I will also ask you and your child's teachers and child to complete additional questionnaires about his or her level of attention, impulsivity, level of activity, as well as other questions related to his/her academic performance and daily life experiences related to learning and behavior. Results from these pre-training measures will be used to assist in understanding your child's learning needs and to evaluate the effectiveness of the training program in improving academic achievement, behaviors, working memory skills, and fluid reasoning.

Where will this take place and how much time will this take for my child and me?
All individual sessions with your child will take place during the school day. Prior to participating in the training, I will meet with your child three different sessions to administer the various assessments described previously. A start-up session will also be scheduled to review the Cogmed working memory training program. During this session, we will also discuss the coaching process and reward schedule to help maintain motivation throughout the training and to also assist him/her in understanding his or her progress.

Your child will receive the computerized intervention 4 days each week for 7 weeks. Each interventions session could range from 30 to 45 minutes with additional time as needed to take a break or carefully answer the exercises he or she is being asked to address. As part of this process, your child will also participate in weekly coaching sessions with a learning support teacher for a 10 to 15 minute period to review his or her data in the program and to develop strategies that may help in improving performance or coping with frustration that may occur in participating in the program. An important part of the coaching process is to provide praise and encouragement. Additionally, weekly incentives will be provided for participating in the program. A reward schedule is also established at the half-way mark and upon the conclusion of the training.

What are the benefits of your child being in this research?
The possible benefits expected from your child's participation in this study are improvement in working memory, which has been found to be linked with improvement

in academic performance and improvement in attention/concentration. Preliminary research has supported that this training may help in achieving substantial and lasting improvement in academic improvement, as well as social and self-management skills. This study will help further investigate the impact this training may have on learning, achievement, and behavior.

Should your child no longer wants to participate in the training, he/she will be allowed to stop participating at any time during the study. I will ask that you contact me and/or his/her learning support teacher if such concerns should arise.

Are there any risks in this research?

Financial risks. There are no financial risks involved in the participation of the training program as the Cogmed RM working memory training is a service provided through the school district.

Treatment. In consultation with the participant's parents, teachers, and information generated from the structured interview and data collection, the researcher and coach will assess whether your child will be an appropriate candidate to complete the training. As outlined by the designers and trainers of the Cogmed program, three areas of difficulties found to be incompatible with the training include: 1. Severe conduct disorder; 2. Severe Depression; and 3. Severe Anxiety (Cogmed America, 2010). Previous research has indicated that children on medications (methylphenidate) compared to those without medication can both equally benefit from the program. Individuals who have a recent history of frequent absences may need to be placed on a waiting list until he or she is able to attend school on a more regular basis due to the necessity for the training to be implemented at a high weekly frequency.

Persons with photosensitive epilepsy will be excluded from participating in the study due to concerns that lights on the computer screen could trigger an epileptic seizure. Individuals found to have severe intellectual developmental disabilities, identified as Mental Retardation (Intellectual Disability) under IDEA regulations, will not be found eligible to participate in this study. As the training is presented as a game-like software program, it can cause frustration and stress in participants as the activities become more challenging. The coaching component provided by a trained Cogmed Coach is an important component in providing support and motivation to the participant as he or she progresses in the program. As part of the weekly coaching session, the participant will be given strategies by the Cogmed Coach to assist in improving performance and to manage frustration. Regarding the participant's behaviors and needs during the intervention session, a training aide will be overseeing each training session to ensure that each participant is managing his or her frustration effectively. The training aide will be able to remind the participant of the strategies that were reviewed as well as intervene if it appears that he or she needs to take a short break during the training or use another strategy.

Additionally, the Cogmed Coach, researcher, and aide will consult on a weekly basis to discuss the progress of the participants and note any behavioral/emotional concerns displayed by any of the participants that may require additional attention and to ensure the program continues to be implemented with fidelity. A reward system is another important component incorporated into the Cogmed training program. External reinforcement is incorporated in the program through the immediate opportunity to participate in the RoboRacing game at the end of the training and weekly incentives provided to the participant. Additional reinforcement is also being provided in this research to include the half-way mark and at the conclusion of the program. To assist in building internal motivation, the Cogmed Coach will be reviewing the participant's performance during the coaching meetings. Assessments.

