COGNITIVE AND ACADEMIC GAINS AS A RESULT OF COGNITIVE TRAINING

by

Alicia J. Luckey

A Dissertation Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy

ARIZONA STATE UNIVERSITY

December 2009

COGNITIVE AND ACADEMIC GAINS AS A RESULT OF COGNITIVE TRAINING

by

Alicia J. Luckey

has been approved

November 2009

Graduate Supervisory Committee:

Maryann Santos De Barona, Chair
Linda Caterino
Amy Guimond

ACCEPTED BY THE GRADUATE COLLEGE

ABSTRACT

The purpose of this study was to test Feuersetein's Structural Cognitive Modifiability model by evaluating changes in cognitive skills and reading scores after participation in one of two cognitive skills training programs. The Woodcock Johnson Tests of Cognitive Abilities and Tests of Achievement, 3rd editions were used as evaluation tools. Specific scores evaluated included General Intellectual Ability (GIA), Working Memory (MW), Sound Awareness (SA), and Word Attack (WA).

Three groups, differentiated by parent report, were studied. These groups included; Attention Deficit Hyperactivity Disorder, Dyslexia, and students who were not reported to have any type of disability. The intervention programs differed by focus (Reading or Cognitive) and intensity of training.

Significant differences were found between pre and post test scores for all four variables measured. GIA scores increased from pre- to post-test by almost one standard deviation. MW and SA scores increased 2/3 of a standard deviation, and a five standard score point gain was achieved for WA.

There were no significant differences in gain scores between intervention groups in regards to intensity of training or diagnostic group. Students enrolled in the reading-focused intervention group showed slightly higher gains in WA when compared to students in cognitive-focused intervention programs. Students enrolled in the cognitive-focused intervention programs showed larger growth for GIA when compared to students in reading focused intervention. No significant differences were found between intervention groups on measures of MW or SA.

Limitations of the current study included lack of a control group and the use of parent reported diagnoses to differentiate diagnosis groups. Additionally, examiner effects including the halo or expectancy effect may have impacted scores at post-test. The sample was limited in regards to ethnicity and SES, which may limit generalizability of findings to other ethnic or SES groups.

Directions for future studies may include using more robust achievement measures to evaluate academics before and after training, and getting confirmed diagnoses from medical and psychoeducational reports to differentiate groups. Follow up assessment to determine if gains are maintained in the long-term and focus on gains in particular areas of reading may allow for more specific interpretation of findings.

I would like to dedicate this project to my family. First, to my husband, Jason; whose unconditional love and unyielding support has enabled the successful completion of this project. To my son, Isaac, whose smile and energy are ever abounding, and who reminds me on a daily basis to play, even if just for a little while. To my daughter, yet to be born, whose presence helped motivate me through the final steps of this project. And last, but by no means least, to my loving and ever supporting parents, who have always believed in me. Thank you.

ACKNOWLEDGEMENTS

I would like to thank all of my committee members. First, Dr. Maryann Santos de Barona, who has worked above and beyond my expectations by giving of her guidance and support, not only on this project, but for the past six years. Her high expectations have helped push me to expect more from myself on a daily basis. Next, Dr. Linda Caterino, who has always been available and helpful, and has remained dedicated to my success, no matter the circumstance. Her thoughtfulness and never ending support has helped me be successful on a professional level and has helped me believe in myself. Finally, to Dr. Amy Guimond, for helping me navigate through the statistics necessary for the completion of this project. Her understanding, acceptance, and incredible support has helped me tremendously in numerous ways. I would like to thank all committee members for dedicating their time, expertise, and knowledge along with guidance and support which enabled the successful completion of this project. I would also like to thank the LearningRx Corporation, Dr. Ken Gibson, and Dean Tenpas, whose help throughout this process allowed the vision for this project to become a reality.

TABLE OF CONTENTS

Page

Page

Page

Page

Page

Page

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

There is a need for research-based intervention programs to help students improve their academic performance. These interventions also must be readily accessible to educators. The Individuals with Disabilities Education Improvement Act (2004, 602 3(B)), which calls for research-based interventions to be used with struggling students, has shed light on interventions. Most interventions which are research-based use drill and practice to improve math and reading achievement. Some of these interventions include small group instruction. Particularly with reading interventions, students are often required to read, correct, and re-read material, questions are asked for understanding and students repeat this same type of drill and practice until mastery. Other interventions include summer school or extended school day programs with a focus in the area of improving a particular math or reading skill. Interventions for these extended school day and summer school programs do not always utilize small group instruction, but do include focused practice each day in a particular academic area with goals and pre and post tests to measure gains.

An area of research which has received considerably less attention involves improving academic performance by enhancing cognitive skills and overall cognitive ability. In particular, it is not known if the intensity of a cognitive skills intervention program or qualifications of the trainer, age and initial ability level of participants influence and/or promote change in achievement or cognitive skills. It is also unknown if a program solely focused on improving cognitive skills can improve reading achievement scores to the same extent as a program that is focused both on reading achievement and cognitive skills. Finally, it is unknown if such interventions result in differential results for students with different educational disabilities including those with attention and those with reading difficulties.

This chapter will focus on laying the foundation and addressing the importance for conducting the current study. The definition of intelligence is briefly discussed as is the Theory of Cognitive Modifiability, which is the theoretical basis for this study. Working memory and reading achievement will be defined, discussed, and intervention programs aimed at improving these skills will be reviewed. Some literature on Attention Deficit Hyperactivity Disorder will be presented including interventions specific to this particular population. This is followed by a discussion of the relevance of age and gender to the current study. Finally, the statement of the problem is presented, followed by the specific questions and hypotheses relevant to this study.

INTELLIGENCE AND COGNITION

Questions revolving around intelligence have been abundant since the time man first began to delve into the existence of the mind. From the early work of categorizing thoughts and reactions (Descartes, 1637) and defining knowledge as being two related entities (Hume, 1739-1740) to current fMRI studies, brain mapping and imaging research, questions continue to arise. Some questions such as *what is intelligence* and *how can it be measured* have been addressed throughout the years, but these questions unfailingly resurface as the definition of intelligence is under constant reconstruction.

Defining intelligence often involves using circular logic which simply states that intelligence is defined by how it is measured. However, the measurement of intelligence, and hence, its definition, varies depending on where one searches for the answer. Currently, one of the most empirically supported and comprehensive theories of intelligence is the Cattell-Horn-Carroll Theory of intelligence (CHC) The CHC is a compilation of Cattell and Horn's theory of crystallized and fluid intelligence (Cattell, 1941; Horn 1965) and Carroll's three stratum theory (1993). This 3 level, hierarchical model was statistically derived from confirmatory factor analyses and includes an overall intellectual ability (g), ten broad abilities, and over 70 narrow abilities. Nine of the ten broad abilities addressed by the CHC model currently are able to be measured with standardized cognitive and academic assessments and include; Processing Speed (Gs), Short Term Memory (Gsm), Long Term Retrieval (Glr), Visual Processing (Gv), Fluid Reasoning (Gf), Auditory Processing (Ga), Comprehension-Knowledge or Crystallized (Gc), Reading and Writing (Grw), and Quantitative Knowledge (Gq).

For purposes of this research study, the terms cognitive ability and cognitive skills will be used in place of intelligence. These terms are preferred because they frame the variables under study as particular skills rather than address the entire theoretical construct of intelligence. Working memory is an example of a particular cognitive skill that will be addressed within this study. Additionally, the General Intellectual Ability (GIA) Index, which is a compilation of seven subtests, one from each broad ability (excluding Grw and Gq), will be assessed in this study. The GIA addresses cognitive skills as a whole, but does not measure each broad ability in depth, nor does it measure the entire construct of intelligence. Addressing the entire theoretical construct of intelligence is beyond the scope of the current study.

THEORY OF COGNITIVE MODIFIABILITY

The possibility of modifying and/or improving cognition has been debated through the years. Some researchers argue that cognition is a stable trait (McCall, Appelbaum, & Hogarty, 1973; Zigler, Balla, & Hodapp, 1984), while others believe that it can be improved through intensive intervention (Schaie, 2005; Sharron, 1987). Some theorists posit that overall cognitive ability is something one is born with, and does not change as children age. Goswami (2002) held the view that specific abilities are modifiable, but overall competence is not. In contrast, Harlow (1949) believed cognitive ability developed as a whole as one matured and learned new information.

Several theories have contributed to the belief that cognitive training can modify cognitive skills, thereby enhancing intelligence (Cashdan, 1969; Corter & McKinney, 1966; Klingberg et al., 2005; Sharron, 1987). Theorists in the field of learning and intelligence have identified learning as a process that develops through an individual acting upon his or her environment and constructing knowledge based on his or her experiences (Piaget, 1961,1971; Skinner, 1954; Vygotsky, 1978; and Bronfenbrenner, 1979). Information processing theory, which includes the acquisition, elaboration, and management of information in the sense of inputs, encoding, and expression of information also has been influential (Presseisen, 1992). The ability to learn and manage the processes of input and expression affects the acquisition of knowledge, structure of the brain, and ability to express what had been learned. These theories suggest the possibility that cognitive change can occur through a series of experiences in which learning occurs.

Feuerstein's theory of Structural Cognitive Modifiability (Feuerstein & Rand, 1977; Feuerstein, et al., 1980) is based on the idea that intelligence is malleable. Feuerstein, as well as other researchers, have tested this theory with a series of intensive training procedures known as Instrumental Enrichment (IE). IE consists of direct instruction in completing a series of cognitive exercises including abstract reasoning, deduction, induction, and spatial orientation tasks. Feuerstein first tested individuals to pinpoint some of their intellectual problems, then carried out highly structured teaching (Instrumental Enrichment). He then retested the children to see how their performance had changed. Children previously tested with IQ scores of 55-65 obtained scores within normal limits at post test. Longitudinal as well as international studies have been carried out by Feuerstein and others using the IE procedures, showing improvement in cognitive ability (Feuerstein et al., 1980; Rand et al., 1979; Ruiz, 1985), as well as lasting cognitive change (Rand et al, 1981).

WORKING MEMORY AND COGNITION

Working memory refers to a system within the brain that allows for temporary storage and manipulation of information to complete complex cognitive tasks such as learning, reasoning, and language comprehension. It is involved in the preservation of information while simultaneously processing the same or other information (Swanson & Howell, 2001). Described as a kind of sketch-pad or mental workspace for the brain to use when completing higher order problem solving tasks (Baddeley, 1992; Smith et al., 2001), it is a system so powerful that it has been referred to as being a "pure measure of a child's learning potential" (Alloway, 2006).

Many students with academic difficulties in the area of reading have a processing weakness in working memory (Wendling & Mather, 2009), and it is this processing weakness that contributes to their "disability." Cognitive skills and academic performance are related (Mayes & Calhoun, 2007), and there is a growing need for empirically validated, teacher friendly intervention programs to help students improve their academic performance. This need is in part a result of the Individuals with Disabilities Education Improvement Act (2004), which calls for research-based interventions to be used with struggling students. However, most current interventions, tutoring centers, and programs designed to improve achievement use practice procedures aimed at continually repeating and re-doing the difficult items. An example of this may include practicing difficult words until they become recognized as sight words or practicing multiplication tables until they are simply memorized. Current interventions, even when research based, are solely focused on practice with academic skills without attention paid to improving underlying cognitive skills that may make learning easier.

An area of research which has received little attention involves improving academic performance by enhancing cognitive skills and overall cognitive ability. Though the relationship between academic achievement and cognitive ability is present in the literature, intervention programs aimed at improving cognitive ability for the purpose of increasing achievement are scarce (Wendling & Mather, 2009). Additionally, to date, and to the knowledge of this researcher, research does not exist that examines the effect of cognitive skills training on improving reading achievement.

READING ACHIEVEMENT

Literacy is the gateway to success. In a world where the printed word is so valuable, technology and computer skills are mainstream, and the ability to understand what is read is a determining factor in success, the ability to read is paramount to success within one's education. Individuals who struggle with understanding the written word may be labeled as *disabled,* and require specific specialized instruction and accommodations to succeed with the general education curriculum. These students who are labeled as having a reading disability, by definition have a deficit in a basic psychological process (IDEIA; 2004 (602 (3) A)). These basic psychological processes have been defined to include cognitive skills such as crystallized or fluid ability, processing speed, long term or short term (working) memory, visual processing, or auditory processing (Flanagan, Ortiz, & Alfonso, 2007). Oftentimes the specialized instruction received for reading difficulties focuses exclusively on the drill and practice of phonetic and sound awareness, and recognizing of sight words, with little attention paid to improving the underlying processing deficits (cognitive skills).

Word Attack and Sound Awareness. Word attack skills refer to the ability to decode letters (symbols) into language. Throughout the literature the terms word attack and decoding are used synonymously. Many children who have difficulty with reading, experience a deficit in the ability to decode words (Share & Stanovich, 1995). Word attack is an essential skill for learning how to read (Fox & Routh, 1984). Not only is it essential for being able to read single words, but the ability to decode single words is related to comprehension of what is being read (Torgeson, 2000).

The terms sound awareness and phonological awareness are used interchangeably throughout the literature. Phonological awareness plays a key role in reading development, though its definition is not universally accepted. Some researchers refer to phonological awareness as the ability to recognize a single sound (phoneme), with the ability to work with sound at the multisyllabic level or with word play such as rhyming viewed as a more sophisticated skill;

others use the term to refer to all of the aforementioned abilities (Anthony & Lonigan, 2004). Nonetheless, research has shown that phonological processing skills are important for word recognition and comprehension tasks (Swanson & Howell, 2001).

Working Memory and Reading Achievement. Although the mastery of word attack and sound awareness abilities are essential for reading, cognitive skills, particularly working memory also play a critical role (Swanson & Howell, 2001). Working memory is thought to directly impact the ability to remember what is read as well as reading fluency (speed of reading). Verbal working memory has been shown to correlate with word recognition at a moderate level (.64) (Swanson & Howell, 2001). A proficient reader does not rely constantly on the particular decoding of each sound within a word, but rather processes several bits of information simultaneously and reads each word as a whole while accessing all the information presented within a sentence, paragraph or passage (Palmer, 2000). To become a proficient reader, a well developed working memory is necessary.

RESEARCH AND INTERVENTIONS

Glass (1968) compared cognitive change in children attending Head Start programs to children not participating in Head Start and found that the effect of Head Start education was an IQ gain of only 2-3 points. This study suggested that early education did not dramatically change IQ in preschool aged children. However, some modern day theorists (Berliner, 1988; Jensen, 1998) have agreed that education and environment do play a role in shaping intelligence; even if the magnitude of that role is unclear. Berliner's meta-analysis, which specifically reflected upon the malleability of intelligence within bilingual populations, produced the finding that 40% of intelligence could be attributed to environmental factors. Jensen (1988) cited a specific example of a child who had been environmentally deprived, and once exposed to the outside environment, had measurable gains on IQ tests.

Some intervention programs have been able to improve cognitive skills and overall cognitive ability for students with initially low ability scores, as well as students with specific disabilities (Cashdan, 1969; Corter & McKinney, 1966; Feuerstein & Rand, 1977; Feuerstein et al., 1980; Sharron, 1987). Other research indicates that students with higher initial IQ scores show greater gains in IQ scores over time (Ackerman & Lohman, 2003; Cronbach & Snow 1977; Feuerstein & Rand, 1977; Shaywitz et al., 1995; Snow & Yalow 1982). Known as the Matthew Effect, this phenomenon will be researched in the present study to determine if initial level of cognitive ability affects the degree of gain in cognitive or reading achievement following intervention.

ATTENTION DEFICIT HYPERACTIVITY DISORDER

A major educational challenge facing teachers is working effectively with students who have attention difficulties or Attention Deficit Hyperactivity Disorder (ADHD). Students with ADHD make up approximately 3-5% of the school age population (Biederman, Mick, & Faraone, 2000); this translates into at least 1 student in a class size of 25 who has ADHD.

The Diagnostic and Statistical Manual of Mental Disorders, 4th Edition, Text Revision (American Psychiatric Association, 2000), includes diagnostic criteria for Attention Deficit Hyperactivity Disorder which includes symptoms of hyperactivity, inattention, and impulsivity. Some symptoms must have been present before the age of seven and there must be impairment across more than one setting. In addition to this definition, theoretical conceptualizations of ADHD that have emerged over the past 20 years suggest that ADHD has a neurocognitive basis with specific cognitive skill deficits, most notably in working memory. Although other executive functions such as processing speed also may be impaired in those with ADHD, research has overwhelmingly demonstrated that students who suffer from ADHD have strong and consistent patterns of weakness in the area of working memory (Halperin, Trampush, Miller, Marks, & Newcorn, 2008; Klingberg et al., 2005; Lui & Tannock, 2007; Martinussen, Hayden, Hogg-Johnson & Tannock ,2005; Martinussen & Tannock, 2006; Karatekin, 2004; Pallas, 2003; Rapport, Chung, Shore, Denney, & Isaacs, 2000; Rapport et al.,, 2009; Schwebach, 2007; Sonuga-Barke, Dalen, Daley & Remington, 2002; Willcutt, Doyle, Nigg, Faraone, & Pennington, 2005; Wolfe, 2006; Wu, Anderson & Castiello, 2006).

In fact, studies using the Wechsler Intelligence Scale for Children (3rd and 4th editions, Wechsler, 1994 & 2003), Woodcock Johnson Tests of Cognitive

Abilities (3rd edition, Woodcock, McGrew, & Mather, 2001) and the Stanford Binet Intelligence Scales (5th edition, Roid, 2003) have found that ADHD students consistently score lower than controls on working memory tasks (Lacene, 2004; Marusiak & Janzen, 2005; Poock, 2005).

In addition to having behavioral and working memory challenges in the classroom, many students with ADHD also suffer from difficulties with reading; it is estimated that 75% of students with ADHD have a co-morbid reading disability (Mayes & Calhoun, 2007; Naidoo, 2008). Thus, when looking at interventions to help students who suffer from ADHD, effective reading interventions aimed at helping this population of students are equally important.

Research with ADHD students. Some clinical trials aimed at improving working memory in ADHD students have shown positive results (Klingberg, et al., 2005; Klingberg, Forssberg, & Westerberg, 2002) in both working memory and overall cognitive ability. However, these studies have been conducted within lab-type environments and there is a need for research on intervention techniques that can be implemented within educational settings.

Interventions which have shown growth in working memory abilities also may curb later difficulties within the academic setting (Halperin et al., 2008; Martinussen et al., 2005; Willcutt, Doyle, et al., 2005). There is evidence to indicate that the system responsible for phonological working memory, an ability needed for reading, also is related to the cognitive skill of visuo-spatial working memory, (Baddeley, 2007;Rapport et al., 2008). The link between working memory skills and phonological processing may be partially responsible for explaining the high rate of comorbidity between ADHD and reading abilities (Mayes & Calhoun, 2007; Naidoo, 2008). Several researchers have found that both students with Reading Disabilities and those with ADHD have significant weaknesses in working memory; presently, the mechanism by which memory difficulties link these two disorders is unclear (Avis, 2003; Muse, 2008; Willcutt, Pennington, Olson, Chabildas, & Hulslander, 2005). What is known is that both phonological awareness abilities and word attack skills are crucial for literacy acquisition (Gillum, 2007; Hohmann, 2002; Samuelsson, Lundberg & Herkner, 2004), areas in which students with ADHD have historically shown weaknesses (Brock, 1996; Cherkes-Julkowski, et al., 1989; Elbert, 1993; Farmer, 2003).

Current research on global ability scores (similar to the GIA) which include samples of students with Attention Deficit Hyperactivity Disorder (ADHD) are either limited in sample size (Schuster, 2006) or have not included a control sample for comparison (Anjum, 2005). This makes generalizability of findings for global ability scores for ADHD samples difficult. Nonetheless, results from these studies have shown that students with ADHD score in the average range on global ability scores, indicating no difference between students with ADHD and those without on tests of cognitive ability.

GENDER AND AGE DIFFERENCES

Although some researchers have not found differences between males and females on overall intelligence or achievement measures (Chen & Zhu, 2008;

Lindblad, 1996; Rumsey, 2004); some patterns of strengths and weaknesses between genders on specific cognitive academic skills have been observed. For example, scores on spatial visualization, quicker inspection time, and general math ability have been found to be higher in males than in females (Geiser, Lehmann, Eid, 2008; Pesta, Bertsch, Poznanski, & Bommer, 2008), whereas females tend to score higher than males in emotional intelligence and reading ability (Jausovec & Jausovec, 2008; Husain & Millimet, 2009; Marks, 2008).

In addition to studying gender differences, taking into account the age of the child during intervention is a key component to understanding these findings and how the intervention may be most appropriate for future implementation. Older children tend to score higher on measures of cognitive ability, executive function tasks and academic achievement (Husain & Millimet, 2009; Sengstock, 2001). In contrast, Anderson's terminal status theory suggests that as individuals age, a larger proportion of one's final intelligence is attained; as a result, the likelihood of change in ability decreases with age (Nyborg, 2003). Final intelligence refers to cognitive ability at the point in which scores become stable over time. Using Anderson's theory and Sengstock's research as a guide, this study will investigate the effect of age in a sample of children from early childhood (age 4) to early adulthood (age 18) on overall cognitive ability, working memory and reading achievement.

INTENSITY OF INTERVENTION

Though positive results exist for the improvement of cognitive skills (Holmes, Gathercole, & Dunning, 2009; Klingberg et al., 2005), the intensity of intervention, including the length of the program and number of hours per week spent on training has not been investigated. Heywood et al. (n.d.) found that children in cognitive skills enhancement programs that lasted two years had higher gains at post test than children in programs which only lasted one year. Other cognitive skills interventions that have been researched (i.e., CogMed (Klingberg et al., 2002;2005), have a pre-established number of weeks or hours of training, and hours of training received has not varied within a program, making different levels of intervention difficult to analyze. To add to the literature in regards to intensity of training and specificity of training, this current study looks at two different programs with differing levels of intensity and different areas of focus.

STATEMENT OF THE PROBLEM

Attention Deficit Hyperactivity Disorder (ADHD) is a prevalent diagnosis of school age children. Teachers are increasingly challenged to find ways to improve achievement for students with ADHD, particularly in the absence of accessible empirically validated methods. Most current intervention programs focus on the drill and practice of reading to improve achievement, with little attention paid to the cognitive ability of working memory, a critical factor to reading success. Cognitive abilities, particularly working memory, play a crucial role in academic achievement (Cattell, 1983; Sattler, 2001), and a key characteristic of ADHD is a deficit in the cognitive skill of working memory. However, intervention programs focused on improving working memory to help struggling readers are not readily available.

The existing research on cognitive skill enhancement have shown positive results in regards to improving working memory (Holmes, Gathercole, & Dunning, 2009), though most of this research is computer based, (CogMed (Klingberg et al., 2002; 2005), and sample size has typically been small, limiting the generalizability of results. Additionally, factors such as gender, age, diagnosis of ADHD, and initial cognitive ability levels have not been considered as possible variables within these research studies.