The research will follow the guidelines and ethical guidelines outlined by the National Association of School Psychologist, American Psychological Association, and National Board of Certified Counselors. This ethical obligation includes protecting the rights and welfare of the participants. Due consideration will be given to protect individual integrity and individual differences and to ensure knowledge in the validity and reliability of the instructions and techniques. Identifying information will be removed in order to protect the privacy of the participants. Additionally, the researcher has received extensive training in conducting the assessments included in this research through graduate training and post-graduate training to ensure that is administered as standardized and interpreted accurately.

Who will see the information about my child?

Records from the study may be reviewed by departments of George Washington University in order to oversee research safety and compliance. Within the school setting, information on your child's results on the assessments and the intervention will only be shared with the school staff directly involved in the intervention and coaching with your child in order to assist in assessing his or her needs and progress in the program. Upon the conclusion of the training, a summary of your child's results of the training will be provided to you and your child. Data collected in this study will not reveal identifying information about any of the participants in the study.

I welcome questions, concerns, and feedback throughout the course of the study. Contact information is provided at the end of this letter. I would greatly appreciate your permission to work with your child on this project.

Please sign and date below both copies of the parent consent forms to allow your child to participate. Please keep one copy for your records and return the other copy to me by sending the signed permission form to me in the enclosed, self-addressed/stamped envelope. You can also
return this form to the main office of your child's school building and the secretary will be able to forward it to me at the district's administration office. As indicated previously, whether you accept or decline to have your child participate in this research, it will not affect your child's school services or academic standing.

If you any questions, please contact me at aheishman@bigspring.k12.pa.us or 717-776-2000 ext. 1114.

Questions or concerns about your child's rights as a participant can also be addressed to the Office of Human Research at George Washington University.

George Washington University
Office of Human Research
2030 M St. NW Suite 301
Washington, DC 20036
Phone: 202.994.2715
Fax: 202.994.0247
Email: ohrirb@gwu.edu.

Questions or concerns can also be directed to the Principal Investigator of this study, Dr. Carol Kochhar Bryant.

Dr. Carol A. Kochhar-Bryant,
Professor, Senior Associate Dean
Graduate School of Education and Human Development
George Washington University
2134 G. St, NW, 2nd Floor
Washington D.C. 20052
202-994-1536
kochhar@gwu.edu

Sincerely,

Angela Heishman, M.S., NCC, LPC, NCSP, ABSNP
Nationally Certified Counselor
Licenses Professional Counselor
Nationally Certified School Psychologist
Diplomate of the American Board of School Neuropsychology

Big Spring School District
45 Mount Rock Road
Newville, PA 17241
aheishman@bigspring.k12.pa.us
(717) 776-2000 ext. 1114

RETURN TO :
Big Spring School District
Angela Heishman
District Office
45 Mount Rock Road
Newville, Pa 17241

Please fill out the following permission forms if you will allow your child to participate in the research study and please provide a way to contact you in the future:

Name:_____________________________________

Telephone:_______________________

Email_______________________________

Please return these forms to me in the enclosed, self-addressed, stamped envelope, or to the school secretary to place in the student mailbox at your child's school, or mail it to this address:

Big Spring School District
Attn: Angela Heishman
45 Mount Rock Road
Newville, PA 17241

PERMISSION FOR SCREENING

I give permission for my child __________________________ to be assessed by Mrs. Angela Heishman to collect pre-test and post-test measures. My child will be administered achievement tests, memory assessments, and assessments of fluid reasoning. He or she will also complete a self-report survey to rate his or her behaviors. His or her teacher and you as a parent will also be asked to complete behavioral questionnaires and surveys to assist in assessing the effectiveness of the training and to gather additional information about his or her academic, social, and behavioral needs.

Parent/Guardian Signature_________________________________

Date__________________

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***

PERMISSION FOR PARTICIPATING IN THE INTERVENTION

I give permission for my child __________________________ to participate in Cogmed, a computerized working memory training program. My child will receive a research-based computerized training intervention with motivation coaching in the school setting for approximately seven weeks. This study will also serve as a pilot study to examine a new tool to measure training improvements called the Cogmed Progress Indicator (CPI) and designed to complement the training index currently incorporated with the training program. The coach and end user will be able to track the progress and receive a clear report of the training effects at the end of the training period. Additional information about the computerized training program can be found in the attached material and at www.Cogmed.com.