Presently, several areas within cognitive skills intervention research appear to be lacking. First, research in this area has not yet addressed the degree to which the intensity of an intervention program, age and initial ability level of participants, or the qualifications of the trainer influence or promote change in working memory, overall cognitive ability, or reading achievement scores. It also is unknown if a program solely focused on improving cognitive skills can improve reading achievement scores to the same extent as a program that is focused both on reading achievement and cognitive skills. Holmes, Gathercole, & Dunning (2009) have shown that increasing working memory ability has the potential to increase math achievement, though similar research regarding reading achievement is lacking. Finally, it is not known if the degree of improvement in skill varies based on an ADHD diagnosis or reported reading difficulties.

With laws in place that require research-based interventions to address academic difficulties (IDEIA (PL 108-446 § 614 (b) (6) (B)), all areas of intervention deserve attention, including those which are aimed at improving cognitive skills. It also is essential that the details of the intervention, including length and intensity of the program; age, gender, and diagnosis of the participants, as well as the focus of the interventions are investigated so that the variables with the most promise can be combined for ultimate utility and promotion of achievement.

The current research study will address the extent to which reading achievement and cognitive skills can be differentially impacted through participation in two different intervention programs. One of these intervention programs focuses on improving reading achievement and cognitive skills, and the other intervention program focuses solely on improving cognitive skills. Different levels of intervention, in regards to length and intensity of the intervention, will be examined to determine if the degree of change for reading achievement or cognitive skill is affected. Additionally, this study will examine whether students with reported attention or reading difficulties experience the same type and amount of change as students without reported attention or reading difficulties. The research is based in the Theory of Structural Cognitive Modifiability

(Feuerstein, 1977; Feuerstein & Rand, 1979) and research which indicates a strong link between cognitive skills and achievement.

THE INTERVENTION PROGRAMS

The purpose of the intervention programs under study was to improve cognitive ability and reading ability through individual intensive intervention that seeks to promote "rapid mastery of skills and embed the new skills at an automatic, subconscious level." (LearningRx website, ThinkRx, para.4, n.d.) The two interventions consist of a reading program, "Read", aimed at increasing reading achievement and improving cognitive skills, and a cognitive, "Think" program whose main focus is on improving cognitive skills. In each program, participants received all training in either a center-based format from a certified trainer, "Pro", or through a combination of center-based and home-based training,"Partner." Training in the Partner program was provided by a certified trainer at the center and a parent or caregiver at home. All programs were intended to provide 1:1 training, five days a week for 12 (Think Pro and Partner Programs) or 20 (Read Pro and Partner Program) weeks. Read programs focused for 30 minutes (of each hour session) on cognitive training and 30 minutes on a sound-to-code phonetic approach to reading. See Table 1 for specifics about each training program.

RESEARCH QUESTIONS TO BE ADDRESSED IN THIS STUDY

This section will review the research questions under study and their accompanying hypotheses.

Q1: Are there significant differences between pre and post test scores on General Intellectual Ability (GIA), Working Memory (MW), Sound Awareness (SA) and Word Attack (WA)?

Hypothesis 1: There will be significant differences from pre- to post-test on General Intellectual Ability (GIA), Working Memory (MW), Sound Attack (SA) and Word Attack (WA).

Q2: Are changes from pre to post test, in GIA, MW, SA or WA dependent on gender or age?

Hypothesis 2a: Irrespective of intervention group, there will not be any significant differences between boys and girls on gain scores for GIA and MW.

Hypothesis 2b: Gain scores for SA and WA will be higher for females, when diagnostic group, age, and intervention group are controlled.

Hypothesis 3a: There will be a negative relation between age and gain scores on cognitive measures (GIA and MW) such that increasing age will be associated with smaller gain scores on cognitive measures.

Hypothesis 3b: There will be a positive relation between age and gain scores on achievement measures (SA and WA) such that an increase in age will be associated with larger gain scores.

Q3: Does initial level of ability impact the degree of change in GIA, MW, SA or WA?

Hypothesis 4: There will be a relation between initial level of GIA and gain scores such that students with higher initial GIA scores will have higher gain scores on the measures of MW, GIA, WA and SA.

Q4: Are GIA, MW, SA or WA differentially impacted by type (reading achievement vs. cognitive skills) or intensity (center-based vs. combination) of intervention program or by diagnosis (ADHD, Dyslexia, or No diagnosis)?

Hypothesis 5: When comparing students in Think to those in Read programs, students in Think programs will have greater gains in MW and GIA than students in Read Programs.

Hypothesis 6: Students in Read programs will have greater gains in SA and WA than students in Think programs.

Hypothesis 7a: Students in Pro programs will see greater gains than students in Partner programs on measures of GIA, MW, SA and WA.

Hypothesis 7b: Students in the ADHD group will have bigger gains than students in the No Diagnosis group for both Pro and Partner programs.

Hypothesis 8: Gain scores will not differ for diagnostic groups based on type of program (Think vs. Read) enrolled for GIA, MW, SA or WA.

Hypothesis 9a: There will not be any significant differences between diagnostic groups for gain scores on GIA, SA, or WA.

Hypothesis 9b: Students in the No Diagnosis group will have larger gain scores in the area of MW when compared to students in the ADHD and Dyslexia groups.

CHAPTER 2: LITERATURE REVIEW

This literature review will first introduce the theories which contribute to the understanding of cognitive development will be discussed. These include biological, behavioral, developmental, information processing, social, ecological, and learning theory perspectives. Next, the Theory of Structural Cognitive Modifiability (SCM; Feuerstein & Rand, 1977), which lays the foundation for this particular study, will be reviewed. Within the SCM Theory, the related learning paradigm will be addressed.

Then, the history of intelligence including past definitions and theories of intelligence will be presented, including The Cattell Horn Carroll Theory of Intelligence (CHC; Carroll, 1993; Cattell, 1941; Horn, 1965). The CHC Theory is considered the most current and most widely accepted theory of intelligence. Early ways of assessing cognitive skills as well as current practice will be reviewed, and the link between academic achievement and intelligence will be explored.

Next, Attention Deficit Hyperactivity Disorder (ADHD) will be presented in regards to definitions, defining cognitive markers, and cognitive intervention research that exists for this particular population (i.e., Klingberg et al., 2005). Additionally, Specific Learning Disabilities and reading disorders will be discussed and will include current intervention programs to help improve deficient skills present within these individuals.

Also presented will be the debate regarding fluidity of intelligence and relevant studies which have focused on comprehensive cognitive skills training programs. These include studies reviewing SCM-based Instrumental Enrichment programs (Feuerstein & Rand, 1977), which focused on improving cognitive skills within children. Then, a review of research for each of the seven broad ability factors under the CHC theory which are most often measured by standardized cognitive assessments will be discussed.

Next, instruments relevant to this study including the Woodcock Johnson Tests of Cognitive Ability and Achievement, 3rd Editions will be reviewed relating to instrumental factors to be considered; these include test-retest reliability, practice effects, and the importance of controlling for regression to the mean in a study that includes pre and post testing on the same instrument. Additionally, individual factors to consider when looking at cognitive change including race, age and gender are discussed.

This chapter ends with a discussion of the theory and development of the current intervention program, and compares it to Bruner's four rules of instruction for effective learning (1964). In addition, the preliminary studies involving this program will be reviewed. Finally, explanation of how this study proposes to address the gaps in current literature will be presented.

UNDERSTANDING COGNITIVE DEVELOPMENT

Prominent paradigms used to explain cognitive development relevant to this research include theories from the biological, behavioral, developmental, information processing, social, ecological, and learning theory perspectives. The founders of these prominent theories include Plato, Skinner, Piaget, and Vygotsky. Their theories will be discussed in subsequent paragraphs. Feuerstein, a student of Piaget's, combined several components of Piaget's model (discussed below in detail) and created his own school of thought which most closely represents the theoretical backing for the cognitive skills training program under review in this study. Feuerstein's model will also be discussed.

Biological. The biological paradigm explains cognitive development through genetic transmission and heredity. This theory was the first to address cognitive development and potential and continues to have support. Plato (in *Meno,* 1974) believed that everyone is born with the same level of intelligence, yet some are able to uncover or "recollect" more than others. According to Plato, intelligence is already formed at birth and is inherent in the soul. To Plato, an intelligent person is aware of more information, or has uncovered or recollected more than someone who has not yet uncovered this innate knowledge. Plato believed that it is the discovery of this intelligence throughout life that makes an individual appear intelligent.

More recent explanations of the biological model use similar foundations and base their explanation on heredity; one explanation to describe the development of intelligence with roots in the biological model was put forth by Anderson (1939) and was referred to as "terminal status." Terminal status refers to the idea that intelligence can increase until a certain age, after which cognitive abilities cannot be improved. Generally, heredity has been found to account for about 50% of the variance in IQ (Hauver, 2003; Sattler, 2001). Although this is a significant contribution, an equally significant percentage of the variance is accounted for by one's environment.

Behavioral. Skinner (1954) used a behavioral model to explain cognitive development. Within this model, it was implied that a student worked hard or produced learned material only to avoid an aversive consequence or for positive, extrinsic reinforcement. A major critique of this view is that it does not allow for the idea that individual thought, memories, and other mental activities could guide learning. With a focus solely on rewards and punishments that were extrinsic in nature, it ignored ideas such as motivation and learning for the sake of learning. Leont'ev and Gal'Perin (1965) critiqued this extreme behaviorist view of learning by claiming that the stimulus-response-reinforcement paradigm was inappropriate to human learning because it ignored the internal cognitive processes of memory and intrinsic motivation.

Although Skinner's behavioral model was heavily critiqued and is not a currently accepted explanation of cognitive development, Skinner's contribution to modern day psychology, education, and learning cannot be ignored. Components of the behavioral model have been shown to be effective in teaching specific behaviors to younger students. Providing reinforcements and consequences to increase or decrease behavior is regularly used within the elementary classroom setting. Additionally, Functional Behavioral Analysis, a method used to assess antecedents and consequences of a particular behavior to understand and modify that behavior, is a widely accepted practice (Kerr & Nelson, 2006).

Developmental. The developmental perspective focuses on the relationship between genetic disposition and environmental influences. Within this model, development progresses in a linear, non random manner. Differences between individuals are related to the timing and rate of development; however, all skills are acquired in the same order, developing from simple to complex (Sattler, 2001).

Jean Piaget's developmental theory of intelligence suggests that cognition develops through equilibration, where individuals come to assimilate and accommodate new information into already existing structures. His model is rooted in the theory that an individual happens upon a stimulus and then produces a response (Stimulus-Organism-Response (S-O-R)). Piaget believed two main biological tendencies, organization and adaptation, drive individuals' interactions with the environment. Individuals have an inherent tendency to organize what they see in the world and fit any new encounters or information into an existing organizational structure. Adaptation occurs when something does not fit within the existing structure. Assimilation involves fitting new experiences into an existing structure whereas accommodation involves changing one's existing mental structure to accommodate new information. Piaget (1973) believed that heredity (biology) and environment (nurture) both contributed to cognitive development. Simply stated, biology drives individuals to do certain activities within society, and doing these activities results in knowledge (intelligence); therefore, both contribute to cognitive growth. Piaget's theory is stage-based, with individuals believed to pass through the stages in the same order, and at mostly the same ages.

The first of these stages is the Sensorimotor stage, which spans birth to age two. During this stage, children use their five senses to explore the world. They are egocentric, and have difficulty seeing things through others' perspectives. During this stage, the child is only able to think about what they are physically doing. The outcome of this stage is symbolic representation, or the ability to use language to represent something that is not actually present; for example, using the word "apple" to represent an actual apple, even if the apple is not in present view.

The second stage is the Preoperational Stage, which extends between ages two and seven years. Although egocentrism weakens during this stage, children are unable to use logical thinking and in the early phases of this stage cannot understand the concept of conservation. Conservation refers to the ability to understand that four beads placed close together is the same quantity as four beads placed far apart. Conservation of numbers occurs around the age of five or six, whereas conservation of mass appears around age seven or eight.

The third stage is the Concrete Operational Stage and occurs from about seven to eleven years of age. During this stage, children begin to think logically and classify objects. Additionally, reversible thought is possible, although it is limited to concrete objects and only two characteristics at a same time. An example of reversible thought is the understanding that 2 + 3 = 5 and the opposite is 5 – 3 = 2.

The final stage, the Operational Stage, begins around age twelve and extends into adulthood. During this stage, abstract thinking, deductive reasoning, and concept formation are used to solve problems. In this last stage, logical thought is possible and concrete objects are not needed to problem solve. Individuals at this stage are capable of planning ahead and understanding many possible outcomes to a solution, as well as stating and testing hypotheses (Piaget, 1973).

One criticism of Piaget's theory is that it does not account for the differences in cognitive development between families and cultural groups. Another criticism is that it does not give credit to adults within the child's environment (Silcock, 1999). Additionally, factors relating to an individual's thought processes, and how memories affect learning, are not addressed. Information Processing Theories and Feuerstein's Model of cognitive modifiability help correct for these limitations.

Information Processing Theory. Like the developmental model, information processing models help explain cognitive development by describing how mental processes and strategies develop with age. Additionally, it addresses how knowledge is gained through the interaction of cognitive, motivational and self components. First, a child is taught to use a specific learning strategy; then, the repetition of that strategy results in new knowledge, including the range of when and where it can be used as well as its effectiveness in specific settings (Sattler, 2001).

Information processing theory is helpful in understanding cognitive development and expression as well as areas of deficiency. The four major levels in this framework consist of input, integration, storage, and output. Input refers to how information is taken in through the senses and enters into the brain. Integration refers to the interpretation and processing of the information. Newly learned material must be integrated into existing knowledge in order to process and understand what is being learned. Storage refers to the encoding of material, the process of remembering the information for later retrieval. Output refers to the expression of information that resides in "storage" through verbal or motor output (Kaufman & Lichtenberger, 2005).

These four areas can be helpful in measuring and understanding cognitive skills, particularly areas of deficit. As an example, poor memory reflects a deficiency in the storage and retrieval of information while poor expression of information suggests a deficiency in the area of output. Although information processing considers all major areas of thinking, it does not account for outside influences on thinking. These outside influences can be accounted for by social theories.

Social. Vygotsky provides a paradigm by which concepts initially learned in a social context become part of an individual's cognitive background. Society is seen as necessary to reach one's potential intelligence. Both Vygotsky (1994) and Piaget (1995) agree that environmental factors, inclusive of a society which includes elders, are needed for intellectual development. Vygotsky's "zone of proximal development" (ZPD) emphasizes this point. The ZPD represents the difference between what a child can do with and without help (Vygotsky, 1978). For example, a child initially will follow an adult's example, then gradually gain the ability to do certain tasks without help or assistance. Additionally Vygotsky (1994) maintained that later generations benefit greatly from ideas formed by previous generations in that later generations are only burdened by the learning of these ideas and not the laborious task of invention.

Ecological Model. Like Vygotsky, Urie Bronfenbrenner's ecological model (1998) includes a sociocultural perspective that acknowledges the reciprocal influence of child and environment, i.e., the child has an impact upon the environment just as the environment has influence over the child. It is based on five environmental systems that influence children's development. The first system is the Microsystem; it is the most proximate to the child and exerts the most influence. The Microsystem has received the most research attention and is of most interest and relevance to the current study. Other systems included in the ecological model include the Mesosystem, which refers to the interaction between particular Microsystems, such as how school personnel relate to parents, and how that impacts the child; the Exosystem, not believed to have a direct impact upon the child, but which indirectly affects them by affecting something within their Microsystem, e.g., something happening within the workplace of a parent; the Macrosystem ,which refers to the cultural and spiritual belief systems that surround the individual child in a broader sense; and finally the Chronosystem, which refers to the pattern of events that occur over one's life or sociohistory (such as a pattern of divorce within the family). The most prevalent criticism of this theory is its lack of accountability for biological influences upon cognitive processes existing within the individual (Bronfenbrenner, 1998).

The ideas of Reuven Feuerstein (1977) align with Bronfenbrenner's description of sociocultural influences within the child's Microsystem. His theory refers specifically to the direct influence that teachers and adults within the child's immediate environment have upon the child. Feuerstein considers the cognitive factors influencing the development of the child. His model of structural cognitive modifiability is discussed next.

STRUCTURAL COGNITIVE MODIFIABILITY

Reuven Feuerstein's Model of Structural Cognitive Modifiability (SCM; Feuerstein, 1974; Feuerstein & Rand, 1979) brings together critical elements of the cognitive models of social learning theory, developmental theory, and information processing theory. Feuerstein expanded Piaget's model of Stimulus-Organism-Response (S-O-R) (discussed earlier) by including the role of the human as an interventionist who shapes the way the child perceives the environment. This involvement is represented as S-H-O-R, where the H stands for human intervention. Feuerstein specifically acknowledges the role of parents and teachers in providing the stimulation within the environment or creating thought-provoking scenarios or questions which may facilitate cognitive development. These interactions which build up human thinking skills are referred to as Mediated Learning Experiences (Sharron, 1987).

Within this model, self confidence is highly important to an individual's success; indeed, success with solving logical problems is thought to be as dependent upon perceived confidence as actual competence (Feuerstein, 1974; Feuerstein & Rand, 1979). Additionally, encouragement to break down problems into smaller, more manageable parts and taking a logical rather than a trial and error approach helps children understand how they reached a particular conclusion; this understanding allows for future successful problem solving. The final components critical to the Mediated Learning Experience include planning, goal setting, and being aware of growth and progress.

Also essential to cognitive development is the ability to focus attention on the immediate task. The human interventionist helps students focus on one aspect of a problem at a time, leading to logical thought. Within this model, students are believed to be cognitively deficient because of the human interventionist's inability to properly stimulate and mediate the child's environment. One exception pertains to children with organic brain dysfunction or genetic anomalies, such as Down Syndrome or a brain injury. Although the prognosis may be a bit different for these students, if given appropriate and intensive intervention, barriers are not insurmountable.

THE LEARNING PARADIGM

The idea of cognitive modifiability cannot be discussed outside the context of learning. Without learning, change and growth are not possible. Feuerstein (1980) and Soden (1994) believe that intelligence can be largely attributed to teachable "problem-solving skills" or skills related to pattern recognition. This learning paradigm has sparked considerable debate, mostly about the role of heredity in intelligence (Feuerstein, 1980; Soden, 1994). It explains cognitive development in terms of social learning and classical and operant conditioning, where individual differences exist due to the differentiation of reinforcements. In the case of Feuerstein's model, learning takes place through mediated learning experiences, in which the teacher gives feedback to the learner, thereby allowing for positive reinforcement of appropriate problem solving strategies, which in turn allows for cognitive growth.

INTELLIGENCE: STATIC OR FLUID?

While some theorists believe that intelligence is stable throughout the lifespan, others allow for the influence of educational and environmental experiences on intelligence. Authors that believe in malleability include Ackerman and Lohman (2003) who state, "There is a potential for malleability in IQ, a fact that is at odds with the notion of fixed or innate intelligence" (p.282). Berliner, in his 1988 meta-analysis, found that 40% of within group variation in measures of academic intelligence was attributable to environmental factors. Given this finding, he specifically remarked that “the construct of intelligence is…remarkably modifiable…” (p.275).

The “case of Isabel” (Jensen, 1998, p. 113) shows the dramatic impact environmental influence can have on our preconceived notion of intelligence, and further indicates the extensive need to consider environment factors when assessing intellectual ability. Isabel lived in an attic with her deaf-mute mother as her only social contact from birth until age six years of age. She did not have access to books, toys, or gadgets to play with or learn from. Found by authorities at age six, she obtained a mental age of one year, seven months on an IQ test. After exposure to educational experiences for two years, she achieved a mental age of eight years. She ultimately graduated from high school as an average student.

Most theorists agree that environment and experience have some effect on a person’s intelligence, and that one’s intelligence is not fixed from birth (Ackerman & Lohman, 2003; Berliner, 1988; Jensen, 1998). Those who believe that intelligence is a stable trait throughout the lifespan (Zigler & Hodapp, 1986) do not account for the possibility that environmental change can have an impact on the variance of intelligence.

Two main findings regarding stability of intelligence persist throughout the literature. One finding is that scores generally increase from childhood to adulthood, particularly in the area of verbal reasoning, with smaller increases with age. The second finding is that areas relating to nonverbal abilities, such as working memory, inductive and deductive reasoning and problem solving, decrease after the mid 20's (Ackerman & Lohman 2003).

As children develop, their IQ scores appear to become stable. Correlations with adult IQ at ages one, two, and three were .25, .40, and .60, respectively (Plomin, DeFries & Fulker, 1988). Typically, by age five, IQ scores appear fairly stable when compared to testing at a later age (McCall et al., 1973; Zigler, Balla, & Hodapp, 1984). However, IQ can be affected by several factors. McCall et al (1973) analyzed data trends in IQ scores from the Fels Longitudinal Study on children ages two and a half to 17 years of age; children's IQ changed an average of 28 points over the course of the 15 year study, with one in seven children changing as many as 40 points. Factors relevant to increasing IQ included parental encouragement in accelerating their child's growth and severity of punishment used, both of which accounted for variance above and beyond parental education and IQ levels. Interestingly, children with high IQ scores showed more change than children with lower IQ scores (McCall et al., 1973). Possible explanations for this trend include higher intra-individual variability and the structure of the test, which sometimes awarded more credit for higher level questions (McCall et al., 1973).

A report compiled by Glass (1968) examined the change in IQ score as a result of attending Head Start; an IQ increase of only two to three points was found as a result of attending Head Start. Additionally, although Brody (1992) demonstrated that efforts to increase general intelligence in school-aged children resulted in as much as ½ of a standard deviation, or 7.5 standard score points , he cautioned that "there is no evidence that general intelligence can be substantially changed as a result of experimental interventions" (p. 186).

Another important theory is Anderson's (1939) "terminal status", (Nyborg, 2003) which suggests that a larger proportion of one's final intelligence is attained with age, and that the malleability of intelligence decreases as a larger proportion of intelligence is obtained. Anderson hypothesized this to occur at about age 16, while large-scale studies (such as Yerkes, 1921) suggested that intelligence might peak as young as 13. However, Wechsler (1944) found that the growth of intelligence did not peak at adolescence, but rather at about age 20, with a slight decline thereafter. Wechsler found that declines in intellectual functioning were not uniform across individuals, or across different measures of intelligence.