Parent/Guardian Signature___________________________________ Date_________

Child Assent Form

Dear_______________________________________,

My name is Mrs. Heishman and I am a school psychologist at Big Spring School District and a graduate student at George Washington University. I am doing a project on a working memory program that is completed on a computer. I also will be working with other students in your school on this project. I would like you to help me with this project. If you would like to help, I will need you to give me permission to include you and for us to work together in individual sessions for three sessions at three different times. One session will be prior to you starting the working memory training program. I will also meet with you at approximately four weeks after the training and 4 months after the training.

A learning support teacher will be meeting with you once a week to review the progress you have been making in the training. Each week, you will be able to choose one of the weekly rewards that students have indicated that they would like to receive. You will also be able to participate in reward activities half-way through the training and upon the conclusion of the training.

Your teacher and parents know about my study, and your parents said it was ok for you to help. It is important for you to understand that your help is by choice, and it is ok to say no. At any time, you can choose to stop participating by informing your teacher, parent, or me. If you have any questions, please ask your teacher or me. It is important to note that whether you accept or decline to participate in this research, it will not affect your school services or academic standing.

If you agree to work in the study, please mark the circle "yes" below. If you do not want to participate, circle "No". Sign your name on the line below. Thank you for your help.

Sincerely,

Mrs. Angela Heishman

YES **NO**

Name____ Date__________________

School Permission Form

Date:

Dear Mr. Fry:

I am requesting your permission to complete my dissertation at the Big Spring School District on the Cogmed program, a computerized working memory training that has been in place in the district as part of a pilot program since March of 2011. The purpose of the study is to investigate the effectiveness of the Cogmed working memory training on students identified with a disability and receiving special education services. Particularly, the study will be examining the effectiveness of the training on students with math difficulties and a diagnosis of ADHD, or those with characteristics significantly linked with a subtype of ADHD.

This study will also serve as a pilot study to examine a new tool to measure training improvements called the Cogmed Progress Indicator (CPI) and designed to complement the training index currently incorporated with the training program. The purpose of the CPI aligns with an objective of this study which is to illustrate the impact of training by requiring participants to perform non-trained tasks of working memory over the course of training. Thus, the CPI provides a measure of WM transfer and cognitive change. Through a set of tasks performed five times throughout the training, the outcome will be referred to as progress as measured against the baseline. The coach and end user will be able to track the progress and receive a clear report of the training effects at the end of the training period.

Once the students are selected, I will contact parents to provide them with information about the training program and the pre-test and post-test assessments that will be administered to assess the effectiveness of the program.

Participants will be administered pre-test assessments prior to the intervention, 4 weeks following the intervention, and 4-months following the intervention. Assessments to be administered will assess for academic achievement, memory and learning skills, and fluid reasoning skills. Each participant will also complete a behavioral self-assessment form during each of these testing phases. Each participant's parent and teachers of the participant will also be asked to complete rating scales to assess the presentation of behavioral symptoms to evaluate treatment effects in reducing related symptoms.

Participants will participate in the Cogmed training program four days a week for 7 weeks with each session ranging from 35 minutes to 50 minutes. A trained Cogmed coach, the designated learning support teacher, will meet with each participant once a week for 10 to 15 minutes to review his or her progress in the program. This will also provide the participant with an opportunity to develop strategies to maintain and improve performance and to review techniques to manage frustration that may occur as the training exercises become more challenging. A reward system will also be in place to encourage participation. This system will include reinforcements being provided weekly, half-way through the training, and upon the conclusion of the training.

If you have questions, I will be glad to meet with you in person or can be contacted at aheishman@bigspring.k12.pa.us or at (717)776-2000 at extension 1114. I would greatly appreciate your permission to work at the Big Spring School District on this project. Please sign and date below if you would agree for students in your school to participate and return a copy of this permission letter to me in the enclosed, self-addressed and stamped envelope.