Anderson suggested that changes in IQ from year to year were unrelated to initial IQ scores. However, empirical data has since shown that children with higher initial IQ scores show greater gains over time (Ackerman & Lohman, 2003; Cronbach & Snow 1977; Snow & Yalow 1982). This notion that *one who has more; gains more* can be considered and referred to as the "Matthew Effect", taken from the biblical statement "To all those who have, more will be given, and they will have an abundance, but from those that have nothing, even what they have will be taken away" (Matthew 13:12, *The New Oxford Annotated Bible,* New

Revised Standard Edition). Though the Matthew Effect has previously been used to explain a phenomenon in the field of reading (Stanovich, 1986), and to explain the abundance of scientific publications for particular authors who have previously been published (Merton, 1988) the essence of its origin (cited above) indicates that it could be used to describe any phenomenon in which those who start with more of something, get more of that something, regardless of what the "something" is. Research has shown this phenomenon to be true for intelligence as well. Shaywitz et al (1995) studied the specific prediction that students with high IQ scores would have larger gains in IQ over time when compared to students with lower IQ scores. Four hundred and forty five kindergarten students from Connecticut were chosen as subjects. The sample matched demographic data of the United States from 1985. In grades one, three, & five students were given the Wechsler Intelligence Scale for Children –Revised (WISC-R; Wechsler, 1975) WISC-R and the Woodcock Johnson Psychoeducational Test Battery (W-J; Woodcock & Johnson, 1977) was given in grades 1 and 6. There was a 93% retention rate of participants, concluding with a sample of four hundred and fourteen students. All analyses used the Full Scale IQ score from the WISC-R and the Reading cluster from the W-J. Standard scores were used for analysis. Overall, a small Matthew Effect was observed for IQ scores, although the regression to the mean was large. No Matthew effect was found for reading; instead, students who initially scored poorly as a group had greater gains, albeit still in the deficient range. Thus, poor readers in 1st grade tended to be poor readers in 6th grade, furthering the case for intervention.

Cattell (1971;1987) suggested an alternative view to the development and maintenance of intelligence during the lifespan. Known as the "investment hypothesis", this view refers to the amount of time and energy put toward learning, with greater investments resulting in greater amounts of growth. Both Cattell (1963) and Horn (1970) posited different developmental trajectories for fluid vs. crystallized abilities: namely, that both fluid and crystallized intelligence increase to the age of 20 at which point fluid intelligence begins to decline, while crystallized abilities acquired through experience and education typically increase or remained stable.

If intelligence is accepted as a static concept based solely on genetic endowment, then interventions based on increasing intellectual growth and development are unlikely to be given much credence. This view has the potential to limit expectations, and therefore limit growth of children who test as having a low IQ. Although historically services have been given to children regardless of IQ, these services typically have focused on academic interventions to increase academic growth. Additionally, IQ is still considered a factor when determining eligibility for services, typically with an ability-achievement discrepancy model. It is important to keep in mind that an IQ score does not measure the potential of someone's learning capacity, but rather is the estimated ability based on what has already been learned (Sharron, 1987). By interpreting intelligence as a static concept, one limits the opportunities for students to increase their cognitive skills, learn more effectively, and use their enhanced cognitive abilities to improve academic performance.

Although genetics and early environmental experiences lay the foundation for intelligence, a child's intelligence is not rigid and unalterable (Humphreys & Davey 1988). The earlier referenced "case of Isabel" highlights how the environment can have a profound impact on IQ. Appropriately stated by Ackerman and Lohman (2003), "g" theorists are in a conundrum. If "g" is related to development and experience, as IQ theorists suggest, then it cannot be a fixed aspect of an individual. However, if *g* is malleable, than there is a "dissociation between the construct of *g* and any [current] measure that purports to assess *g*" (p.287 brackets not in original quote).

Although there is ample evidence to support the notion of environmental influences on intelligence, research relating to the degree to which intelligence can be affected through intensive intervention is less abundant.

HISTORY OF INTELLIGENCE AND TESTING

Most theories that shape our current conception of intelligence come from the work of scientists from the 19th and 20th centuries where work originated in the United States, France, and Germany. In the latter part of the 19th century, psychology emerged as a discipline of its own.

Initial statistical studies related to mental processes conducted by Francis Galton (1869-1883) relied heavily on the five senses. Galton assumed that people with the highest intelligence would have greater sensory discrimination abilities and used this premise to develop one of the first tests for intelligence (Aiken, 2004). Galton also developed two statistical processes, regression to the mean and correlation. Regression to the mean refers to the tendency for scores to gravitate towards the average with repeated testing. A correlation refers to a relationship between two variables (positive or negative), indicating how similar or dissimilar two variables are.

The first psychological laboratory was established by Wundt (1879). Wundt believed psychologists needed to understand consciousness, and was primarily concerned with the immediate environment. His studies primarily focused on people's self observation and introspection into their own behavior. For him, psychology was the basis of all other sciences (Kimble & Wertheimer, 1998).

James McKeen Cattell is credited with first introducing the term "mental test" in 1890. Along with many other early psychologists (e.g., Franz Boas, Francis Galton), Cattell focused on sensorimotor abilities and reaction time studies (Kimble & Wertheimer, 1998).

In 1893, psychological tests became available for public viewing in the United States at the Chicago World's Fair. Hugo Munsterberg and Joseph Jastrow made a demonstration testing laboratory available to fairgoers for a small fee. Although the tests were originally developed for children, visitors of all ages were able to take the tests which centered on perception, memory, reading and knowledge. Visitors were told how their performance compared to that of others (Kazdin, 2000).

Another major contributor to the field of psychology, and one of the first to address educational needs in the schools was Herman Ebbinghaus. Ebbinghaus focused mostly on memory tasks such as list learning and the capacity of memory. He developed group administered timed tasks in response to requests from teachers who wanted to evaluate the academic aptitude of school children in their classrooms. Ebbinghaus was also the first to describe the learning curve, which refers to the relationship between the amount of information being learned and the time it takes to learn it. He also developed a statistical formula for understanding the process of forgetting (or the decline in memory) (Wozniak, 1999).

Alfred Binet, Victor Henri, and Theodore Simon subsequently developed methods for studying and measuring these higher level functions (Binet & Henri, 1895; Binet, 1903; Binet & Simon, 1905). Their work culminated with the production of the first practical mental exam to measure mental age, the 1905 Binet - Simon scale. The development of the scale came from a request from the French government who sought a way to identify children with mental retardation. The scale was the first to acknowledge the theory of age-based cognitive development. The scale was translated by Henry Goddard in 1908 and Lewis Terman standardized the translated version on 2,000 American Children in 1916 (Winzer, 1993). It subsequently became the most commonly used intelligence scale in the United States; however, its use was almost exclusively for the identification and evaluation of students with mental retardation (Kaufman & Lichtenberger, 2005). Goddard believed that intelligence consisted of a single underlying factor that was largely determined by heredity (nature) rather than environment, a view very different from that of Binet who believed that children developed sub average intelligence because of shortcomings in their biological development (Binet, 1905).

Terman's extensive efforts in test development led to multiple revisions of the Stanford Binet in 1916, 1937, and 1960. In these revisions, several advances occurred which resulted in the scale becoming the most widely used measure of its time. First, Terman adopted Stern's concept of *mental quotient*, which was computed by dividing an individual's mental age by one's chronological age. The revisions also were age-scaled, which permitted students in different age groups to be compared to each other based on a particular standard score, accounting for development and maturation.

In 1972, Robert Thorndike, Elizabeth Hagen, and Jerome Sattler developed a point-scale version of the test (Stanford-Binet 4th Edition), which used the same type of items at every age level instead of items varying by age. The latest edition, the Stanford-Binet 5th Edition, contains the same point-scale format.

Point scales became quite popular with other theorists as well. David Wechsler's first standardized measure, the Wechsler-Bellevue Intelligence Scale, Form I, used a point scale format (Wechsler, 1931). The test was a compilation of several subtests from several other sources which included the Army Alpha and Beta exams and the 1916 Stanford- Binet. This scale was the predecessor to the original Wechsler Intelligence Scale for Children, the Wechsler Preschool and Primary Scales, and the Wechsler Adult Intelligence Scales, for children, preschoolers, and adults, respectively, as well as subsequent revisions of each of those measures.

SETTLING ON A DEFINITION

The study of intelligence has been hampered by the lack of agreement over a definition (Nyborg, 2003), which has been long debated. In 1921 a symposium entitled "Intelligence and Its Measurement" was held to discuss this lack of agreement. A resulting paper noted that each of 14 different researchers and writers had defined intelligence differently. Spearman spoke of his frustration with this by saying "chaos itself can go no farther... 'Intelligence' has become a mere vocal sound, a word with so many meanings that finally it has none" (1927, p 14). In 1958, the only definition that could be agreed upon amongst scientists was that "intelligence is what intelligence tests measure" (Cattell, 1983, p. 22); obviously, this circular statement does not clarify the nature of intelligence. Still later, in 1987 Sternberg addressed this particular question by stating that "viewed narrowly, there seem to be almost as many definitions of intelligence as there were experts asked to define it" (p. 135). " In 1986, Sternberg & Detterman held a second symposium on this topic, only to have Jensen later report in 1998 that, “The overall picture remains almost as chaotic as it was in 1921” (p 48).

Despite the lack of agreement, prominent definitions have shared some common threads which include; “basic mental processes, and higher order thinking (e.g., reasoning, problem solving and decision making)” (Sattler, 2001, p. 135). Terms gaining acceptance over time include “executive processes”, knowledge, “that which is valued by culture”, and “interaction of processes and knowledge”. Terms which lost popularity between the two symposia included the ability to learn, adaptation to meet the demands of the environment, and the physiological mechanism (Sternberg & Berg, 1986).

A study by Snyderman & Rothman (1987) asked 1,020 experts in the fields of education, psychology, and genetics to rate 13 behavioral descriptions regarding their importance in contributing to the definition of intelligence. Abstract thinking or reasoning, problem-solving ability, and the capacity to acquire knowledge were voted as being important by over 95% of those surveyed, with 80% of respondents feeling memory was important. Over 70% of respondents reported adaptation to one’s environment, mental speed, and linguistic competence to be important. Of those surveyed, 60% stated that mathematical competence, general knowledge, and creativity were important. Only about 25% of respondents indicated that sensory acuity and goal-directedness were important and fewer than 19% felt achievement motivation was an important contributor to the definition of intelligence.

The American Academy of Intellectual Disabilities currently defines intelligence as a general mental capability that "involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly, and learn from experience" (AAID, 2008).

INTELLIGENCE THEORY

Charles Spearman was an early proponent of a factor analytic approach to intelligence. He proposed a two factor theory of intelligence, where one general factor (*g*) was present and was accounted for within each ability measured and the specific factors , (s), included individual skills measured on specific tasks (Spearman, 1927). The general (g) factor was statistically derived based on the shared variance that was present within intelligence tests at the time, namely the Binet scales (Flanagan & Harrison, 2005). Although the *g* factor was represented within each task, the amount of *g* was dependent on the amount of mental effort and complexity required for the task (Spearman, 1927). Complicated tasks such as reasoning, comprehension, and analogies required more *g*, whereas simple tasks such as processing speed and simple memory recall required less (Sattler, 2001). A primary criticism of Spearman was that he failed to account sufficiently for specific factors (Bharti, 2006)

Edward Thorndike developed a theoretical model of intelligence which suggested that certain mental activities had elements in common and combined to form clusters (Thorndike, 1927). He identified three main clusters although he believed there were an infinite number of specific abilities (Bharti, 2006;

Thorndike, 1927). The first of these was social intelligence, which referred to the ability to deal effectively and efficiently with one's social and cultural environment. Being able to establish appropriate social relationships indicates the capacity for social intelligence. The second, referred to as concrete intelligence, which had to do with dealing with things within trade or scientific appliances, also known as mechanical or motor intelligence. Intelligence in this area is displayed by being able to learn steps to a dance routine or rules of a complex game, such as soccer. The third cluster, abstract intelligence, refers to the ability to understand and work effectively with words, numbers, and letters and use them effectively. Use of this intelligence is needed in academic arenas, and at the highest level is present in poets and philosophers (Bharti, 2006; Weiner, Freedheim, Schinka, & Velicer, 2003; Sattler, 2001).

Thurstone's model of Primary Mental Abilities was based on seven factors of intelligence derived from factor analyses. The first two factors are in the verbal domain, verbal comprehension and fluency. Verbal comprehension is the ability to understand verbal material, and fluency involves the speed of developing verbal responses to a question. The third factor, number, is the ability to compute mathematical equations quickly. The fourth factor, memory, involves the ability to remember strings of words, letters, numbers, or a series of other items while the fifth factor, perceptual speed, is the ability to recognize letters, numbers or objects quickly. Inductive reasoning was the sixth; this involves the ability to reason from the specific to the general and includes reasoning for patterns. The final factor, spatial visualization, refers to the ability to visualize shapes and the mental rotation of objects. Thurstone's model did not include an underlying or overarching general ability. Additionally, he believed intelligence could be broken down into these seven factors equally (Bharti, 2006; Freedham & Weiner, 2003; Sattler, 2001).

Vernon proposed a hierarchical theory of intelligence with four levels. General ability (g) was at the highest level. The second level included two major and distinct group factors, verbal-educational and spatial-mechanical. The verbal educational group factor included minor factors (which comprised the third level) related to creative abilities, verbal fluency, attention, logical reasoning, and numerical factors, things typically testable within the academic setting. The spatial-mechanical group factor included factors that were kinesthetic in nature, spatial, psychomotor, mechanical information, handwriting, drawing, reaction times, and athletic ability. The fourth level further defined the minor factors (Carroll, 1993; Sattler, 2001).

The most widely accepted and comprehensive theory to date is the Cattell Horn Carroll Theory of Intelligence (CHC). This model defines intelligence as several different processing abilities and is further defined in the next section.

THE CATTELL HORN CARROLL (CHC) THEORY OF INTELLIGENCE

Foundation. The structure of the Cattell Horn Carroll (CHC) Theory integrates Raymond Cattell and John Horne's theory of crystallized and fluid intelligence (a model focused on two primary abilities) (Cattell, 1941; Horn 1965) with John Carroll's three stratum theory (1993). Carroll's three strata were organized hierarchically as follows: Stratum 1 included one overarching, broad ability (g); Stratum II included ten broad cognitive abilities, which include crystallized and fluid abilities, among others; and Stratum III presently includes 74 narrow abilities, each related to a specific Stratum II ability (Flanagan, Ortiz, & Alfonso, 2007).

According to the Cattell- Horne theory, crystallized Intelligence refers to skills affected by exposure to education and the environment. Facts typically learned within the normal course of schooling, such as what a ruler is or how many hours are in a day, are examples of items referred to as crystallized intelligence. In contrast, fluid intelligence refers to cognitive processing abilities that are mostly nonverbal and culture free, independent of learning that takes place in the classroom or abilities that would be considered affected by real world experience. Reasoning and concept formation are two abilities commonly listed under fluid intelligence.

The ten broad abilities addressed by the CHC model include; Decision Speed (Processing Speed (Gs), Short Term Memory (Gsm), Long Term Retrieval (Glr), Visual Processing (Gv), Fluid Reasoning (Gf), Auditory Processing (Ga), Comprehension-Knowledge or Crystallized (Gc), Reading and Writing (Grw), Quantitative Knowledge (Gq) and Decision time (Gt);. Of the ten identified abilities, only seven are currently measurable using standardized measures of cognitive ability. Those that are not readily available through standardized cognitive assessments include Gt, Grw and Gq. For purposes of this study, the overall broad ability (inclusive of the first seven listed above) as well as the broad ability of Grw will be evaluated. Elaboration of the broad abilities as well as research involving each ability will be presented later in this chapter.

Derivation. To date, the CHC theory is the most comprehensive and empirically supported theory of cognitive ability (McGrew, 2005). Factor analysis was used to support the final derivation of the CHC model. Studies have shown that the factor analytic structure of CHC does not change throughout the lifespan, or across gender, ethnic or cultural groups (Flanagan, Ortiz, & Alfonso, 2007). Research on the CHC theory is recognized as being fluid and its authors reference the theory as a useful framework for designing and evaluating psychoeducational batteries and methods of identifying students with learning disabilities. Readers are referred to Flanagan et al (2000) and McGrew (2005) for a comprehensive explanation of the statistical derivation of this theory, which is beyond the scope of this paper.

CURRENT METHODS OF ASSESSING INTELLIGENCE

Although tests to measure intelligence have existed since the late 1800's, the broad acceptance of CHC Theory has necessitated a new approach to assessment for learning disabilities. However, a single assessment tool presently is not available to measure all areas needed for a comprehensive assessment of intelligence according to CHC Theory. As a result, an alternative, comprehensive measurement approach was developed, the CHC Cross Battery Assessment approach (Flanagan & Ortiz, 2001; Flanagan, McGrew, & Ortiz, 2000; McGrew & Flanagan, 1998; Woodcock, 1990; 1993). The Cross Battery Assessment Approach (XBA; Flanagan, Ortiz, & Alfonso, 2007) allows for the use of different assessment tools to measure broad abilities.

Since 2000, several assessment measures with theoretical underpinnings in line with the CHC Theory of Intelligence have been available. The Woodcock Johnson Tests of Cognitive Abilities, Third Edition (WJ III Cog) (Woodcock, McGrew, and Mather, 2001) was the first comprehensive cognitive assessment tool to measure all seven most easily measured areas of CHC Theory. Since then, the Kaufman Assessment Battery for Children, 2nd Edition (KABC II (Kaufman & Kaufman, 2004), the Differential Ability Scales, 2nd Edition (DAS II) (Elliot, 2007) and Stanford Binet Fifth Edition (SB V) (Roid, 2003) were developed using the CHC Theory framework. However, the WJ III Cog remains the only measure that taps all seven measurable abilities by measuring two separate, narrow abilities that load onto each broad ability (Flanagan, Ortiz, & Alfonso, 2007).

COGNITION AND ACHIEVEMENT

It has been estimated that intelligence scores account for an average of 36%-55% of the variance related to school achievement (grades). Correlations are higher for subskills that load high on crystallized intelligence; these include mathematics, classical languages, and physics. Conversely, correlations are lower for subjects such as geography, drawing, painting, and athletics (Cattell, 1983; Sattler, 2001).

Although older paradigms attempted to separate intelligence or cognitive ability from achievement, more recently cognitive ability and achievement have been conceptualized as occurring on a continuum. More specifically, Carroll (1993) suggested that the most general types of abilities were at one end of the continuum while the most specialized types of knowledge were at the other end (Flanagan, 2007; See Figure 1). This view is supported by Horn (1988) who stated that "cognitive abilities are measures of achievements, and measures of achievements are just as surely measures of cognitive abilities" (Flanagan, 2007; Presentation Slide 8).

This paradigm has significant implications for the definition, assessment and diagnosis of learning disability which have historically relied heavily on a significant discrepancy between ability and achievement. The Cross Battery Approach to assessment of learning disabilities proposed by Flanagan, Ortiz, and Alfonso (2007) is based on cognitive processing deficits that line up with, rather than are discrepant from related achievement scores.

According to Feuerstein, any impairment in cognition, however minor, can significantly impact a child's thinking process due to the impact one cognitive structure has on the next. Aggregated, these seemingly minor impairments in cognition can greatly impact academic performance. For example, a student with poor spatial and temporal organization would have difficulty organizing work, analyzing cause and effect problems, understanding the logical progression of a situation, and solving abstract problems. Additionally, cognitive deficits can interact with social and emotional factors leading to school failure. Normally, cognitive deficiencies such as a lack of vocabulary and impulsive behavior are compensated for by using other cognitive abilities; however, one or two deficiencies for low functioning students may be sufficient to cause failure in school (Sharron, 1987).

Phonological-Core Variable-Difference Model of Reading Disability. Specific areas of achievement related to specific areas of cognitive ability have been identified by the Riverside Publishing Company, publisher of both the WJ III Cog and the WJ III Ach (2001), and by Flanagan, Ortiz, Alfonso, and Mascolo (2006), who did an extensive review of the literature in this area. Furthermore, a theory has been proposed relating specific core cognitive deficits to reading disabilities. This is known as the "phonological-core variable-difference model of reading disability" (Morris, et al., 1998; Stanovich, 1988; Stanovich & Siegel, 1994). According to this model, the abilities of phonemic awareness, rapid naming, and the coding of phonological information in short term or phonological memory (i.e., the CHC narrow abilities of phonetic coding, naming facility, and memory span or working memory) represents a cluster of abilities which enable reading development. When one of these areas is deficient, remediation of reading difficulties has been shown to be extremely difficult with current empirically validated interventions (Vellutino, Scanlin, & Lyon, 2000).

Evans, Floyd, McGrew, and LeForgee (2001) further investigated the relationship between each CHC factor and reading ability to test the phonological-core variable-difference model (using pre-existing subject data from the WJ III Ach and WJ III Cog norming samples). In this study, Comprehension Knowledge (Gc), Processing Speed (Gs), Long Term Retrieval (Glr), Auditory Processing (Ga) all had moderate correlations with reading ability, though specific narrow abilities including working memory (MW) and phonemic awareness also had strong effects on reading ability. This study provided further evidence for the Phonological-Core Variable-Difference Model of Reading Disability. Additionally, the need for CHC-based research focused on particular cognitive skill building to offer specification for reading interventions was identified.

WORKING MEMORY AND READING

Working memory is the brain's ability to temporarily store and manipulate information in order to complete complex cognitive tasks such as learning, reasoning, and language comprehension. Working memory is involved in the preservation of information while simultaneously processing the same or other information (Bunge, Klingberg, Jacobsen, & Gabrieli, 1999; Swanson & Howell, 2001). A narrow ability which falls under the broad ability of Short Term Memory, working memory is extremely important for learning, and has been described as a "pure measure of a child's learning potential" (Alloway, 2006). Alloway's assertion has been supported by findings of strong relations between working memory deficits and academic difficulties, particularly in the area of reading (Mayes & Calhoun, 2007; Wendling & Mather, 2009). Working memory is thought to directly impact the ability to remember what is read as well as reading fluency (speed of reading), with verbal working memory correlating with word recognition at a moderate level (.64) (Swanson & Howell, 2001). A proficient reader does not rely constantly on the particular decoding of each sound within a word, but rather processes several bits of information simultaneously and reads each word as a whole while accessing all the information presented within a sentence, paragraph or passage (Palmer, 2000). To become a proficient reader, a well developed working memory is necessary.

Struggling readers often are labeled as being "disabled." By definition IDEIA 2004 (602(3)A) a reading disability involves a deficit in a basic psychological process, which may include cognitive skills such as crystallized or fluid ability, processing speed, long term retrieval or short term (working) memory, visual processing, or auditory processing (Flanagan, Ortiz & Alfonso, 2007). Many students who struggle with reading have particular difficulty with word attack and sound awareness (Fox & Routh, 1984; Share & Stanovich, 1995) Word attack skills refer to the ability to decode letters (symbols) into language; word attack skills are essential for reading single words, which in turn influences reading comprehension (Torgeson, 2000). Similarly, phonological awareness (sound awareness) plays a key role in reading development (Swanson & Howell, 2001).

In summary, an intact working memory system plays an important role in reading acquisition. Intuitively then, reading acquisition can be difficult for students with deficient working memory systems.

Attention Deficit Hyperactivity Disorder. Students with a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD) have been found to have a hallmark deficit in the area of working memory. Studies using the Wechsler Intelligence Scale for Children (3rd and 4th editions, Wechsler, 1994 & 2003), Woodcock Johnson Tests of Cognitive Abilities (3rd edition, Woodcock, McGrew, & Mather, 2001) and the Stanford Binet Intelligence Scales, 5th edition (Roid, 2003) have found that ADHD students consistently score lower than controls on working memory tasks (Halperin et al., 2008; Karatekin, 2004; Lacene, 2004; Lui & Tannock, 2007; Marusiak & Janzen, 2005; Pallas, 2003; Poock, 2005; Rapport et al., 2009; Schwebach, 2007; Sonuga-Barke, Dalen, Daley & Remington, 2002; Willcutt, Doyle, et al., 2005; Wolfe, 2006; Wu, Anderson & Castiello, 2006). Further, it is estimated that 75% of students with ADHD have a co-morbid reading disability (Mayes & Calhoun, 2007; Naidoo, 2008).

Research. Three to five percent of the school age population are estimated to suffer from Attention Deficit Hyperactivity Disorder (ADHD) (Biederman, Mick, & Faraone, 2000; Radonovich, 2002). Students with ADHD or undiagnosed attention difficulties typically have difficulty in the classroom and with performance on tasks, particularly in the area of reading. According to

Cashdan (1969), a common cause of reading errors is failure to sufficiently attend to a word. Some researchers such as Katz and Deutsch (Cashdan, 1969) found that some children have difficulty reading because they have difficulty switching their attention from hearing to sight and vice versa. Students with attention difficulties and those diagnosed with ADHD have deficits in executive functioning (Rapport, Alderson, Kofler, Sarver, Bolden, & Sims, 2008) which includes; working memory, planning, and reasoning, and which involve at least two of the seven broad abilities, Gsm and Gf. Indeed, interventions that have targeted specific areas related to executive functioning have shown improvements in working memory for students suffering from ADHD (Klingberg et al., 2002)

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

Subjects were randomly assigned to either a home or school condition. Those in the experimental group completed 25 training sessions, approximately 40 minutes in duration, involving 96 working memory tasks over a period of five to six weeks. The control group received similar training but at a lower level of difficulty than the working memory level of the child. Effect sizes on outcome measures including Ravens Matrices (.45), the Stroop Test (.34), and digit span (.59) were significant. Additionally, parents' ratings of symptoms on the Conners' Rating forms reflected significant decreases from pre to post intervention in areas of inattention, hyperactivity, and overall ADHD index. Klingberg and colleagues (2005) concluded that the intervention was as effective as medication in improving working memory abilities in students with ADHD. However, it should be noted that authors did not address the possibility of expectation bias on the part of the parents. Additionally, the only studies involving the CompTrain program were conducted by the developers of the program. Further research is needed to evaluate the ability of programs that focus on improving working memory to increase academic functioning.

LEARNING DISABILITY/READING DISABILITY RESEARCH

According to IDEA 2004 (Revised in 2007), students labeled with a Specific Learning Disability (SLD), either 1) have a significant discrepancy between cognitive and achievement scores, or 2) fail to respond to rigorous and structured interventions. Additionally, a learning disability is defined as:

> "a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which disorder may manifest itself in imperfect ability to listen, think, speak, read, write, spell or do mathematical calculations" (20 U.S.C.§ 1401 [130]).

Academic underachievement must not be solely due to environmental, educational, economic or cultural disadvantage, to an emotional disability, or to motor, hearing, or vision deficits.

With the revision of IDEA in 2004, new procedures for identifying students with specific learning disabilities have been implemented. A severe discrepancy between achievement and intellectual ability is no longer required; instead, “the local education agency may use a process that determines if the child responds to scientific, research-based intervention as part of the evaluation procedures…” (PL 108-446 § 614 (b) (6) (B)). Known as Response to Intervention (RTI), this process has raised some concerns. The first concern is that when used in isolation, a student must demonstrate an achievement discrepancy two grade levels below same-aged peers; this can result in a delay in receiving services. A second concern is that, as with the discrepancy model, RTI fails to evaluate the basic psychological processes considered to be an integral part of the SLD definition. These issues have led several prominent researchers to suggest that SLD identification procedures place greater emphasis on a cognitive approach for identifying SLD that evaluate cognitive strengths and weaknesses that influence academic performance (Flanagan, Ortiz, & Alfonso, 2007; Naglieri, 2003). Although CHC-based assessment is recommended for identification of students with SLD, to date there are no studies that investigate the impact of improving cognitive abilities, nor consider possible implications that improving specific abilities would have with respect to identifying or serving children with SLD.

An additional concern within the learning disability research is that most research based interventions in the schools focus on reading, particularly reading decoding, and they do not address any of the cognitive weaknesses typically associated with reading disabilities such as working memory.

IMPACT OF LEARNING ON COGNITION: CAN IT BE TAUGHT?

As Talyzina (1981) said “The mental development of man is impossible without the influence of learning” (p. 155). However, as Ackerman and Lohman (2003) point out, too few studies focus on the nature of changes in intelligence as a result of education. As a result, neither the nature of the relationship between intelligence and education, nor whether one can be taught to be intelligent are known.

There are different views regarding these points. Goswami (2002) stated that “children become able to learn almost anything with appropriate effort, tuition, skill, and strategies as they get older… [and although] these factors all affect overall performance, they do not change basic competence.” (p.301, brackets not in original quote). Goswami’s view appears a bit muddled as he first implies that all cognitive skills have some capacity to be taught then suggests that overall ability cannot be changed.

Witmer (1907) spoke of intelligence as measured by the ability to do academics; successfully overcoming an academic challenge, for example, responding to a remedial program targeting reading would be proof that the child has changed from unintelligent to intelligent. To Witmer, an unintelligent child cannot perform academically in the average range, unlike an intelligent child who can. Witmer believed that intelligence could be cultivated, especially if deficiencies are addressed early in a child's life. As an example, Witmer believed that a boy with a speech defect could have overcome his problem if he was given instruction in articulation when he was young. Much research has been conducted since the time of Witmer; however, the basic tenet that training can influence intelligence forms the basis of the current study.

Similar to Witmer, Harlow (1949) presented the view that one must *learn how to learn* efficiently. He believed that this knowledge is acquired through "learning sets." Once an individual is taught how to tackle a difficult problem, less effort subsequently is needed to solve a similar problem because the learning set has already been acquired. Bruner (1964) emphasized the importance of teaching a student how to acquire knowledge and problem solve independently, rather than engage only in rote memory learning.

While it is apparent that individuals can learn and problem solve, it is unclear if individuals can learn to be intelligent. Goswami (2002) believes that even though "…children [are] able to learn almost anything with appropriate effort, tuition, skill, and strategies as they get older… [although] these factors all affect overall performance, they do not change basic competence." (p.301). Ackerman and Lohman (2003) felt that this issue deserved more attention as few studies had focused on the change in intelligence as a result of education.

Overall, the experience of attending school has been shown to play a minor role in individual differences in IQ when inequality of schooling is addressed. Research conducted by Bouchard & Segal (1985) indicates that only 2-10% of the variance in cognitive functioning may be associated with school quality.

Preschool enrichment programs, such as head-start programming, have shown that at the conclusion of the enrichment program, children in the program had higher IQ's than those not in the program. Gains on readiness and achievement measures were also higher (US Department of Health and Human Services, 1985). However, two years after the conclusion of the enrichment program, there were not any educationally meaningful differences between students who attended the program and those who did not.

Research on attempts to increase general intelligence in school-age populations suggests changes in IQ scores are relatively small, about 7.5 points or less (Brody, 1992). However, there is evidence that suggests that some aspects of intelligence behavior can be taught (Perkins & Grotzer, 1997). Effective interventions include those that help individuals reorganize their approach to cognitive tasks and those that make their current abilities more effective. Sattler (2001) calls for "more research to determine the best methods for enhancing intelligence, and to the extent which these methods can enhance intellectual functioning" (p. 166).

Ceci (1991) reviewed the literature and found that the amount rather than the quality of education influences IQ scores; this includes the delay of schooling, intermittent school attendance, the effect of early termination of schooling, and the influence of summer vacation, to name a few. Although it has been argued that IQ actually affects the school experience (Ackerman & Lohman, 2003), Ceci argued that quantity of education influences IQ scores. Ceci's argument of quantity over quality of schooling needs further assessment, as does the idea that education (or training) can influence intelligence.

Cognitive Training on Overall Ability. Although there is research into the effects of cognitive skills training on specific subskills, only one comprehensive intervention program targeted for children has been extensively researched in the literature. In addition to the concept of structural cognitive modifiability, the Instrumental Enrichment program (IE) incorporates Mediated Learning Experiences. Mediated Learning Experiences refer to a specific quality of a learning experience, in which there is a "mediator" who is concerned with how the learner approaches the problem rather than whether the correct answer is obtained. The mediator serves three roles: helping the child understand how their brain is working to solve a particular problem, interpreting the significance of the learner's accomplishment by focusing attention to the success with encouragement, and generalizing the learning experience to other situations within the learner's life. For example, the mediator may ask, "When else could you use a similar strategy to help you?" or "When else do you find it useful to categorize information?" With Mediated Learning Experiences as the core component of Instrumental Enrichment (IE), Feuerstein helped many children with very poor intellectual functioning raise their performance on intelligence tests (Sharron, 1987).

Feuerstein recognized that children raised during the Holocaust and in the fragmented cultures of North Africa had experienced deprivation and performed poorly on traditional IQ tests; to avoid the inevitable poor expectations, education and opportunities that follow a low IQ score, he developed the Learning Potential Assessment Device. This measure was able to ascertain potential for learning, allowed for understanding existing cognitive deficits, and enabled a teacher to focus on and remediate deficient areas. Skills tested included the ability to represent abstractly, changes in geometric shapes, anticipation of what was next, perceptual analysis, comparisons, ordering objects in a sequence, and visual rotation.

Feuerstein first tested children to identify their intellectual problems, and then carried out instrumental enrichment activities, which consisted of highly structured teaching. He then retested the children to see how their performance had changed. Children previously tested with IQ scores of 55-65 obtained scores within normal limits.

Feuerstein sums up the benefits of Instrumental Enrichment as follows:

> “It is geared to confront the learner with many opportunities to develop the capacity to change reality, to

> interpret reality, to produce new relationships and thereby generate new information" (Sharron, 1987) p. 100)."

He further delineates that Instrumental Enrichment is more effective with children who are retarded on a social level rather than organically.

Teachers of IE were highly trained to provide students with mediated learning experiences. Training consisted of about seven weeks of training, which included theory, learning the instruments, crucial supervision, and lesson planning.

Instrumental Enrichment (IE) Studies. Feuerstein and his colleagues conducted three long-term studies of IE. In addition, several other international studies have used the IE program to help students under the direction of other researchers (Alvarez, Santos, Santiago, & Lebron, 1992*;* Kettle, 1992; Kozulin, Kaufman, Lurie, 1997; Kreiger & Kaplan, 1990). Consistently, IE produced cognitive changes within students who have traditionally been poor performers.

The first study, conducted in Israel (Feuerstein & Rand, 1977), used a sample of 218 children ages 12 to 14 classified as having intelligence at the borderline or 'educable mentally retarded' Level. Half of the sample received IE and the other received a general enrichment program which included additional instruction in general school subjects. Thurstone's Primary Mental Abilities Tests were administered at the beginning and end of the two year program; these tests yielded separate scores for verbal, numerical, spatial relations, reasoning, perceptual speed and an overall intelligence score. The groups receiving IE achieved higher scores on numerical and spatial relations as well as figure groups, achieving significantly greater scores on the overall intelligence score. Additionally, the IE group outperformed the general enrichment group on geography and bible study questions and scored equally on all other subjects (general knowledge, nature, antonyms, part-whole relationships, geometry, reading, comprehension and basic math). This indicated that students who received IE instead of additional time on general subjects performed as well as or better than students receiving additional academic instruction in these areas. This suggests that cognitive interventions are at least as effective, and sometimes better, than students receiving supplemental academic instruction.

An additional finding was that 46% of the original low performing group receiving IE moved across the median line of average ability, compared to only 13% of the general enrichment group. Of the relatively high performers, 88% in the IE group crossed the median line (of average ability), indicating above average ability, whereas only 53% of the original high ability GE group reached this level. This finding gives additional credence to the Matthew Effect being applied to cognitive ability.

In addition to their cognitive and academic gains, students in the IE groups also made better gains than the control group in the following areas: interaction with classmates, level of disruptive behavior, willingness to take turns, the ability to start and finish work independently, persistence, pride in work, efficiency of transition of task, helping others, caring and sharing of school materials and cooperative work.

In a follow up study conducted two years later (Feuerstein et al., 1980), the better performance of the IE groups was not only maintained, but increased, indicating that their improved cognitive abilities allowed them to continue to expand intellectually even after the IE program had ceased.

The Yale University cognitive modifiability project (Singer & Jensen, no date) represents the most elaborate long-term study conducted outside of Israel. The study consisted of 275 students in the experimental (IE) group and 174 students in the control group. Pre and post measures included Raven's Standard Progressive Matrices, Thurstone's Primary Abilities, Wechsler Intelligence Scale for Children, the Piers Harris Self Concept Scale, and a measure of intrinsic motivation, the Haywood Mazes. Within the experimental group, some students had less than a year of IE and some had more than a year of IE, by design. Post-testing conducted two years after the program began found larger gains for students receiving IE for longer periods. Additionally, students in the experimental group had more intrinsic motivation in their work and reported significant gains in self-esteem and self-perception measures when compared to students in the control group. This finding is contrary to that found in the Israeli study by Feuerstein and colleagues, who did not find any differences in self-image from training.

In the early 1980's, an extensive project involving Instructional Enrichment was conducted under the direction of Heywood, Arbitman-Smith, Brabsford, and Declos at Vanderbilt University; the project also included colleagues in Louisville and Phoenix. Participants included students identified as Emotionally Disturbed, Learning Disabled, Mentally Retarded, and gifted, as well as some low functioning students who had not been labeled.

Students in Nashville received about 50 hours of Instructional Enrichment over a one year period while students in Louisville and Phoenix received at least 80 hours a year for two years. Pre and post-testing consisted of the Raven's Progressive Matrices, Peabody Individual Achievement test, Wide Range Achievement tests, Key Math, California Test of Basic Skills, Lorge-Thorndike nonverbal test, Primary Mental Abilities Test and the Woodcock Johnson Psycho-Educational Battery.

All students receiving IE demonstrated gains in IQ. Students in the one year program gained seven to eight IQ points over one year of IE, compared to only a two point gain with the control group; students in the two year programs gained 15 IQ points. With this finding, researchers supported Feuerstein's recommendation of 300 hours as the minimum needed to produce significant and generalizable changes in cognitive functioning.

Children exposed to the IE curriculum performed better on WJ measures of broad cognitive ability, verbal ability, reasoning, and memory. Only perceptual processing speed did not improve, and researchers hypothesized that this was because IE teaches students to slow down to solve problems more effectively.

In addition, students in the IE group outperformed the control group in all academic areas assessed; these included language expression, social studies, math concepts, math applications, science, reading comprehension, and reference skills. Researchers hypothesized that the learned mediating strategies used by the classroom teachers were likely applied when they taught other subjects, resulting in second order achievement gains.

Mentally retarded children who received IE training took longer and made more correct decisions during a mazes test than those who did not receive IE. Students of average or above average intelligence demonstrated the greatest improvements: those whose learning difficulties may arise from environmental disadvantage or a specific learning disability obtained better results than students with mental retardation. However, students with mental retardation appeared to benefit more in Phoenix, perhaps because of the longer program.

Feuerstein believed was IE was successful for three reasons. First, Instrumental Enrichment is systematic, intensive, and targets the most common thinking deficiencies; second, IE exercises are content free and assume little prior knowledge; and third, children enjoy the activities which appears to motivate the learner for further intellectual activity. Interestingly, this third reason is also a primary tenant of Bruner’s (1964) rules of instruction for most effective learning.

And it is believed by Sharron (1987), who reviewed all IE studies in his book, to be the goal that has led to long term effects of the program.

Individuals who have benefited from IE include illiterate adults, normal and gifted children, mentally retarded, emotionally disturbed, socially-disadvantaged children, low achievers, and brain damaged children. There are still research studies investigating the effects of IE on students' intelligence, however there has not been a shift to make IE more readily available to the public, and it remains as a purely scientific ideal for research.

Research Related to Broad Cognitive Abilities. This section focuses on research specifically related to improving broad abilities which together constitute the overall score of General Intellectual Ability (GIA) from the Woodcock Johnson Tests of Cognitive Abilities, Third Edition (WJ III Cog). These seven broad abilities include; Comprehension-Knowledge (Gc); Fluid Reasoning (Gf); Visual Spatial Thinking (Gv); Auditory Processing (Ga); Short Term Memory (Gsm); Long Term Retrieval (Glr); and Processing Speed (Gs). Each broad ability will be defined and discussed separately, and research related to improving specific abilities will be presented. The narrow ability, Working Memory, will be discussed in the section addressing the broad ability under which it is subsumed, Gsm. Reading Achievement, a narrow ability under Reading and Writing Ability (Grw), will be discussed with that broad ability. For more information regarding narrow abilities one may choose to consult Sattler (2001) and Flanagan, Ortiz, and Alfonso (2002).

In general, many studies which focus on the plasticity of intelligence investigate the effects of training on adults (Crawford & Stankov, 1996; Mahncke, Connor, Appelman, Ahsanuddin, Hardy, Wood, et al. 2006; Thompson & Forth, 2005). However, research on the impact of cognitive training on school aged children is imperative for understanding the possibilities for intervention and implications of training weak cognitive skills.

Comprehension-Knowledge. Comprehension-Knowledge (Gc), also known as Verbal Ability or Crystallized Intelligence, is the ability to understand ideas and express one's thoughts with words. It represents the breadth and depth of knowledge of a culture and the ability to reason using previously learned knowledge or procedures. This factor is heavily influenced by exposure to mainstream culture and formalized education; in turn, it heavily influences all academic areas of achievement, including reading, writing, math, oral language and listening comprehension (Riverside Publishing Company, 2001b). Subtests of general knowledge and vocabulary often measure this broad ability.

Research on Gc. Empirical research in regards to improving Gc through intervention is minimal, though it has been shown to increase or at least remain stable throughout the lifespan (Cattell, 1963; Horn, 1970). Though using drills to increase vocabulary and practice on learning factual information are good interventions for students with low Gc skills (Wendling &Mather, 2009), literature on specific interventions to increase crystallized intelligence complete with statistical analyses were not found in the literature at the time of this study.

Fluid Reasoning. Fluid Reasoning (Gf), also referred to as Fluid Intelligence, includes the ability to reason, draw inferences, problem solve and understand implications and concepts (using unfamiliar information or novel procedures). This includes basic reasoning processes and manipulating abstractions, rules, logical relations. Specific academic achievement areas affected include: Math Reasoning, Math Calculation, Reading Comprehension, and Written Expression (Riverside Publishing Company, 2001b). The vast majority of fluid reasoning tests use nonverbal stimuli, but require an integration of verbal and nonverbal thinking.

Research on Gf. Inductive and deductive reasoning have been shown to remain fairly consistent throughout the lifespan (Goswami, 2002a). Although some research exists regarding the development of reasoning, less work has been done regarding the promotion or enhancement of reasoning abilities. Existing cognitive training research suggests that fluid ability can be improved with intervention (Irwing, Hamza, Khaleefa, & Lynn, 2008; Thompson & Foth, 2005). Goswami (2002b) stated that “children become able to learn almost anything with appropriate effort, tuition, skill, and strategies as they get older” (p. 301), highlighting the idea that reasoning can develop with appropriate training and skill building. This perspective was supported by Schubert and Nielsen (Cashdan 1969), who found that some children who had difficulty forming concepts and understanding a pattern copying task did much better and improved quickly after receiving clues on how to complete the task.

In a recent study published in the Proceedings of the National Academy of Sciences, Jaeggi and her colleagues (2008) showed transfer of training on working memory to skills associated with fluid intelligence. Participants (approximately 16 per group) were trained for 25 minutes per day for 8, 12, 17, or 19 days. Fluid intelligence was assessed before and after the training using standardized tests focusing on visual analogy problems. The experimental groups outperformed the control group only after 17 days of training.

A thorough understanding of concepts is important in mathematics (Skemp, 1970). Concepts typically are taught through showing a series of items that fit the concept rather than by using a definition. As an example, Skemp uses the example of understanding the color "red." Rather than explaining that red "is the color experienced from light of wavelength in the region of 6,500 Angstrom units", the concept of red is taught by showing a variety of red objects, such as a red flower, a red tie, a red bird, and labeling them as such. The test of someone's learning a concept is whether the concept can be used correctly; in this case, the ability to correctly identify a red object.

Visual Spatial Thinking. Visual Spatial Abilities (Gv) include visual processes ranging from simple perceptual tasks to higher level visual and cognitive processes. It refers to the ability to perceive, analyze, synthesize and think with visual patterns and to store and recall visual representations. It is not considered to have much impact on academic achievement (Riverside Publishing Company, 2001b). Gv requires fluidity of thought while working with visual stimuli and also includes memory when visual stimuli are presented.

Research on Gv. Research in this area suggests that there are several visuo-spatial memory systems. Memory for visual and spatial information develops quite differently than developmental pathways associated with other types of memory (Schumann-Hengsteler, 1995). Older children are able to verbally recall a specific object and its location much better than their younger counterparts; however, age differences were not found when children were asked to find objects they had placed somewhere (Schumann-Hengsteler, 1992).

Gender differences in spatial abilities have been found consistently, with males outperforming females on a wide variety of spatial tasks (Linn & Petersen, 1985); McGee, 1979; Newcombe, 198; Voyer, Voyer, & Bryden 1995). Although explanations of these differences have ranged from biological to societal differences, the most common explanation appears to be due to the differences in life experiences (Hyde & McKinley, 1997). Although performance amongst females was increased with spatial training, a marked difference remained between males and females after intervention (Baenninger & Newcombe 1989).

Auditory Processing. Auditory Processing (Ga) includes abilities such as recognizing differences and similarities between spoken sounds, including the ability to both separate and combine spoken sounds. In other words, it is the ability to perceive and discriminate speech sounds under normal and under distorted conditions. These skills have an impact on Oral Language, Listening Comprehension, Basic Reading, Reading Comprehension, Basic Writing Skills, and Written Expression (Rath, 2001; Riverside Publishing Company, 2001b).

An interaction between auditory processing and working memory exists on several phonemic awareness tasks. When asked to take the middle of the sound out of a word, the rest of the sounds must be remembered. Tasks which require an individual to reverse sounds or repeat sounds heard also incorporate working memory. Analysis and Synthesis are two subskills that contribute to Ga.

Research on Ga. In a recent study, Mcarthur, Ellis, Atkinson, and Coltheart (2008) used a six week training program designed to target students' auditory processing deficiencies. Three groups, consisting of students with a specific reading disability, speech language impairment, or no disability, were examined. Of the 28 students who received training, twenty-five performed within the average range on their skill deficit when retested. Authors indicate that they controlled for test-retest effects. Both experimental and control groups had significantly higher scores on spoken language and spelling tests after training. The authors concluded that although students with a reading disability or speech language impairment could improve their auditory processing, overall reading and spelling did not improve with the intervention.