Thank you for your time, effort, and cooperation.
Respectfully,

Angela Heishman

Signature of Superintendent ____________________________________Date:

____

Appendix B

Tables of the Participants' Scores from Group One

on the Cogmed Progress Indicator

Table B.1

Table of Each Participant's CPI Scores from Group One on Working Memory Tasks Across Sessions

Student Number	Baseline Score	Session 10	Session 15	Session 20	Session 25
1	455	370	440	370	385
2	300	470	440	425	300
3	0	140	370	400	300
4	485	425	355	300	--
5	300	400	440	270	--
6	300	340	300	425	300
7	555	370	470	400	--
8	525	440	340	470	--
9	485	425	425	440	500
10	440	325	525	400	---
14	400	500	--	470	485
21	500	300	440	725	540
22	425	300	500	400	---
23	485	300	470	525	---

Table B.2

Table of Each Participant's CPI Scores from Group One on Following Directions Tasks Across Sessions

Student Number	Baseline Score	Session 10	Session 15	Session 20	Session 25
1	440	455	325	300	500
2	385	340	340	440	--
3	370	340	340	370	340
4	370	400	240	116	--
5	470	400	400	400	--
6	270	400	340	370	325
7	385	300	455	200	---
8	400	270	110	270	170
10	400	400	340	400	300
14	240	400	370	440	470
21	355	525	540	400	--
22	240	240	300	340	--
23	240	100	385	400	240

Table B.3

Table of Each Participant's CPI Scores from Group One on Math Challenge Tasks Across Sessions

Student Number	Baseline Score	Session 10	Session 15	Session 20	Session 25
1	106	111	115	135	154
2	177	208	208	208	298
3	128	127	77	77	128
4	116	107	107	107	---
5	88	88	137	137	72
6	127	167	136	136	147
7	146	132	148	148	159
8	187	156	172	172	153
9	157	146	124	124	125
10	158	178	147	147	---
14	178	267	309	309	253
21	207	216	205	205	216
22	88	118	107	107	---
23	63	116	108	108	---

Appendix C

Tablet of Participant's Scores from Group Two

on the Cogmed Progress Indicator

Table C.1

Table of Each Participant's CPI Scores from Group Two on Working Memory Tasks Across Sessions

Student Number	Baseline Score	Session 10	Session 15	Session 20	Session 25
11	3	3	3	3.55	2.70
12	3	3.40	4.40	5.00	4.00
13	5	5.70	3.70	4.70	3.40
15	3.40	4.85	3.70	3.00	----
16	5.00	7	5.70	5.70	5.40
17	4.40	4.55	5.25	4.70	5.00
18	5.55	6.10	7.00	7.00	6.40
19	5.0	5	3.70	4.55	5.0
20	4.0	3	3.70	3.70	4.00

Table C.2

Table of Each Participant's CPI Scores from Group Two on Following Directions Tasks Across Sessions

Student Number	Baseline Score	Session 10	Session 15	Session 20	Session 25
11	2.00	3.40	1.40	3.85	3.40
12	2.70	3.85	2.70	3.40	1.40
13	3.25	4.00	4.70	4.70	5.00
15	3.00	3.70	2.55	3.85	3.40
16	3.85	5.55	5.40	4.70	5.40
17	3.70	3.85	4.70	5.00	1.40
18	4.40	4.40	4.70	4.85	5.00
19	3.85	3.25	2.40	1.74	5.00
20	4.10	4.00	4.40	4.25	4.00

Table C.3

Table of Each Participant's CPI Scores from Group Two on Math Challenge Tasks Across Sessions

Student Number	Baseline Score	Session 10	Session 15	Session 20	Session 25
11	15.34	13.03	12.68	10.01	16.34
12	15.34	14.34	14.34	16.34	16.01
13	14.01	17.34	17.68	17.34	20.34
15	14.01	13.02	14.34	16.01	7.70
16	20.02	25.68	29.68	27.68	28.02
17	18.34	14.35	12.68	9.34	14.34
18	15.34	17.34	17.01	18.01	16.35
19	12.35	16.01	16.68	19.34	17.35
20	13.34	17.34	17.34	17.01	14.02