The Berard Auditory Integration Training program, or Berard AIT, was based on the premise that auditory processing difficulties contribute to learning difficulties. Consisting of 20 half-hour sessions of listening to specially modulated music over a 10- to 20-day period (Edelson & Rimland, 2008), the program's website home page (www.aithelps.com) claims that AIT has

> "significantly reduced some or many of the handicaps associated with autism spectrum disorders, central auditory processing disorders (CAPD), speech and language disorders, sensory issues including auditory, tactile or other sensory sensitivities (hyper or hypo), dyslexia, pervasive developmental disorder (PDD), attention deficit disorder with or without hyperactivity, anxiety, and depression."

This claim was corroborated by Edelson and Rimland's meta-analysis analyzing of 28 AIT studies; 23 of 28 articles found a significant benefit for students receiving AIT when compared to control counterparts. However, most studies in the meta-analysis focused on students with Autism.

Gerth, Barton, Engler, Heller, Freides, and Blalock (1994) researched the effects of AIT on students with auditory disorders, without respect to specific disabilities, and found more than a standard deviation of improvement in auditory processing. Similarly, Maddell (1999) also studied AIT for students with auditory processing deficits, irrespective of specific disabilities. Students included in this study included those with Autism, Attention Deficit Hyperactivity Disorder, and Central Auditory processing disorders with learning disabilities. Subjects' speech perception was assessed by asking them to recognize words in both quiet and competing noise environments. Maddell found that word recognition scores improved in the presence of increasing background noise for students who had been trained in AIT.

More recent approaches to auditory processing training have garnered attention. Fast Forward, a cognitive training program that targets a specific cognitive skill, is being used within some school systems. This computer-based program uses games to teach the processing of speech sounds and focuses on short term auditory memory and sequencing. The program claims to correct neural pathways and to help process the sounds of language through an intensive set of drill and practice. This program is intended to be used for 100 min/day, five days/week; for four to eight weeks; and despite its user friendly appeal, requires a provider to ensure treatment is carried out effectively (Central Auditory Processing Deficit Therapies (2003). The greatest outcomes have occurred with students with an "auditory decoding deficit."

The Lindamood Bell Program is a well known auditory processing program often used in the schools by speech language pathologists to help students with auditory processing. The effects on auditory processing and reading skills has not been consistent, although some research has shown that auditory processing training generalizes to improvements with reading (Irvin & Hoedt, 1979).

Memory. Short-term (G_{sm}), long-term (G_{lr}) and working memory (MW) (included within G_{sm}) all require an individual to recall information, with working memory including the manipulation of the information within one's mind. Short term memory is the immediate recall of information, whereas long-term memory can include some shorter term recall as well as longer recall periods (up to about 30 days). Processing speed and attention to task also play important roles in memory capacity. Age differences related to memory capacity and information processing also exists.

Several common strategies to help one remember items are employed fairly often. One of these strategies is known as chunking, such as connecting pieces of information together such as the numbers in a phone number; knowing that (480) is the area code to a ten digit number helps as this becomes only one thing to remember rather than three separate digits. Further, knowing that 347 is a prefix for the area you are calling in, allows one to remember the first six numbers by really only remembering two chunks of information, allowing for the remembering of a ten digit phone number much more manageable.

Another mnemonic strategy includes using keywords for remembering what has been read. Within this strategy, a key word is used to describe the gist of what was read. The keyword is then replaced with a mental image and other mental images are used to connect other important facts to that particular key word. Then, when needed, the keyword can be retrieved and all related mental images will also be recalled (Wright, n.d.).

Memory strategies and interventions for increasing memory have existed for a long while. Other strategies, programs, and particular interventions have been researched fairly recently. Overall, the area of memory development has received the most attention in the literature.

Research on Gsm. Although experimental studies involving memory development have been around since the late 1800's, the first large scale study of relevance for this study includes the research conducted by Brunswick, Goldscheider, and Pilek in 1932. In this large-scale study, 700 children and adolescents ranging in age from 6-18 years of age were given a large variety of memory tasks with the purpose of providing a general description of short term and long-term memory. Tasks included short term, long term, verbal and nonverbal tasks with both abstract and meaningful stimuli. Age differences were noted in that younger students (aged 6-13) needed more practice when learning nonsense syllables when compared to the learning of words or numbers.

Memory span is not only affected by age but also is greatly impacted by the relevance of the material being remembered. In fact, when task-relevant knowledge is controlled for, age differences in memory span disappear (Dempster, 1985).

Another factor impacting memory performance, particularly working memory, is the speed with which information can be processed. The amount of information remembered is constricted based on the speed of processing. In fact, many researchers who propose age differences in memory span cite that the rate of processing is responsible for these differences (Hitch & Towse, 1995; Hulme, Thompson, Muir, & Lawrence, 1984).

Eysenck (1987) reported that short and long-term memory did not increase correlations between reaction times and intelligence; however, Polczyk & Necka (1997) tested and confirmed a hypothesis that the correlation between RT and intelligence was smaller for people with weaker working memories.

Graham (1968) found that memory span restricts the range of sentence types and length of spoken and understood utterances. If a child has the capability of remembering a string of two unrelated words, the length and complexity of a sentence being spoken to them or that they are able to produce will be less than for a student who has a memory span large enough to correctly remember the order of six words. Comprehension of spoken sentences and words also was affected by memory span.

Memory strategies are behavioral or mental activities aimed at increasing memory capacity or capability; they can be used either at the time of encoding (learning) or at the time of retrieval of material (Flavell, Miller, & Miller, 1993; Schneider, 2002). They are typically time consuming and require much effort. John Flavell and colleagues have shown that rehearsal and strategic organization strategies for memory develop between five and ten years of age, and thus subsequent research has focused on these strategies (Flavell, Miller, & Miller,1993). Studies of theirs and from Schneider (2002) have shown that children of preschool age did not benefit from memory strategies, however, those of kindergarten age and older were able to use memory strategies, when trained, and subsequently increased their memory performance.

Recent studies have used the technology of functional magnetic resonance imaging (fMRI) to study brain activity before and after specific cognitive training. Olesen, Westerberg, and Klingberg (2004) demonstrated increased brain activity in the prefrontal and parietal regions of the brain after a five week training program in which healthy adult subjects were given working memory tasks to complete on a daily basis. Although subject size was small (N=3) and (N= 8), significant differences in brain activity after training were found in both studies.

Other studies have focused on subjects with an acquired brain injury or stroke. Westerberg, Jacobaeus, Hirvikoski, Clevberger, Ostensson, Barfai, et al (2007) studied the effects of a working memory intervention on 18 stroke victims. The CogMed ® Robo Memo Cognitive Medical Systems, a computer-based program that presents visuo-spatial tasks which tap into working memory, was used five days a week for approximately 40 minutes each day. Results indicated significant treatment effects and authors concluded that this cognitive training program significantly increased the working memory capabilities of stroke victims studied.

Processing Speed. Processing Speed (Gs) refers to the ability to find figures, make comparisons and carry out other simple tasks that involve visual perception, speed, and accuracy. It typically refers to the ability to work quickly and accurately to complete simple tasks. Processing speed is typically measured using timed paper and pencil tasks. Achievement areas impacted include; Listening Comprehension, Basic Reading, Reading Comprehension, Math

Calculation, and Written Expression (Riverside Publishing Company, 2001b). Discrimination between shapes or pictures of objects often is required, suggesting that visual processing also is being measured by these subtests. Fluency subtests are included within the academic measures of the WJ III Ach subtests to measure writing, reading, and math. These fluency subtests tap academic knowledge as well as information processing speed.

Research on Gs. There is debate regarding whether age differences are associated with information processing speed, specifically whether increased speed is due to the ability to use strategies or increased familiarity with the items used. Findings by Cowan, Nugent, Elliott, Ponomarev, & Saults in 1999 indicated suggested that age differences in processing speed were due to maturational and developmental factors. Cowan and colleagues reported that the average amount of information attended to at a specific moment in time (apprehension span) increased significantly with age. These maturational factors place inherent limits on processing speed and short term memory capacity; however, processing speed also is influenced by an individual's knowledge base, suggesting that the development of memory abilities is strongly related to biological and experiential factors.

Gilbert first linked intelligence to reaction time (RT), the ability to make quick decisions in 1894 (Jensen, 1982). Since then, Arthur Jensen has studied intelligence and its correlation with reaction time (Jensen & Munro, 1979); specifically, moderate positive correlations were found between the Raven's

Standard Progressive Matrices and decision time, suggesting that higher Raven's scores were associated with quicker decision times, as measured by the Hick test. Jensen posited that the correlation between reaction time and intelligence provided evidence that intelligence involved more than knowledge and skills. Noting the RT growth curve that occurred from childhood to teens, Jensen concluded that dormant neural elements gradually become functional with developmental growth. However, caution is suggested with this interpretation because of the correlational nature of the work; questions regarding direction and causality remain. In fact, Jensen alluded to an overarching third factor, the 'g' factor, as the underlying cause for the relationship between RT and intelligence. Neubauer (1997) agreed with this, stating that a unitary process was apparently responsible for the relationship between psychometric intelligence and speed of processing. Both Jensen and Neubauer felt that RT was a basic psychological process. Nettelbeck (1998) disagreed with the assumption that RT was a basic psychological process, and instead felt that RT was affected by higher order cognitive processes.

Carroll (1987) concluded that Jensen's findings could be explained by the fact that lower IQ individuals were less capable of meeting the requirements necessary for speedy reaction times. Additionally, he felt that Jensen's findings of a relation between IQ and reaction time was premature.

Despite the apparent low loading that processing speed has on g, it does appear to impact everyday life. A meta-analysis of six different studies aimed at improving processing speed found that specific training increased speed of processing on selected measures, and that this increase in processing transferred to every day life and improved the lives of those involved in the training (Ball, Edwards, & Ross, 2007).

Reading. The specific subtest from the broad ability of the Reading and Writing ability used for this study is word attack. Word attack, also referred to as decoding, is a subtest requiring the decoding of nonsense words, which tests phonemic awareness and decoding. This particular subtest falls under both broad abilities of Auditory Processing (Ga) and Reading and Writing (Grw); in this study, it is used as a measurement of reading ability (Grw).

Research within Grw. Typical remediation of students with learning disabilities or reading difficulties include small classes or groups taught by special education teachers or reading specialists. Students receiving special education services under Other Health Impairment specifically for Attention Deficit Hyperactivity Disorder also receive smaller class sizes and individualized attention. Unfortunately, although good progress may be present within this model at first, the sustainability of this progress is under question as Cashdan (1969) found that changes did not typically sustain themselves, whereas Hagen (1983) found that differences did exist between intervention and control groups longitudinally. Additional criticism of teaching in small groups includes that the teaching is less complex and is often taught with their assigned intellectual score in mind. Unfortunately, with this mindset, students rarely progress beyond what is being expected of them, and expectations often remain low (Sharron, 1987). Even when teaching satisfies all necessary criteria to be successful, remedial teaching is often poorly integrated with the child's regular classroom experiences, making generalization of what is learned difficult. Additionally, modifying parental attitudes and home environments is rarely attempted. Cashdan (1969) suggests that the educational system may have greater success if more time, effort, and money were spent in strengthening general classroom facilities and paying more attention to specific difficulties within the general education classroom.

Reading programs such as Headsprout Reading Basics (Layng, Twyman, & Stikeleather, 2004) and Spire (Clark & Edmonds, 1975) teach reading through phonetic coding in a small group format, but focus exclusively on drill and practice of reading and phonemic rules. These programs lack attention to building underlying cognitive structures which aid in reading ability. A major underlying cognitive structure that aids in reading ability is working memory.

According to Feuerstein (1980) the purpose of special education should be to reintegrate children into general education and ordinary society. He believes that maintaining contact with average functioning children is one of the most powerful ways to achieve this goal.

WOODCOCK JOHNSON TESTS

Cognitive Ability. The Woodcock Johnson III® Test of Cognitive Abilities (WJ III Cog; McGrew & Woodcock, 2001) yields seven cluster scores as well as an overall General Intellectual Ability (GIA) from administration of the standard battery. The seven cluster scores include: Comprehension-Knowledge (Gc), Long-Term Retrieval (Glr); Visual Spatial Thinking (Gv), Auditory Processing (Ga), Fluid Reasoning (Gf), Processing Speed (Gs), and Short Term Memory (Gsm). The GIA score is a differentially weighted overall *g* score rather than a summation of particular subtest scores, and is available in both the standard and extended battery. The GIA-standard battery includes the following subtests: 1) Verbal Comprehension (Gc), which taps into the narrow abilities of lexical knowledge and language development. It is comprised of four smaller subtests including picture vocabulary, synonyms, antonyms, and verbal analogies; 2) Visual-Auditory Learning (Glr), which taps into the narrow ability of associative memory and includes a learning task in which novel symbols are associated with words and the examinee must remember the associations they have learned while simultaneously learning new associations; 3) Spatial Relations (Gv), which taps into the narrow abilities of Visualization and Spatial Relations. For this test examinees are required to mentally rotate objects to determine which ones fit together to form a puzzle; 4) Sound Blending (Ga), this taps the narrow abilities of Phonetic Coding: Synthesis. With this task, students listen to a series of sounds from a tape and must blend them together to form a whole word; 5) Concept Formation (Gf) which taps the narrow ability of Induction. In this test, students must learn rules and apply them to novel problems, it requires nonverbal reasoning ability; 6) Visual Matching (Gs), which taps into the narrow ability of perceptual speed. For this task students must quickly and accurately find two numbers from an array of numbers that are the same; 7) Numbers Reversed (Gsm), which taps into the narrow ability of working memory. On this test students are required to repeat a series of numbers in reverse order from what is given. These seven tests that make up the GIA are weighted differently at each age level, given developmental trends in particular areas of cognitive ability (Schrank, McGrew, & Woodcock, 2001).

Academic Achievement. The Woodcock Johnson III® Tests of Academic Achievement (WJ III Ach; Woodcock, McGrew & Mather, 2001) yields Broad achievement scores in the areas of Reading, Writing and Math as well as subtest composite scores under each of these broad abilities. Within the reading tests, scores are available in the areas of fluency, comprehension, sound awareness, and basic reading. Within the writing tests, scores can be obtained for fluency, written expression, writing samples, and spelling. Within the math tests, scores are available for fluency, problem solving, and basic calculation. For this study, two subtests from the Reading battery were administered: Word Attack and Sound Awareness.

Word attack, also known as decoding, refers to the ability to decode letters into language. Many children who have difficulty with reading are unable to decode words (Share & Stanovich, 1995). Word attack is an essential skill for learning how to read (Fox & Routh, 1984) as well as understanding what is read (Torgeson, 2000).

Sound Awareness, or phonological awareness, also plays a key role in reading development. Research has shown that phonological processing skills are important for word recognition and comprehension tasks (Swanson & Howell, 2001).

Standardization. The WJ III Cog and WJ III Ach were co-normed on 8,818 individuals representative of the United States population as measured by the 2000 Census. School aged children and adolescents made up the majority of those sampled (N= 4,784), with fewer but a similar number of preschool aged (N=1143), college students (N=1165), and adults (N=1,843) sampled. The sample was stratified on community size, sex, race, type of school, and parent education (Woodcock, McGrew & Mather, 2001)

Reliability. Reliability refers to the consistency of a measure within itself (internal), consistent over time (test-retest), consistent with an alternative form of the measure (alternate form), and consistent when used by others (inter-rater reliability). Reliability scores of .80 or higher are considered standard as being a high reliability for tests used for individual assessment (Sattler, 2001). The term Standard Error of Measurement (SEM) is an estimate of the amount of error associated with an obtained score, and is directly related to the reliability of a score.

> "Internal consistency reliability methods are based on the assumption that the average correlation between items within a test is the same as the average correlation between items from a

hypothetical alternative form which is created via splitting the test into two smaller tests (e.g., one test based on odd items, one test based on even items).” (Schrank et al., 2001, p. 10).

According to the manuals (WJ III Cog and WJ III Ach; Woodcock, McGrew, & Mather, 2001), the internal consistency reliability coefficient for the GIA Standard Battery (the seven subtests listed earlier) was .97 (SEM 2.60). Internal Reliability Coefficients on the seven clusters associated with the CHC theory ranged from .81-.95 (SEM ranged from 3.35 -6.54), and for the Working Memory Cluster was .91 (SEM 4.50).

Test-retest reliability for Total Achievement on the WJ III ACH was .98, and internal consistency reliability (split-half) on word attack and sound awareness were .87 (SEM 5.36) and .81 (SEM 6.55), respectively.

Validity. Validity refers to the degree to which an assessment tool measures what it purports to measure. There are several different types of validity: content, structural, external and concurrent validity. Content validity is derived from a theoretically based test design.

WJ III Cog. The WJ III Cog was developed with CHC Theory as the basis for the test design. Numerous factor analyses have shown strong evidence for this theory (Flanagan, Ortiz, & Alfonso, 2007). Structural validity focuses on whether the measures are consistent with the theoretical domain definition of intelligence. Evidence for the construct validity of the WJ III Cog is provided in Schrank, McGrew, and Woodcock (2001), who used confirmatory factor analysis (CFA) to determine construct validity. Almost all tests from the WJ III Cog load on one factor, indicating that what is being measured is relevant to the overall construct of cognitive ability. The correlations between related clusters are higher than correlations between clusters that are not related (r= .20-.60), indicating that clusters are measuring distinct abilities (Schrank et al., 2001). Additionally, external and concurrent validity between the GIA-Std and other measures of intelligence, including the Wechsler Intelligence Scale for Children-Third Edition (WISC III; Wechsler, 1991), the Differential Ability Scales (DAS; Elliott, 1990), the Kaufman Adolescent and Adult Intelligence Test (KAIT; Kaufman& Kaufman 1993), and the Stanford Binet Intelligence Scale –Fourth Edition (SB IV; Thorndike, Hagen, & Sattler, 1986) have been conducted. These external validity scores range from .67 and .76, indicating sufficient validity in this area (Sattler, 2001; Schrank et al., 2001).

WJ III Ach. Validity studies for the WJ III Ach also exist in the literature. In regards to content validity, reliability scores range from .50 to.70 for non-related achievement measures. Concurrent or external validity between reading scores including areas of basic reading, decoding, and broad reading and other measures of achievement including the Wechsler Individual Achievement Test (WIAT) (Wechsler, 1992) and the Kaufman Test of Educational Achievement (KTEA) (Kaufman & Kaufman, 1985) range from .63-.82.

MEASUREMENT RELATED FACTORS TO CONSIDER

Repeated Testing. Although repeated testing is the only way to measure change in IQ and achievement over time, this method has the problem of practice effects. A practice effect is defined as improvement in test performance due to repeated exposure to test materials; it is typically viewed as a source of potential error when looking at statistical results (Duff et al., 2007). No studies on practice effects involving the WJ III tests could be identified; additionally, available research involving practice effects in general involve minimal time between administration (less than three months) and/or involve adult subjects (Basso, Carona, Lowery & Axelrod, 2002; Falleti, Maruff, Collie, & Darby, 2006; Siders, Kaufman, Reynolds, 2006). Those results show improvement in composite scores of intelligence, though working memory indices remain stable. The problem of practice effects are somewhat remediated when alternative test forms are used (Benedict & Zgaljardic, 1998). Additionally, information regarding practice effects on achievement measures also appears to be lacking in the literature.

Regression to the Mean. Another consideration when using cognitive scores from two different time points is regression to the mean. This refers to the likelihood that, regardless of the first score obtained; the second score will likely be closer to the mean score of the test. As an example, a student who obtained a SS of 80 on the Working Memory Cluster at the first time point (T1) is likely to obtain a SS somewhere between 80 and 100 at time point two (T2); the score is usually estimated to be at the mid point of SS = 90. To avoid misinterpreting results, the most recent approach to control for regression to the mean outlined in Furr and Bacharach (2007), will be used in this study.

INDIVIDUAL RELATED FACTORS TO CONSIDER

Genetics. Genetics, as discussed in this section, refers to the "DNA differences amongst individuals that are inherited from generation to generation,"(Plomin & Petrill, 1997, p.3) rather than mutations of DNA or cells that are not inherited.

The contribution of genetics to overall intelligence has received much research attention. Twin and adoption studies saturate the literature, and offer the best vantage point for examining genetic and environmental influences on intelligence. Because identical twins have identical DNA, and fraternal twins share 50% of their DNA, identical and fraternal twins reared in the same environment can be compared to twins who have been adopted but reared in separate environments in order to understand the effect of genetics on intelligence. Research consistently estimates that about 50% of the variance in intelligence is due to genetic factors, with environment accounting for another 25%. About 17% of the remaining variance is thought to be due to non-shared environmental influences, such as peer groups and school experiences (Haier, 2003; Plomin & Petrill, 1997; Sattler, 2001). These estimates are based on overall intelligence scores; however, differences in heritability appear to be dependent on the type of cognitive skill. For example, the broad factor of memory shows little heritability, whereas verbal abilities are moderately dependent on genetics and information processing speed is almost entirely dependent on genetic factors (Baker, Vernon, & Ho, 1991; Plomin & Petrill, 1997; Thapar, Petrill & Thompson, 1994). In addition, Plomin & Petrill have found that genes play a bigger role in the age-related expression of intelligence, with identical twins having more similar expression of cognitive ability as they age. This finding may seem somewhat counterintuitive as one may imagine that environmental factors play a bigger role in determining ability as people age.

Genetics typically are thought to be expressed in a one-way causal direction; however, Plomin (2003) stated that, "behavioral differences can cause brain differences [which] can change the expression of genes" (p.111). This statement, although framed from a genetic perspective, suggests that intelligence is fluid, and that environment, which often shapes behavior, has an impact on genetic expression.

Race/Ethnicity. The Spearman Hypothesis states that race differences are more prominent on measures more closely related to "g", such as abstract problem solving and reasoning opposed to rote memory tasks (Spearman, 1927). Although differences between African Americans and Whites on intelligence tests were documented by Spearman as early as 1927, criticism of intelligence tests peaked in 1949, the year the Wechsler Intelligence Scale for Children was published (Wechsler, 1949). Overall IQ differences of 15-18 points in favor of Whites were found, with larger differences noted on subtests measuring fluid reasoning than on subtests involving rote memory (Jensen 1969). However, between race differences were smaller than intra-race differences; additionally, this research did not control for social, educational, school, or other environmental differences.

Lynn and Owen (1994) tested Spearman's hypothesis in sub-Saharan Africa by administering a paper and pencil aptitude test to 1,056 Whites, 1,093 Blacks and 1,063 East Indians. There was a 2 Standard Deviation (SD) discrepancy between Africans and Whites, with African's scoring lower than Whites and a 1 SD discrepancy between Whites and East Indians, with East Indians scoring lower. IQ score differences between Blacks and Whites were most prominent on subtests which loaded higher on g (abstract reasoning, problem solving); the subtests on which there were racial differences correlated.62 with the *g*-factor. Interestingly, the difference in IQ scores between Whites and Indians on subtests with higher g-loadings was only .23, leading the researchers to conclude that the subtest score differences between Whites and Indians was not based on the g factor. These findings suggested that there were other variables contributing to the discrepancy between Whites and Indians that could not be explained by the *g* factor as it was measured.

Research as recent as 2000 (Nyborg & Jensen) has confirmed Spearman's Hypothesis. Nyborg & Jensen studied over 4,400 Vietnam War veterans using 9 assessment measures. An average correlation between race differences on a test and its g loading was .81; this led to the conclusion that Spearman's original hypothesis about a Black-White difference on the g factor was supported as fact.

Similar effects involving the g factor have been found in other studies, such as Jensen's study cited in Nyborg (2003) which used up to 17 test batteries. Studies outside of the United States also produced similar results.

Richard Lynn's 1991 review of 11 studies from West, East, Central and Southern Africa indicated that the average IQ of Blacks was 70 (median 75); this is 15 points lower than the mean typically found for Black Americans (85) and 30 points lower than that usually found in U.S. Whites. He invoked an evolutionary explanation for these differences; specifically, he asserted that Caucasians developed in colder, northern climates whereas Blacks developed in warmer, more tropical climates. He believed that only those who could problem solve issues of food, shelter, and basic survival were able to procreate, whereas those living in more tropical climates did not have these adversities to overcome. Although Lynn begins most of his arguments with genetic undertones, his argument of evolution is one in which the environment shaped genetics and ultimately impacted intelligence. Arguments against Lynn's explanation include that of circumstantial evidence and a lack of empirical data (Eysenck, 1991).

Despite racial differences in IQ scores, Feuerstein urges researchers to try to improve cognitive functioning rather than merely accept the finding. Feuerstein does not assume that specific groups differ in ability but rather asserts that a lack of human mediation or specific interaction within the family or cultural group results in lower IQ scores. Feuerstein believes the reasons certain groups perform poorly on IQ measures, can be attributed to cultural, social or particularly parental influence within the immediate environment (Sharron, 1987). His goal was to modify the influence of these variables through individual training.

Age. Jensen (2003) found that age had an effect on *g*, with older children scoring higher than younger children on overall measures of *g*, and beyond basic knowledge differences due to age. There was a larger effect on g for race differences, than for age particularly on subtests that included higher order thinking skills such as abstract reasoning. On subtests which required less mental effort, such as, memory , there was a larger effect for age than for race. This age/race interaction suggests that cognitive development during childhood involves mental growth factors other than *g*, while the black white difference at any age is almost exclusively a matter of *g*. Feuerstein would dispute this, and rather argue that differences between racial groups are due to cultural, societal, and parental influences on the child.

Gender. The issue of gender differences in IQ has received a great deal of attention. Few gender differences involving cognitive ability have been found. The most consistent difference has involved spatial ability, with males having better spatial perception and mental rotation ability; however, no gender differences related to spatial visualization ability have been found (Hyde & McKinley, 1997). Differences between gender on verbal ability and overall general ability are virtually nonexistent (Brody, 1992; Chen & Zhu, 2008; Halpern & La May, 2000; Lindblad, 1996; Neisser et al 1996; Rumsey 2004).

There is some evidence that males struggle more with reading than females (Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008; Hyde & McKinley, 1997; Husain & Millimet, 2009; Marks, 2008). Additional research indicates that males' scores are more variable over time, particularly in the areas of general knowledge math, spatial ability and spelling (Hyde & McKinley, 1997; Jousavec & Jousavec, 2008).

ENVIRONMENTAL FACTORS

A discussion of individual characteristic variables affecting intelligence would not be complete without a review of the impact of environmental effects on individuals' intelligence scores. Environmental factors shown to impact the development of intelligence include parental involvement, nutrition and environment, poverty, positive reinforcement, and schooling (Sattler, 2001). Additionally, the results of numerous studies focused on cognitive skill training suggests that intensive intervention aimed at improving cognitive skills are successful, though most of these studies were conducted over 25 years ago (Feuerstein & Rand, 1977; Feuerstein et al., 1980).

Both risk and protective factors strongly influence the impact of environment on intellectual functioning. Some distal risk factors mentioned in the literature include poverty, maternal depression, ethnic minority status, and maternal medical problems, while proximal risk factors include low birth weight, and parent interaction styles (Pike, Iervolino, Eley, Price, & Plomin, 2006)

Students with a number of risk factors consistently score lower on IQ tests, than those with fewer (or no) risk factors (Pike et al., 2006). Pike and colleagues evaluated over 10,000 children as part of a family study and found that socio-economic status (income of family) and parent reports of a chaotic home environment were the strongest predictors of cognitive outcomes, whereas maternal depression and parenting style affected problem behaviors more than cognitive outcomes.

Malnutrition has been shown to be a factor when considering overall intelligence. Results from a study conducted by Eysenck and Eysenck (1991) indicated that malnourished individuals given vitamin supplements increased their overall IQ score by 11 points when compared to a control group.

DEVELOPMENT AND THEORY OF INTERVENTIONS IN STUDY

The LearningRx Training Programs were developed by Dr. Ken Gibson after several years of personal research related to cognitive skills. The programs emphasize four key areas believed to be fundamental in improving cognitive skills: 1) One-on-one Training, 2) Sequencing, where new exercises and training are introduced in a logical order from simple to complex, 3) Loading, where individual training tasks are layered and progressively increase in difficulty, and 4) Intensity, where training is delivered at a rapid pace with techniques that create and maintain a high level of intensity. Students are pushed past their comfort zone to more challenging but achievable levels.

Additionally, the programs adhere to Bruner's (1964) four rules of instruction for the most effective learning. The rules and the manner in which they are incorporated follow.

1) *Experiences must be described which explain why the child is willing and able to learn.*

Program practice: Every drill has a real world application to motivate the child to persevere when challenged, For example, a student who has difficulty finishing school work within the allotted class time may be informed that a drill focused on improving processing speed will enable him/her to do their work more quickly. Additionally, students identify their own benefit to the drill after being coached by the instructor on possible benefits. In trainer training, individuality and specificity of benefits are stressed.

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

Program practice: The structure for teaching within the program is well specified in student and trainer handbooks, as well as in the training provided. Drills build on one another and strengthen cognitive skill areas. Some drills combine skills, such as memory and processing speed. For example, some of the memory training drills include using short term, long term, and working memory skills as well as processing speed skills, such as repeating a list of words from memory within a certain time frame. Skills typically are not combined until basic proficiency in those skills has been achieved. Although the model of instruction is the same for all students, individualization occurs based upon students' strengths. For example, a student with strong short term memory, but difficulty with processing speed would spend more time on drills related to processing speed. The programs are individualized based on student needs.

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

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

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

Immediate corrective feedback is provided each drill procedure throughout the training. Corrective feedback includes correcting errors by immediately presenting the correct answer and then requiring the student to repeat the sequence or drill correctly. Consistent corrective feedback procedures are used, which enable the student to be successful on repeated attempts; these procedures are present throughout the program with the goal that students will ultimately be able to self- correct. Students also receive daily points which can be saved and used for extrinsic rewards available through the center. Deferred rewards are intrinsic to the program, as students do not receive a prize after every training session, but must first reach a cumulative point total before cashing in.

Additionally, at the beginning of each session, the student is asked about any noticed improvements in their everyday life. These might include whether the student is completing homework more quickly, finding it easier to read, or enjoying reading for the first time.

RESEARCH ON LEARNINGRX PROGRAMS

Psychologists have considered the role of language as a mediating process in learning and in concept formation. The Learning Rx training program involves conceptual learning and understanding specific principles in order to demonstrate learned concepts, specifically designed to be generalized to other aspects of life. More specifically, it includes the ability to demonstrate knowledge of learned concepts, particularly the student's ability to demonstrate learned principles within the classroom curriculum by applying "learning sets" (Harlow, 1949). These "learning sets" are obtained from specific training aimed at teaching concepts (i.e. how to reason and problem solve, or how to use mental imagery) and by increasing brain power through intensive drills such as those associated with processing speed, divided attention, and memory.

Although other currently available programs also provide individualized, self-paced, prearranged yet flexible sequences of instruction, LearningRx's use of a one-on-one human interventionist approach makes it unique. The LearningRx Program, which will be explained in greater detail in chapter three, includes several different training programs. Each program is either considered to incorporate Pro training, which includes one on one training with a certified trainer five days a week, or Partner training which involves the parent in some of the training at home. Programs include basic skills, a reading program, and a math program. Additionally, a program referred to as Lift-Off is available for students aged four to six.

Three independent researchers have conducted research on the LearningRx Training programs, to date; Marachi (2006), Luckey (2007), and Carpenter (2009). All studies included evidence of significant differences from pre to post test as a result of cognitive skills training. The Marachi (2006) study included 1,265 students aged 4 to 22 participating in LearningRx programs across the nation, but several limitations within this research study existed. The Luckey study improved upon the initial Marachi (2006) study by accounting for time elapsed between pre and post test scores in final analyses and using Repeated Measures ANOVA statistical analyses to account for the same students taking the same test at both pre and post test. Additionally, each program was analyzed in detail, reporting findings for each of the programs as well as comparing Read programs to Think programs to analyze differences between scores.

The Luckey (2007) study included 2,080 students between 4 years and 19 years of age who completed a LearningRx program in 2006. Student data was compiled from 36 different LearningRx centers enrolled in one of ten programs throughout the United States. After accounting for the time that had lapsed between pre and post test, students gained an average of six months in rate of reading and an average of a little more than four years in the ability to identify specific sounds within a word.

Visual Processing as well as Long Term Retrieval showed consistent growth across all programs, with gains ranging from three years, 10 months, to four years, three months. Processing Speed had the smallest growth, ranging from six months to one year.

For academic skills, the Read programs produced greater gains than the Think programs for students struggling with sound awareness and word attack, although students in both programs demonstrated gains in these areas.

For cognitive skills, both the Read and Think programs produced similar cognitive skills gains. The only exception involved Short-Term Working Memory, where gains in both Think programs (Pro and Partner) were higher than gains achieved in Read programs for this skill.

Carpenter (2009) expanded the research on the LearningRx programs by including a control group in his study, though participants were limited regionally, to a small town in Colorado. Though Carpenter did not account for the time elapsed between pre and post test when assessing age equivalent score differences between the two time points; he did include covariates such as race, age, gender, and disability in the Regression analyses results presented. Results indicated that raw score points for treatment group were different than control group participants ranging from one and a half to six raw score points.

CHAPTER 3: METHODOLOGY

PARTICIPANTS

A sample of 975 individuals ages four to eighteen years of age was selected from a larger, existing data base, which had been gathered by a private corporation, to which this researcher was given access. Age listed by gender, intervention group, and diagnosis is included in Table 2. All individuals in the sample had attended one of two types of cognitive intervention programs implemented in 51 centers in the United States over a two year period. Those included in the current study met the following criteria: students were between the ages of 4 yrs, 8 months and 18 yrs, 11 months of age, enrolled in one of four different cognitive intervention programs, and were evaluated using subtests from the Woodcock Johnson Tests of Cognitive Abilities, 3rd Edition (WJ III Cog) and the Woodcock Johnson Tests of Achievement, 3rd Edition (WJ III Ach) prior to and at the conclusion of their participation of their respective program.

The distribution of participants was as follows; 359 females, *M* age=131 months (10 yrs, 11 months), *SD* = 35 months (2 yrs, 9 months), 616 males, *M* age= 130 months (10 yrs, 10 months), *SD* = 35 months (2 yrs, 9 months).

Based on parent report of participant ethnicity, with 98% of the sample providing information, 84% of the sample was White, 6% African American, 4% Hispanic, 2% Asian, less than 1% Native American, and 2% self selected “other.” When asked about level of parent education, 39% of parents did not to respond; of the remaining 61%, less than 1% did not finish high school, 7% graduated high school, 6% attained a 2 year college degree, 25% achieved a 4 year college degree, and 23% achieved a post graduate degree. Table 3 presents frequencies of descriptive variables for the entire sample.

DIAGNOSIS: IDENTIFYING DIAGNOSTIC GROUPS

All participants were either determined to have Attention Deficit Hyperactivity Disorder, a Reading Disability, or to have no diagnosis of any kind. Students identified as ADHD in this study met the following criteria: had an ADHD or ADD diagnosis according to parent report, and were not reported to have any co-morbid diagnoses such as learning or developmental disabilities. Students with co-occurring disabilities were excluded from the study. Parents reported diagnoses on the intake paperwork that they completed prior to enrolling their child in the intervention programs. Specific research related to parent report of ADHD is not found in the literature, though parents have been found to be reliable reporters in regards to ADHD symptoms. Dewey, Crawford, & Kaplan (2003) found that parent rating scales of ADHD were very reliable, correctly classifying 65% of children with a diagnosis of ADHD.

Students identified as having a Reading Disability in this study met the following criteria: had been diagnosed with Dyslexia or Reading Difficulty according to parent report, and were not reported to have any co-morbid diagnoses such as ADHD or developmental disabilities. Students with parent reported co-occurring disabilities were excluded from the study. Parents reported reading difficulty on the intake paperwork that they completed prior to enrolling their child in the intervention programs.

Students identified as having No Disability in this study were indicated by parent report prior to enrollment to not have any disabilities, nor to have ever been labeled as having any disabilities.

TRAINING

Programs. The two training programs, Read and Think, were focused either on improving cognitive ability exclusively or on improving both reading ability and cognitive ability. The amount of time spent in training with a certified trainer as well as the length of the program varied within these two programs. All programs consisted of training five days a week for either 12 or 20 weeks. Each individual training session lasted 60 minutes.

Each program included hour-long one-on-one training sessions from a certified trainer. All training within Pro programs was center-based and conducted by a certified trainer, whereas training within the Partner programs included parents or caregivers as the home based trainer on the two days the student was not attending center-based training.

For Partner programs, a homework log with specific training exercises was assigned to the home-based trainer. Home-based trainers were asked to log hours of training with student. At the beginning of each session at the center, the certified trainer reviewed the home training log and the student received points towards their goal based on completion of home training.

The Read Programs consisted of 30 minutes of training focused exclusively on phonological processing drills and basic word attack skills and 30 minutes spent on cognitive training drills. Both Partner and Pro Read Programs were 20 weeks long.

The Think Programs focused exclusively on cognitive training drills. A minimal amount of time was spent on sound awareness and word attack drills. Think Programs were 12 weeks long and included the option of Partner or Pro formats.

TRAINERS

Certified. Based on hiring policies and procedures outlined in staff and center handbooks, certified trainers typically held a four year college degree and underwent 20 hours of direct training. This training included instruction on intervention program content and procedures, trainer policies, ten observations of a master level certified trainer, ten guided sessions where the trainee gradually increased the number of procedures on which they took the lead, exposure to research on the intervention program, and passing a trainer certification test.

Home-Based. Home-based trainers were utilized if the participant was enrolled in a Partner Program. Home-based trainers may have varied from a mother, father, grandparent, or older sibling in the home. There was someone identified as the primary home trainer, though an individual student may have had more than one person involved in home training. The person identified as the primary home trainer observed the first six sessions conducted by the certified trainer, participated in the last 15 minutes of those sessions and received immediate feedback from those sessions. Subsequently, home-based trainers observed 15 minutes of a center-based session each week where the certified trainer observed them working with the trainee, provided and demonstrated procedures. These weekly sessions with the home trainer continued throughout the training. Sessions with the home-based trainer were recorded on a log and student received incentives (points towards prize goals) for each hour of training they did at home.

TRAINING TASKS

Intervention procedures consisted of tasks that emphasize auditory or visual processes that require attention and reasoning. Trainees were taught to develop the appropriate strategy to complete the task through the highly structured training experience, which includes progressively challenging tasks that allows all students early success. The drills used a meta-cognitive approach to developing cognitive skills that includes immediate feedback and highlighting the relevance of the particular procedure to the participant's daily life.

The interactive and individualized training combined with the immediate feedback facilitates learning. Additionally, use of a metronome helped students gradually increase the fluency of their response; requiring quicker responses serves to make cognitive functions more automatic.

Though there was not any systematic way to address the fidelity of training for each student, logs were kept by trainers and periodically reviewed by center directors to ensure program procedures and flow of training were consistent with the program and trainer handbooks.

MEASURES

Each student was assessed on up to 14 different subtests that measure 11 different areas of cognitive processing both before and at the conclusion of training. The average length of time between tests was five months. The measures include the Woodcock Johnson Tests of Cognitive Abilities, Third Edition and the Woodcock Johnson Tests of Achievement, Third Edition (WJIII-COG & WJ III ACH; Woodcock, McGrew, & Mather, 2001). Subtests were administered and scored by a certified evaluator on staff according to the procedures specified in the test manuals.

The following subtests were administered from the WJIII-COG: Test 1: Verbal Comprehension, Test 2: Visual Auditory Learning, Test 3: Spatial Relations, Test 4: Sound Blending, Test 5: Concept Formation, Test 6: Visual Matching, Test 7: Numbers Reversed, and Test 9: Auditory Working Memory. Administration of these subtests allowed both the Working Memory Cluster (Tests 7&9) and the overall General Intellectual Ability (GIA) (Tests 1-7) to be obtained.

Administered subtests from the WJ III Ach included Test 13: Word Attack and Test 21: Sound Awareness.

VARIABLES

General Intellectual Ability (GIA). The WJ III Cog was the first comprehensive cognitive assessment tool to measure all seven broad cognitive abilities outlined in the Cattell-Horne-Carroll Theory of Intelligence (CHC). The overall ability level score (GIA) is obtained by a statistical compilation of seven subtests, each contributing to one of the seven broad constructs.

The General Ability Index (GIA) was calculated by the Compuscore program (Riverside Publishing, 2001a). The GIA has a mean of 100 and a standard deviation of 15. Any score below an 85 is considered Below Average and any score above 115 is considered to be Above Average. The results of a validity study that compared the GIA with the Differential Ability Scales (DAS) score of General Conceptual Ability indicated a 60% shared variance between the scores (Anjum, 2005). Another validity study looked at the WJ III GIA score and compared it to the Nonverbal Intelligence Quotient Score from the Comprehensive Test of Nonverbal Intelligence (CTONI) and found that in 32% of the individuals, scores only differed by 5 points, with 60% of individuals having scores within 10 points of each other (Lassiter, Matthews, & Feeback, 2007).

Working Memory (MW). One of the clinical clusters that can be obtained from the WJIII Cog, the working memory cluster score is an arithmetic average computed by combining the two subtests which comprise the Working Memory Cluster, Numbers Reversed and Auditory Working Memory. Concurrent validity studies verify the validity of the WJ III Cog measure of overall ability

(GIA) and MW clusters (Anjum, 2005; Sanders, McIntosh, Dunham, Rothlisberg, & Finch, 2007). The Working Memory cluster has a mean of 100 and a SD of 15.

Word Attack (WA). Word attack refers to the ability to read a word using the learned sound-symbol relationship associated with letter sounds. Word attack falls under the broad ability of Reading and Writing (Grw) and is measured by the WJ III Ach subtest of Word Attack, which requires correctly reading nonsense words while adhering to general principles of sound-symbol relationships present within the English language. The Word Attack subtest has a mean of 100 and a standard score of 15.

Sound Awareness (SA). Sound awareness, or phonological processing, is the ability to focus on the sound structure of language apart from its meaning (Woodcock, McGrew, & Mather, 2001). The WJ III Ach subtest of Sound Awareness assesses phonological ability, which falls under the broad ability of Auditory Processing (Ga). This test requires the individual to identify rhyming words, and substitute, delete, or reverse sounds in words presented aloud. The Sound Awareness subtest has a mean of 100 and a SD of 15.

Both the WJ III Ach subtests of Word Attack and Sound Awareness have been validated through numerous studies (Huff, Dancer, Evans, & Skoch, 2006).

Gain Scores. Gain scores were computed by taking the post test score and subtracting the pre-test score. Gain scores will be computed for each of the four standard score variables (GIA, MW, WA & SA). Procedures which accounted for regression to the mean were used when computing gain scores (described below).

STATISTICAL ANALYSES

Preliminary Analyses. Before conducting analyses on study variables, the normality of variables was evaluated using histograms, box plots, Tests of Normality and by comparing the 5% trimmed mean values to mean values of the entire sample. Additionally, regression to the mean was dealt with using a correction procedure to determine a predicted true score. Regression to the mean refers to the likelihood that upon a second testing session for the same subject, an individual's score is likely to be closer to the mean of the test than it was during the first testing session. For example, if a student scored above the mean on the first testing session, it is likely that their second score would be lower (i.e., closer to the mean). To control for regression towards the mean, a predicted true score was calculated and used for analyses rather than the obtained score. The predicted true score is intended to reflect the discrepancy in an individual's observed score between the two testing sessions, and therefore control for regression to the mean (Furr & Bacharach, 2007).

The process used was as follows; a) multiply the obtained score by the test-retest reliability of the test; b) multiply the mean of the dependent variable (obtained for the group) by 1 minus the reliability, and c) add the results of a and b. This method accounts for statistical regression to the mean and the reliability of the test (Furr & Bacharach, 2007). Separate means were used for each respective group in calculating predicted true scores.

Descriptive statistics were computed and included means and standard deviations for Working Memory, General Intellectual Ability, Sound Awareness, and Word Attack scores at pre and post test. ANOVAs then were conducted to determine if pre-test group differences on gender, age, ethnicity, and diagnostic group existed within the data. Any pre-test group differences found were controlled for in subsequent analyses. Correlational analyses were run to determine relations between all variables.

Analysis Plan. Hypothesis 1: There will be significant differences from pre- to post-test on General Intellectual Ability (GIA), Working Memory (MW), Sound Attack (SA) and Word Attack (WA).

The first hypothesis was addressed with repeated measures ANOVA's to determine whether or not there are significant differences between pre and post test scores.

Hypothesis 2a: Irrespective of intervention group, there will not be any significant differences between boys and girls on gain scores for GIA and MW.

Hypothesis 2b: Gain scores for SA and WA will be higher for females, when diagnostic group, age, and intervention group is controlled.

The second hypothesis was addressed with a two- way Multivariate Analysis of Covariance (MANCOVA) to determine whether or not there were significant differences between gain scores for boys and girls, while controlling for age, intervention group, and diagnosis. The dependent variables included gain scores for GIA, MW, SA, and WA. The between subject factor was gender (male or female).

Hypothesis 3a: There will be a negative relation between age and gain scores on cognitive measures (GIA and MW) such that increasing age will be associated with smaller gain scores on cognitive measures.

Hypothesis 3b: There will be a positive relation between age and gain scores on achievement measures (SA and WA) such that an increase in age will be associated with larger gain scores.

The third hypothesis was addressed by conducting four bivariate correlations, between age and each gain score (GIA, MW, SA and WA). First, scatter plots were examined to assess the linearity of relations. Each correlation analysis was considered significant at the .05 level of statistical significance.

Hypothesis 4: There will be a relation between initial level of GIA and gain scores such that students with higher initial GIA scores will have higher gain scores on the measures of MW, GIA, WA and SA.

The fourth hypothesis was addressed by conducting four partial correlations, controlling for gender, age, diagnosis, and intervention type. First, scatter plots were examined to assess the linearity of relations. Each correlation analysis was considered significant at the .05 level of statistical significance.

Hypotheses 5 – 9: Hypotheses five through nine (discussed below) were addressed by conducting two separate analyses, the first addressed the dependent variables of MW, SA and WA, controlling for initial GIA, and the second addressed GIA alone. For the first analysis, a three-way Multivariate Analysis of Covariance (MANCOVA) was conducted in order to determine whether disability group, treatment intervention, and intensity will affect children's gain scores on measures of MW, GIA, Word Attack or Sound Awareness. The dependent variables will include MW, WA and SA subtest gain scores. Between subject factors included; Disability (ADHD, Dyslexia, or none), treatment intervention (Read or Think), and Intensity (center based or combination). The covariates included gender, age and initial GIA. A power analysis was conducted simultaneously to ensure sufficient power for analyses. A power analysis yielding a score of .80 or above was sufficient to report scores from this analysis. The second analysis included an ANCOVA with the dependent variable being the GIA gain score. Between subject factors included: Disability (ADHD, Dyslexia, or none); treatment intervention (Read or Think); and Intensity (Pro or Partner). The covariates included gender and age.

Hypothesis 5: When comparing students in Think to those in Read programs, students in Think programs will have greater gains in MW and GIA than students in Read Programs.

Hypothesis 6: Students in Read programs will have greater gains in SA and WA than students in Think programs.

Hypothesis 7a: Students in Pro programs will see greater gains than students in Partner programs on measures of GIA, MW, SA and WA.

Hypothesis 7b: Students in the ADHD group will have bigger gains than students in the No Diagnosis group for both Pro and Partner programs.

Hypothesis 8: Gain scores will not differ for diagnostic groups based on type of program (Think vs. Read) enrolled for GIA, MW, SA or WA.

Hypothesis 9a: There will not be any significant differences between diagnostic groups for gain scores on GIA, SA, or WA.

Hypothesis 9b: Students in the No Diagnosis group will have larger gain scores in the area of MW when compared to students in the ADHD and Dyslexia groups.

CHAPTER 4: RESULTS

In this section, procedures to determine outliers of variables as well as controlling for regression to the mean are first discussed. This is followed by a presentation of descriptive statistics and the results of preliminary analyses conducted on the study variables. Then, results for the previously discussed hypotheses and follow up analyses will be presented. Based on the results from the preliminary analyses, some hypotheses were modified and analyses added to include the Dyslexia/Reading Disability group; these modifications will be described in the relevant sections.

MINIMIZING ERROR

Assessing Normality. When assessing for normality, it is typical to examine a distribution for both skewness to determine the asymmetry of a distribution, and kurtosis to examine the amount of peakedness of the distribution. However, Tabachnick and Fidell (2007) indicated that large samples of over more than 200 cases or more will not be substantively affected by either skewness or kurtosis.

Additionally Schinka & Velicer (2003) indicated that with large sample sizes the appropriate way to assess normality is by visually inspecting the shape of the distribution. This is preferred over formal statistical measures with sample sizes of 300 or larger because normality of the distribution is likely to be rejected, even if the deviation from normality is minimal. Therefore, procedures outlined by Pallant (2007), and discussed by Tabachnick & Fidell (2007) were used to assess normality of the current sample. First, an evaluation of histograms, box plots, and Tests of Normality were conducted. This was followed by comparing the mean values of each variable to the 5% trimmed mean values.

Though some mild outliers were detected from box plot output, none were considered extreme. Additionally, when mean values of all data were compared to 5% trimmed mean values, the two mean values were very similar (.10 or less) on each variable. Therefore, following Pallant's recommendation (2007), all values were retained for analyses.

Regression to the Mean. Regression to the mean effect is likely whenever the same standardized test is administered to an individual (Hopkins, 2002). That is, the second score is likely to be closer to the test mean than the first score, irrespective of the first score being above or below the mean. Therefore, the regression to the mean phenomenon must be considered when using a dataset with test-retest data. To control for regression to the mean with this sample, procedures outlined by Furr & Bacharach (2007) were used to transform pre-test scores. This process consisted of: a) multiplying the obtained score by the test-retest reliability of the test; b) multiplying the mean of the dependent variable (obtained for the group) by 1 minus the reliability, and c) adding the results of a and b.

Results from four separate one-way ANOVAs indicated means for each of the three diagnostic groups across all four dependent measures differed significantly at pre-test: General Intellectual Ability (GIA), F (2,614) = 3.65, p

<.05; Working Memory (MW), F (2,504) = 6.20, $p < .01$; Sound Awareness (SA), F (2,966) = 12.97, $p < .01$; Word Attack (WA), F (2, 958) = 13.64, $p < .01$. Therefore, the means for respective diagnostic groups were used to compute the predicted true scores and the predicted true scores were used in subsequent analyses. This method accounts for statistical regression to the mean and the reliability of the test. Table 4 illustrates means and standard deviations for dependent variables.

COMPUTING GAIN SCORES

A gain score was computed for each dependent variable: Sound Awareness (SA), Word Attack (WA), Working Memory (MW) and General Intellectual Ability (GIA). The gain score was obtained by subtracting the predicted true score from the post-test score. The gain score was used for most statistical analyses in this study. Table 5 presents gain scores for each dependent variable for the overall sample, whereas Table 6 presents pre-test scores, Table 7 presents post-test scores, and Table 8 illustrates gain scores by diagnostic group and intervention group. Due to lack of statistical difference between pro and partner groups at pre-test, intervention groups were combined as follows: Read Pro and Read Partner into Read, and Think Pro and Think Partner into Think.

DESCRIPTIVE AND PRELIMINARY ANALYSES

Descriptive Analyses. As previously noted, obtained pre-test scores and predicted true scores for each dependent variable are presented in Table 4.

Unless otherwise noted, analysis and discussion of variables refer to the predicted true scores.

Pearson correlations were computed to examine the relationships among study variables. Several significant relations were found. Those with medium and large relations which were significant at Alpha level of .01 are presented below. Medium relations were defined as -.30 to -.49 and .30 to .49; strong relations were defined as values between -.50 and -1.0 and .50 and 1.0 (Cohen (1988). Medium relations included the following: age at pre-test was negatively related to initial word attack scores (r = - .245, $p < .01$), pre-test scores on word attack were negatively related to gain scores on word attack ,and pre-test scores on working memory were negatively related to gain scores of working memory; pre-test scores of working memory were positively related to pre-test scores of word attack and sound awareness and initial scores of overall GIA was positively related to initial scores of word attack. Those with strong relations (correlations between .50 and 1.0) included: pre-test scores of word attack were positively related to pre-test scores of sound awareness; and pre-test scores of overall GIA was positively related to initial scores of sound awareness and working memory. Interestingly, intensity of the program (Pro vs. Partner) was not significantly related to any other variables (including initial scores or gain scores on any variables). The correlations referenced above without statistics in text are presented in Table 7.

Preliminary Analyses.

Pre-test differences among diagnostic and intervention groups. It was important to analyze pre-test differences amongst diagnostic and intervention groups to understand differences between groups that existed before intervention so that interpretation of findings could be best understood. Additionally, understanding pre-test differences allowed for the control of variables that were statistically significantly different in subsequent analyses.

Several two-way between subjects' analysis of variance (ANOVA) tests were conducted to evaluate whether pre-test scores were significantly different for students in different diagnostic or intervention groups. Follow up tests to significant main effects were conducted using Tukey's HSD test to control for family wise error rate between groups with unequal sample sizes (Cohen, 2003). The between subject factors were diagnostic groups, with three levels (ADHD, Dyslexia, or No Disability group), and intervention groups, with four levels (Read Pro, Read Partner, ThinkPro, and Think Partner); the dependent variable included the four pre-test measures of Word Attack (WA), Sound Awareness (SA), Working Memory (MW), and General Intellectual Ability (GIA).

The Wilks' Lambda F test first was used to determine if pre-test differences existed between Pro and Partner programs (with Read and Think programs combined). Pre-test scores on all four dependent measures did not differ significantly; F (4,249) = .953, p = .434. Second, Read and Think programs were evaluated separately to determine if pre-test score differences existed within respective programs (between Pro and Partner). Within the Read program, dependent measures did not differ significantly between Pro and Partner groups; F (4,182) = .972, p = .276. Similarly, within the Think program, dependent measures did not differ significantly between Pro and Partner groups F (4,225) = .984, p = .469.

General Intellectual Ability (GIA). To determine if pre-test scores for General Intellectual Ability differed significantly by intervention group, a one way between subjects ANOVA was conducted. There was a significant main effect for initial General Intellectual Ability (GIA) as it related to diagnostic group (as reported earlier; General Intellectual Ability (GIA), F (2,614) = 3.65, p <.05). Follow up tests indicated that students in the Dyslexia group had lower initial GIA scores than students in either the ADHD group or the No Diagnosis group. Effect size (Cohen's d) was calculated for each significant finding by dividing the difference between the pre-test mean of group A and pre-test mean of group B by the pooled standard deviation of pre-test scores of the two samples (Cohen, 1992). According to Cohen's rules of thumb for determining magnitude of effect size, .2 is considered small, .5 medium, and .8 large (Cohen, 1992). The difference between the Dyslexia group and ADHD group was small, Mean difference = 4.83, Cohen's d = .39 and between the Dyslexia group and the No Diagnosis group was medium, Mean difference = 5.22, Cohen's d = .47. Additionally, there was a significant main effect for intervention group, F (1, 615) = 72.08, p < .001. Follow up tests indicated that students in Read programs had lower initial GIA scores than students in Think programs, Mean difference =7.0 The difference between intervention groups was medium (Cohen's d = .69). The interaction between diagnostic group and intervention for GIA was not significant.

In summary, pre-test scores for GIA were lowest for the Dyslexia group when compared to both the ADHD and the No Diagnosis groups. Additionally, students in Read programs had lower pre-test scores than those students in Think programs.

Working Memory (MW). To determine if pre-test scores for Working Memory differed significantly by diagnostic or intervention group, a two way between subjects ANOVA was conducted. Significant main effects were found for Working Memory (MW) as it related to diagnostic group, F (2, 493) = 3.70, p < .05; and intervention group, F (3, 493) = 4.84, $p < .001$. Follow up tests showed that the Dyslexia group had significantly lower pre-test scores on MW than the no Diagnosis group (Tukey's HSD, Mean difference = 6.11, p < .05. This was a medium effect size (Cohen's d = .57).

Additionally, students in Read programs had lower initial MW scores than students in Think programs, F (1, 505) = 26.12, p < .001. This difference between Read and Think groups was medium (Cohen's d = .46). The interaction between diagnostic group and intervention group for MW was not significant.

In summary, the Dyslexia group had lower pre-test scores on Working Memory (MW) than the No Disability group, but there was no significant difference between the Dyslexia group and ADHD group. Students in Read Programs had lower pre-test scores on MW than students in Think Programs.

Word Attack (WA). To determine if pre-test scores for Word Attack differed significantly by diagnostic or intervention group, a two way between subjects ANOVA was conducted. Significant main effects were found for Word Attack (WA) as it related to diagnostic group, F (2, 947) =7.72, $p < .001$, and intervention group, F (3, 947) = 48.07, $p < .001$. Follow up tests showed that the Dyslexia group had significantly lower pre-test scores on WA than either the ADHD group (Tukey's HSD, Mean difference = 7.42, $p < .01$), or the No Diagnosis group (Tukey's HSD, Mean difference = 7.82, $p < .01$). The effect size between the Dyslexia group and the ADHD group was medium (Cohen's d = .66) and the difference between the Dyslexia group and the No Diagnosis group approached a large effect size (Cohen's d = .79).

Students in both the Partner and Pro Read programs had lower mean pre-test WA scores, 93.71 and 94.04 respectively, than students in the Partner and Pro Think programs, where respective means of 104.9 and 106.06 were obtained. Due to non-significant differences between Pro and Partner groups on this variable, the two groups were combined within each type of program. The combined mean pre-test values for Read and Think, 93.81 and 105.25, were used in the equation to calculate the effect size. The effect size between Think and Read Programs on initial scores of word attack was large (Cohen's d = 1.38). The interaction between diagnostic group and intervention was not significant.

In summary, the Dyslexia group had the lowest pre-test score on Word Attack (WA) of any of the three diagnostic groups. Additionally, students enrolled in the Read program had the lowest pretest WA scores when compared to Think program counterparts, indicating a possible determining factor for the type of program chosen for the student based on pre-test scores of WA. There were no significant differences in pretest scores on WA for students enrolled in Pro or Partner programs, indicating that the pretest scores on WA did not appear to make any difference in regards to the intensity of program that was chosen for the student.

Sound Awareness (SA). To determine if pre-test scores for Sound Awareness differed significantly by diagnostic or intervention group, a two way between subjects ANOVA was conducted. Significant main effects were found for Sound Awareness (SA) as it related to diagnostic group, F (2, 955) = 12.91, $p <$ .001; and intervention group, F (3, 955) = 23.94, $p < .001$. Follow up tests showed that the Dyslexia group had significantly lower pre-test scores on SA, than either the ADHD group (Tukey's HSD, Mean difference = 8.32, $p < .001$) or the No Diagnosis group (Tukey's HSD, Mean difference = 8.31, $p < .001$). Effect sizes for these between group differences were medium (Cohen's d = .64 and .70, respectively). Additionally, students in Read programs had lower initial SA scores (Partner (M = 93.34) and Pro (M = 94.04) than students in Think programs (Partner (M = 103.61) and Pro (M = 103.90). This difference between Read and Think groups was large (Cohen's d = 1.01). The interaction between diagnostic group and intervention for sound awareness also was significant. F (6,955) = 2.28, $p < .05$.

Follow up tests indicated significant differences between the Dyslexia group and both the ADHD group and No disability group within Read Pro, Think Pro and Think Partner, but not for Read Partner, for initial scores on sound awareness.

Within Read Pro, the Dyslexia group had lower initial scores on SA than either the ADHD group (Mean difference = 8.11, $p < .05$) or the No Diagnosis group (Mean difference = 9.43, $p < .001$). Effect sizes for these between group differences were large (Cohen's d = .93 and 1.10, respectively).

Within Think Pro, the Dyslexia group had lower initial scores on SA than either the ADHD group (Mean difference = 10.42, $p < .05$) or the No Diagnosis group (Mean difference = 8.25, $p < .05$). Effect sizes for these between group differences were large (Cohen's d = 1.05 and .94, respectively).

Within Think Partner, the Dyslexia group had lower initial scores on SA than either the ADHD group (Mean difference = 9.03, $p < .05$) or the No Diagnosis group (Mean difference = 8.47, $p < .05$). Effect sizes for these between group differences were large (Cohen's d = .89 and .91, respectively).

In summary, the Dyslexia group had the lowest scores on SA when compared to either of the other two diagnostic groups and across Think Pro, Think Partner and Read Pro. Within the Read Partner group, there were no significant differences between diagnostic groups.

DEMOGRAPHIC VARIABLE DIFFERENCES

To determine if the proportion of subjects within each intervention or diagnostic group differed by demographic variables, several analyses were conducted and results are presented below.

Age. For age, a between subjects analysis of variance (ANOVA) analyses was conducted to determine if there were differences in age within separate intervention or diagnostic groups. A significant main effect was found for diagnostic group, F (2, 963) = 8.60, $p < .001$, and for intervention group, F (2, 963) = 4.14, $p < .001$. Follow up tests revealed the only significant diagnostic group difference to be between the ADHD group and the No disability group, with students in the ADHD group being older (Mean age =11.4 years) than students in the No Diagnosis group (Mean age = 10.6 years); Tukey's HSD, Mean difference = 9.83; $p < .001$). This was a small difference (Cohen's d =.29). Follow up tests on intervention group indicated that pre-test age differences were significant when comparing Read Pro to both Think Partner (Tukey's HSD Mean difference = 12.17; $p < .05$) and Think Pro groups (Tukey's HSD Mean difference = 11.79; $p < .05$), with students in Read Pro being older. The difference for both comparisons was medium (Cohen's ds = .35 and .35).

Gender. To determine if the hypothesized proportion of males differed significantly from the proportion of females within the diagnostic or intervention samples, Chi Square tests were conducted. The Chi Square tests evaluating the gender differences within the No Diagnosis and Dyslexia groups included a hypothesis of equal proportions, whereas equal proportions were not assumed with the ADHD sample due to differences in proportions between gender in this group which is present in the literature. The literature clearly indicates that the proportion of males diagnosed with ADHD outweighs the proportion of females diagnosed with ADHD. This figure varies slightly based on the specific literature reviewed, however results tend to hover around a difference of 3:1; with males being diagnosed more frequently than females (Gaub & Carlson, 1997; Sameroff, Lewis, & Miller, 2000). Therefore, the follow up Chi Square test which focused on the proportion of males vs. females diagnosed with ADHD when comparing to the other two groups did not assume equal proportions, but rather used proportions which represented the 3:1 gender differences found in the literature.

When comparing all three diagnostic groups (ADHD, Dyslexia, and No Diagnosis group) results indicated that gender varied significantly by diagnostic group□χ^2(2, N = 975) = 23.91, $p < .001$, with a Phi (Φ) effect size of .157. Follow up tests indicated significant gender differences within the ADHD group;□χ^2(1, N = 359) = .6.44, $p < .05$, with more males and fewer females in the sample than the expected 3:1 proportion. No significant gender differences were found within the Dyslexia group□□χ^2(1, N = 67) = .3.36, $p = .07$. The proportion of males within the No Diagnosis group was greater than the proportion of females,□χ^2 (1, N = 549) = 10.80, $p < .001$.

No gender differences were noted within intervention groups, χ^2(3, N = 975) = 1.91, $p = .59$.

Parent Education (SES). Additional Chi Square tests were conducted to determine if parent level of education differed for students based on diagnostic or intervention group. Using the 2007 Census data for educational attainment, sample proportions were compared to national proportions in this area; unequal proportions were hypothesized for the sample 2007 Census for a population older than 25 years of age: less than a HS diploma = 16%; HS graduate (and some college) = 49.6%; two year degree = 7.4%; four year degree = 17.1%; Graduate degree = 9.9%). There were no significant differences between diagnostic groups on the variable of parent education, χ^2 (8, N = 596) = 6.50, p = .592, but a significant difference was found between intervention groups, χ^2 (12, N = 596) = 37.95, p < .001, with an effect size of .146. Follow up tests conducted with the previously specified hypothesized proportions indicated that within both Pro and Partner programs (Think and Read combined), students whose parents had four years of education post high school or more were overrepresented when compared to students whose parents had less education; Pro, χ^2 (4, N = 162) = 86.52, p < .001); Partner, χ^2 (4, N = 434) = 311.94, p < .001).

Because Pro programs incurred more financial cost to families than Partner Programs, an additional Chi Square test was conducted to determine if there were significant differences between Pro and Partner programs. Parent education was divided into two groups based on degrees completed: those who had obtained a two- year degree (Associate's) and less, and those who had obtained a four year degree (Bachelor's) or more education. Parents who had obtained a two year degree, and were taking additional classes, fell into the two year degree category, because they had not yet obtained a four year degree. Results indicated significant differences between the two groups, χ^2 (1, N = 596) = 3.73, *p* = .05, with an effect size of .079, though the direction of effect was different than expected, with students whose parents had less education enrolling their children in Pro programs more often, and those parents with more education, choosing Partner programs more frequently.

Ethnicity. To determine if a significant difference existed between the races represented in the sample and diagnostic or intervention groups, two separate Chi Square tests were conducted. Results indicated that race did not differ significantly between diagnostic groups χ^2 (12, N = 975) = 8.29, *p* = .762, or intervention groups; □χ^2 (18, N = 975) = 23.72, *p* = .164.

RESULTS OF HYPOTHESIS TESTING

Hypothesis 1: There will be significant differences from pre- to post-test on General Intellectual Ability (GIA), Working Memory (MW), Sound Attack (SA) and Word Attack (WA).

Results for Hypothesis 1: The first hypothesis was addressed by conducting Repeated Measures Analyses of Covariance to determine if significant differences from pre- to post-test existed on all four dependent variables. Age and gender were entered into the model as covariates.

There was a significant main effect of time (from pre-test to post-test); Wilks' Lambda *F* (4,380) = 95.68, *p* < .001. Follow up analyses indicated that post-test scores were significantly higher than pre-test scores across all measured variables.

Cohen's *d* scores were computed using pooled standard deviations, as outlined in Rosnow & Rosenthal (1996) and by following Cohen's (1988) statistical formula. For each calculation of effect size, Cohen's *d* was computed using pooled standard deviations using the following formula:

$$S_p = \frac{\sqrt{SD_1^2(n_1 - 1) + SD_2^2(n_2 - 1)}}{n_1 + n_2 - 2}$$

S_p = the pooled standard deviation, SD_1= standard deviation of pre-test score, SD_2 = standard deviation of post test score, n_1= number of participants in pre-test sample, n_2= number of participants in post-test sample.

For Word Attack, a moderate effect size between pre-test and post-test was found. Sound Awareness, Working Memory, and General Intellectual Ability scores showed large effect sizes between pre-test and post-test.

The measures directly related to reading, Word Attack (WA) and Sound Awareness (SA) were examined. There was a significant five point standard score difference between pre-test and post-test scores on Word Attack, F (1,383) =71.70, $p < .001$, with a medium standardized effect size, Cohen's $d = .51$. There was a significant 10 point standard score difference for Sound Awareness, F (1,383) = 151.56, $p < .001$, with a large standardized effect size, Cohen's $d = .88$.

The cognitive skills measures of Working Memory (MW) and General Intellectual Ability (GIA) were examined. There was a significant 10 point standard score difference for Working Memory between pre-test and post-test scores F (1,383) = 94.56, p < .001, with a large standardized effect size, Cohen's d = .81. There was a significant 14 point standard score difference for GIA F (1,383) = 358.40, p < .001, with a large standardized effect size, Cohen's d = 1.12.

This finding supported Feurestein's Theory of Cognitive Modifiability indicating that cognitive skills can be modified with intensive intervention. It also supported the hypothesis that cognitive skills training can improve reading achievement.

Hypothesis 2a: Irrespective of intervention group, there will not be any significant differences between boys and girls on gain scores for GIA and MW.

Hypothesis 2b: Gain scores for SA and WA will be higher for females, when diagnostic group, age, and intervention group are controlled.

Results for Hypothesis 2a and 2b: A two- way Multivariate Analysis of Covariance (MANCOVA) was conducted to determine whether there were significant differences between gain scores for boys and girls, while controlling for age, diagnostic group, and diagnosis. The dependent variables included gain scores for GIA, MW, SA, and WA. The between subject factor was gender (male, female).

Results were as follows; Word Attack, F (1, 390) =.33, p = .57; Sound Awareness, F (1, 390) =.04, p = .85; Working Memory, F (1, 390) = .61, p = .44; and General Intellectual Ability, F (1, 390) =.21, p = .65. Hypothesis 2a was supported, in that gain scores did not significantly differ between males and females on scores of MW or GIA. Hypothesis 2b was not supported, as gain scores did not differ between males and females on any of the four dependent measures.

Hypothesis 3a: There will be a negative relation between age and gain scores on cognitive measures (GIA and MW) such that increasing age will be associated with smaller gain scores on cognitive measures.

Hypothesis 3b: There will be a positive relation between age and gain scores on achievement measures (SA and WA) such that an increase in age will be associated with larger gain scores.

Results for Hypotheses 3a and 3b: Separate bivariate correlations were computed between age and each gain score (GIA, MW, SA and WA). First, scatter plots were examined to assess the linearity of relations. Each correlation analysis was considered significant at the .05 level of statistical significance.

Scatter plots confirmed the linearity of relations between age and SA gain scores (r = .07, R^2 = .005, p < .05); age and WA gain scores (r =.12, R^2 = .0001, p<.001); age and GIA gain scores (r =.19, R^2 = .04, p <.01); and age and MW gain scores (r =.06; R^2 = .004, p = .18). These correlations were positive but extremely small and the variance accounted for by age was smaller than 1% in three of the four analyses, and only 4% for gain scores of GIA.

Hypothesis 3a was not supported, whereas hypothesis 3b was supported. In each case age was positively related to each dependent variable, such that older children tended to have higher gain scores. It is unknown why this effect was found, particularly because standard scores are corrected for age. However, it does indicate that the programs were more effective for older students.

Hypothesis 4: There will be a relation between initial level of GIA and gain scores such that students with higher initial GIA scores will have higher gain scores on the measures of MW, GIA, WA and SA.

Results for Hypotheses 4: The fourth hypothesis was addressed by conducting four partial correlations, controlling for gender, age, diagnosis and intervention type First, scatter plots were examined to assess the linearity of relations. Each correlation analysis was considered significant at the .05 level of statistical significance.

The hypothesis was not supported for relations between initial GIA score and gain scores for MW, GIA, or Word Attack. These findings indicated that the Matthew Effect, as discussed in Chapter two, did not exist across these domains. However, there was a significant relationship between initial GIA and gain scores in sound awareness scores, r =.12, adjusted R^2 = .01, $p < .05$, which indicated that students with higher pre-test GIA scores had larger gains in sound awareness. It is unknown why this significance was found for sound awareness alone, though it does have some implication for sound awareness training for students who have lower overall cognitive ability scores.

Hypotheses five through nine, discussed in the following sections were addressed by conducting two separate analyses. First, within each hypothesis, a three-way Multivariate Analysis of Covariance (MANCOVA) was conducted to determine whether disability group, treatment group, treatment intervention type, and intensity were related to students' gain scores on measures of MW, WA or SA. The dependent variables included MW, WA and SA subtest gain scores. Between subject factors included Disability (ADHD, Dyslexia, or none), treatment intervention (Read or Think), and Intensity (center based or combination). The covariates included gender, age and initial GIA. A power analysis was conducted simultaneously to ensure sufficient power for analyses. A power analysis yielding a score of .80 or above will be sufficient to report scores from this analysis.

The second analysis was an Analysis of Covariance (ANCOVA) with the GIA gain score serving as the dependent variable. Between subject factors included Disability (ADHD, Dyslexia, or none), treatment intervention (Read or Think), and Intensity (center based or combination). The covariates included gender and age.

Hypothesis 5: When comparing students in Think to those in Read programs, students in Think programs will have greater gains in MW (first analysis) and GIA (second analysis) than students in Read Programs.

Results for Hypothesis 5: The overall main effect for type of intervention was significant, indicating an overall difference between intervention groups across all outcome measures, Wilks' Lambda F (4,383) = 5.03, p = .001. Follow up tests indicated that significant differences existed for gain in GIA; F (1,386) = 6.41, p = .012, with students in Think programs having larger gains in GIA (M =

16.18, *SD* = 8.71) than students in Read programs (*M* = 12.92, *SD* = 7.41), effect size was medium (Cohen's *d* = .44). Differences between intervention programs for gains in Working Memory were not significant; *F* (1,386) = 1.66, *p*=.196, though power was extremely low for this analysis at .252.

This hypothesis was partially supported, with gains in GIA being larger for students in Think programs when compared to gains in GIA for students in Read Programs. However, gains in Working Memory scores were not significantly different between intervention programs. These findings indicated that the length of the program and time spent on training Working Memory did not make a statistically significant difference in regards to gains achieved for Working Memory.

Hypothesis 6: Students in Read programs will have greater gains in SA and WA than students in Think programs.

Results for Hypothesis 6: Results were obtained from the first analysis described above. The overall main effect for type of intervention was significant, Wilks' Lambda *F* (4,383) = 5.03, *p* = .001. Follow up tests indicated that significant differences existed for gain in Word Attack, *F* (1,386) = 6.85, *p* = .009, with students in Read programs having larger gains in WA (*M* = 7.52, *SD* = 8.01) than students in Think programs (*M*= 4.40, *SD* = 7.21), with a medium standardized effect size, Cohen's *d* = .41.

Differences between intervention programs for gains in sound awareness were not significant, *F* (1,386) = 6.85, *p*=.564, although power was extremely low for this analysis at .050.

This hypothesis was partially supported, in that students in Read programs had larger gains in Word Attack when compared to students in Think Programs; however, there were not any significant differences in gain scores of Sound Awareness when comparing intervention groups. These findings indicated that the length of time spent on Sound Awareness training did not make a statistically significant difference in regards to gains on the measure of Sound Awareness.

Hypothesis 7a: Students in Pro programs will see greater gains than students in Partner programs on measures of GIA (second analysis), MW, SA and WA (first analysis).

Hypothesis 7b: Students in the ADHD group will have bigger gains than students in the No Diagnosis group for both Pro and Partner programs.

Results for Hypotheses 7a and 7b: The first part of this hypothesis (7a) was not supported. There were no significant differences between Pro and Partner (intensity) groups on any gain scores analyzed, Wilks' Lambda *F* (4,383) = .179, *p*=.949. Power for this analysis was extremely low at .088. Further, there was no significant interaction between intensity of program and diagnosis, indicating no difference for any diagnostic group based on intensity level of intervention, Wilks' Lambda *F* (8, 766) = 8.00, *p* = .759. Although power was low for this analysis at .292, when assessing plots of mean scores, differential trends did appear to be present for diagnostic group by intensity and program type.

For example, trends indicated that for GIA and Working Memory gain scores, the ADHD and Dyslexia group had slightly higher gains in the Pro programs when compared to the Partner programs whereas the No Disability group had higher gains in the Partner programs. For Word Attack and Sound Awareness, students in the ADHD group and No Disability group had higher gains in the Partner programs; whereas students in the Dyslexia group had higher gains with the Pro programs. None of the trends reported here were statistically significant; this may have been due to low power for the analyses.

This finding suggests that gain scores were not statistically significant when students were trained less often by a certified trainer, nor did having more than one trainer or completing training in more than one environment make a difference in regards to gains achieved.

Results for hypothesis 7b indicated that gain scores for Sound Awareness differed significantly between the three groups, F (2,286) = 3.19, $p < .05$. Follow up analysis indicated that this gain score was only significantly higher for the Dyslexia group, with students in this group experiencing bigger gains in Sound Awareness when compared to students in both the ADHD and No Diagnosis groups. No significant differences were found for the other dependent measures. As a result, hypothesis 7b, was not supported.

There was a statistically significant result in regards to improvement in sound awareness for the Dyslexia group. This finding, together with the finding which suggested that students in the Dyslexia group had lowest pre-test scores in this area, indicates that students with lower sound awareness scores at pre-test had significantly higher gains in sound awareness when compared to students who had higher pre-test scores in this area.

Hypothesis 8: Gain scores will not differ for diagnostic groups based on type of program (Think vs. Read) enrolled for GIA (second analysis), MW, SA or WA (first analysis).

Results for Hypotheses 8: Results supported the null hypothesis of the interaction between program and diagnosis, indicating that there were no significant differences in gain scores on each dependent variable between diagnosis groups across Read and Think Programs. The interaction between program and diagnosis was not significant, Wilks' Lambda F (8,766) = .623, p = .759. However, power for this analysis was low at .292.

Hypothesis 9a: There will not be any significant differences between diagnostic groups for gain scores on GIA (second analysis), SA, or WA (first analysis).

Hypothesis 9b: Students in the No Diagnosis group will have larger gain scores in the area of MW when compared to students in the ADHD and Dyslexia groups (first analysis).

Results for Hypothesis 9a and 9b: Hypothesis 9a was partially supported, as results indicated that there were no significant differences in gain scores for GIA or MW between the ADHD, Dyslexia and No Diagnosis groups, indicating that response to intervention across these three groups in respect to cognitive skills was not variable between diagnostic groups. However, differences did exist for SA and WA, with students in the Dyslexia group having larger gains in both academic areas measured. For Sound Awareness, F (2,286) = 3.19, $p < .05$. and for Word Attack, F (2,959) = 3.95, $p < .05$. This finding suggests that students with lower pre-test scores in the areas of Sound Awareness and Word Attack had larger gains in these areas when compared to students in the ADHD or No Diagnosis groups. Hypothesis 9b was not supported, as the No Diagnosis group did not have significantly larger gains in the area of MW when compared to students in other diagnostic groups.

CHAPTER 5: DISCUSSION

This chapter first addresses the theoretical basis for the study, and then reviews the objectives of the study. Then, the variability in pre-test scores between intensity of program, program type and diagnostic groups is explained, followed by a discussion of differences between pre-and post- test scores for each variable in the overall sample. Differences between intensity and type of program, as well as between diagnostic groups are addressed. Findings related to age, gender, and demographic variables are discussed. Finally, study limitations and future directions as well as study strengths, contributions and final thoughts are presented.

UNDERLYING THEORY

The foundation for this study was based upon the Structural Cognitive Modifiability model developed by Feuerstein (SCM; Feuerstein, 1974; Feuerstein & Rand, 1979). Within his theory, it is believed that cognitive skills have the potential to be changed with intensive intervention. This theory incorporates aspects of learning theory from Bronfenbrenner (1979), Piaget (1973), Vygotsky (1978) and information processing theory (Kaufman & Lichtenberger, 2006). This study evaluated the SCM theory by assessing if cognitive abilities could be modified through training.

The cognitive ability domains for evaluation within this study were defined by the Cattell-Horn Carroll Theory of intelligence (CHC). The CHC Theory divides overall intellectual ability and academic achievement into several broad domains, which are considered to be related in the form of a continuum. Within this theory, cognitive domains also are considered to be strongly related to academic achievement. The evaluation tools used in this study, The Woodcock Johnson Tests of Achievement and Cognitive Abilities, Third Editions, in this study are based on CHC Theory.

The Phonological Core Variable Difference Model of reading disability was also included as a theoretical foundation for this study. Within this model, it is believed that there is a cluster of abilities including word decoding and sound awareness that together with working memory enable students to be proficient readers. When one of these areas is deficient, remediation by currently empirically validated interventions is difficult, indicating that new types of interventions need to be evaluated.

MAIN OBJECTIVES

There were three main objectives of this study. The first objective was to systematically study the effects of an intervention program aimed at improving cognitive and academic skills. Effects of the program were measured by evaluating differences between pre- and post-test scores across cognitive and academic domains. By examining overall intelligence scores, the question of cognitive modifiability was addressed by examining changes in working memory and General Intellectual Ability as well as academic scores of word attack and sound awareness.

The second objective of this study was to determine if differences in type or intensity of cognitive program differentially affected gains in processing domains. This was accomplished by evaluating gain score differences across different types of programs (a reading based program (Read) and a cognitive based program (Think)) and different intensities of instruction. The different intensities of instruction were labeled as Pro and Partner. The Pro program included training five days a week from a certified skills trainer. The Partner program included training three days a week from a certified trainer and a home training component, which was expected to occur for an additional two to three times a week.

The third objective was to evaluate differences in gain scores between three diagnostic groups: an Attention Deficit Hyperactivity Disorder (ADHD) group, a Dyslexia group, and a group with no known disabilities. The purpose of this objective was to understand if students in different diagnostic groups responded differently to interventions.

PRE-TEST SCORE VARIABILITY

Participants in the Pro and Partner programs did not differ significantly at the time of pre-test on any of the ability or achievement measures examined. This finding permitted these groups to be combined for subsequent analyses. It also suggests that parent decisions to enroll their child in the Pro or Partner program were not based on their child's pre-test scores.

Although there were no differences in the intensity of the program in which students were enrolled, students in the Read Programs had significantly lower pre-test scores than those in the Think programs on the reading related subtests of sound awareness and word attack as well as on the cognitive skills measured, specifically General Intellectual Ability and Working Memory. This suggests that lower performance in reading may have influenced the decision regarding program type (Read vs. Think).

Diagnostic Group Differences.

Cognitive scores. It was expected that pre-test scores on the Working Memory cluster would be lower for both the reading difficulties group and the ADHD group, given that students with ADHD and those that struggle with reading often have working memory difficulties (Halperin et al., 2008; Karatekin, 2004; Lacene, 2004; Lui & Tannock, 2007; Palmer, 2000; Rapport et al., 2008a). It also was expected that the three diagnostic groups would not differ at the time of pre-test on GIA. However, in this sample, there was a significant difference between the Dyslexia and No Diagnosis groups, with the Dyslexia group having lower MW scores. The lower pre-test scores for working memory amongst students who had more difficulty with reading may lend more credibility to the theory that there is a relation between working memory and reading achievement, and supports the Phonological Core Variable Difference Model related to reading disabilities (Evans, Floyd, McGrew, & LeForgee, 2001; Mayes & Calhoun, 2007; Wendling & Mather, 2009).

However, no difference was found on MW between the Dyslexia and ADHD groups. There was a significant difference found between Diagnostic groups for pre-test scores of GIA, with students in the Dyslexia group having lower scores in this area when compared to both the ADHD and the No Diagnosis groups. It is unknown why this finding was significant.

Achievement scores. At the time of pretest, the Dyslexia group had significantly lower pre-test scores than both the ADHD and the No Diagnosis group on Word Attack and Sound Awareness. This finding supports the validity of parent-reports of a reading disability because children with dyslexia or reading problems would be expected to perform less well than other students on these particular subtests.

DEMOGRAPHIC VARIABILITY

The sample was analyzed in regards to possible race, gender and SES differences in order to determine if there was bias within the sample that was analyzed for any of these demographic variables. Results indicated that race stratification did not differ significantly between diagnostic or intervention groups.

Gender did not vary significantly with regard to program type, with a similar proportion of males and females enrolled in both Think and Read programs. Gain scores did not differ significantly between males and females on the four dependent variables measured.

There were more males represented overall, with more males and fewer females than expected in both the ADHD group and the No Diagnosis group. Within the Dyslexia group, there were an equal number of females and males represented.

Students whose parents had four years of education post high school or more were overrepresented in the overall sample. There were no differences on parent education between diagnostic groups; however, differences in parent education were found for student enrollment between Pro and Partner programs, with students whose parents had less education enrolling their children in Pro programs more often, and those parents with more education, choosing Partner programs more frequently.

The trend found in this study was similar to that found by the National Center for Education Statistics which indicated that parents with higher levels of education understand the importance and invest more time in their child's education (Herrold & O'Donnell, 2008).

Socio economic status (SES) was measured by highest level of parent education attained, with the expectation that parents with higher levels of education made more money and would be more likely to opt for the more intensive and expensive training programs (Pro). This hypothesis was not supported. Instead, students whose parents had less education more often enrolled their children in Pro programs, whereas parents with more education chose Partner programs more frequently. This finding suggests that the choice for intensity of program may not have been related to program cost, but rather that more educated parents chose to be more personally involved in the education process of their child as home trainers. It is possible that parents with more education felt more competent to actively participate in their child's training, or those parents with less education felt the need to give their child everything they could in respect to allowing professional trainers to do all of the training with their child. There were not any differences found between gains achieved between Pro and Partner programming for any of the four variables measured, however, indicating that this finding, though interesting, did not have any affect on the findings related to gain scores.

With respect to age, students in the ADHD group were approximately one year older than students in the No Diagnosis group; though this result was significant, the effect size was small. It is possible that other options, such as medication, may have been tried as a first option for students with ADHD before enrolling in the program, therefore making ADHD students older at time of enrollment. Students in Read Pro programs were older than students in either of the Think programs (Pro or Partner), suggesting that Read Pro programming may have been chosen more often for older children because previous and more traditional attempts at remediation had not produced desired results.

Finally, older children tended to have higher gain scores in each of the four variables addressed; however, the variance was extremely small, accounting for less than 1% for working memory, sound awareness and word attack and for only 4% of the variance related to gains of General Intellectual Ability (GIA).

EXAMINING GAIN SCORES

In this next section, significant differences between pre- and post- test scores across all four study variables will be discussed. Results are presented separately for the variables of General Intellectual Ability, Working Memory, Word Attack, and Sound Awareness to include differences with respect to program type and diagnostic group.

None of the four variables measured differed in gain scores when considering intensity of training; that is, gain scores for students in Pro programs did not differ significantly from those in Partner programs on any of the four variables. However, some interactions were found between diagnostic group and intensity of program, and these will be discussed below.

All differences presented were significant (at the $p < .05$ level), unless noted otherwise. Differences will be discussed in terms of standard scores and using a scale related to one standard deviation equaling 15 points. Most cognitive and academic assessment measures used for this study, including the Woodcock Johnson Tests of Cognitive Abilities, 3rd Edition and the Woodcock Johnson Tests of Achievement 3rd Edition, utilize these standard score terms.

General Intellectual Ability (GIA). When all study participants were combined, a 14 point standard score difference between pre test and post test scores existed. This difference is almost equal to one full standard deviation on this measure, and suggests that overall intelligence is, in fact, fluid. This finding supports the Structural Cognitive Modifiability Theory which posits that intelligence is a fluid construct (Ackerman & Lohman, 2003; Berliner, 1988; Feuerstein, 1974; Feuerstein & Rand, 1979; Jensen, 1998).

Initial GIA scores did not impact the amount of gain achieved for GIA, Working Memory, or Word Attack, but did affect the amount of gain achieved for Sound Awareness: students with higher initial GIA scores had larger gain scores on this measure. Although a definitive explanation of these results is not possible at this time, this finding suggests that students with higher overall General Intellectual Ability may be better able to benefit from the intervention in the area of Sound Awareness. The finding did not support the Matthew Effect for GIA discussed in chapter two, demonstrating that students with higher levels of GIA at pre-test did not have greater gains in the area of GIA from intervention. Additionally, these findings have implications for interventions aimed at improving phonological awareness skills in that students with higher levels of overall ability may be able to reap bigger benefits from these types of interventions.

Students enrolled in Think programs had two points average gain score higher than students in Read programs on General Intellectual Ability. This difference, though significant and with a medium effect size, was only two standard score points, and cannot be interpreted as a meaningful difference.

This finding suggests that the type of program the student was enrolled in did not make a substantial difference in the amount of gain achieved.

Working Memory (MW). For the total sample, there was a ten point standard score significant difference between pre- and post-test for the Working Memory Cluster. This difference is substantial at 2/3 of a standard deviation. Students who were enrolled in Read programs and Think programs had similar gains on the Working Memory Cluster.

Word Attack (WA). When evaluating results from all study participants, a five point standard score difference existed between pre- and post-test scores on Word Attack. The Word Attack gain scores for students enrolled in Read programs were three standard score points greater than for students enrolled in Think Programs. Students in Read programs gained an average of one half a standard deviation on this measure.

Sound Awareness (SA).

When the entire sample was examined, students achieved an average standard score gain of ten points in sound awareness. Students enrolled in Think programs and those enrolled in Read programs had similar gains in this area, indicating no significant difference between program type for improving sound awareness.

STUDY SUMMARY

Scores for General Intellectual Ability, Working Memory, Word Attack and Sound Awareness improved substantially through intensive cognitive training.

There were not any significant differences in gain scores based on intensity of training, and students in the Dyslexia group had higher gains in Sound Awareness, though this was the only difference found between diagnostic groups.

Differences between Think and Read programs with regard to improving cognitive skills (GIA and MW) were minimal. Students who were enrolled in Think Programs had significantly higher GIA gain scores although this consisted of only two standard score points; improvements in MW were not significant between Read and Think groups. Differences between Think and Read programs with regard to improving academic skills (WA and SA) also were minimal, with a three standard point difference favoring students in Read programs for Word Attack, and no difference found for Sound Awareness.

STUDY LIMITATIONS AND FUTURE DIRECTIONS

Study Limitations. The current study is not without its limitations. First, a control group was unable to be obtained. The robustness of findings would be increased if a group of students, matched on age, ethnicity, and SES who were not participating in the program also were tested with the same instrument during a similar time frame. Additionally, because of the lack of a control group there is limited generalizability regarding the interpretation of and confidence in results. Because all students were enrolled in an intervention program, there may have been some expectancy effects or placebo effects that impacted overall findings.

Additionally, random selection and random assignment to intervention groups is important for meaningful and generalizable findings. Although a control group was not available, comparing diagnostic groups did allow for a No Diagnosis group to be used as a comparison to both the ADHD and Dyslexia groups.

The groups were based on parent reports of diagnoses or disabilities. Though results indicated that parent report may have been fairly accurate, particularly for the Dyslexia group, the current study may have been more robust if a more stringent protocol was used to identify these students, such as confirmation of ADHD diagnoses or only including students who had Individualized Education Plans for Learning Disabilities in Reading.

It is possible that there was an examiner effect related to gain scores. The examiners who tested children for pre and post test worked at the center; as a result, there may have been an expectancy effect or a halo effect given the expectation of improvement, particularly if the same examiner gave the pre and the post test examinations. This may have inflated scores at post test, thereby possibly showing false gains in scores. In future studies, an examiner who is uninvolved within the center and unaware of either the child's prior test performance or whether the testing consists of pre- or post-testing would help eliminate any examiner bias.

Students were assessed on the same forms of the Woodcock Johnson tests on pre- and post- test assessments; retesting occurred within a year. This may have contributed to inflated post test scores due to practice effects.

Relating to generalizability, most students in this sample were Caucasian, which does not allow for results to be generalized across all ethnicities, even though race was equally stratified amongst groups studied. Additionally, families sought and paid for the services of the centers; students whose families could not afford the program were unable to receive the service. This limits generalizability across all SES groups because participation in the intervention program was not random across the population.

Additionally, most students and parents in the programs in the current study would be considered as being "invested" in the process (Cattell, 1971, 1987), which means it is likely that because money was paid for this private intervention, there was interest in succeeding with the program. This may have positively impacted their cognitive and academic growth more than might occur if the program was widely implemented within a school setting.

Another possible compounding factor that was not addressed in this study was the lack of a hearing or vision screening before testing sessions or during intervention. This may have negatively impacted growth in scores, if students had difficulty hearing or with their vision.

Finally, there was not any way to directly measure fidelity of implementation of the programs across trainers or centers. However, training logs on each student including lesson plans and progress monitoring were maintained and periodically reviewed by the center director to ensure consistent implementation of program across students. Additionally, due to the number of participants in the study and representative sample from 51 centers nationwide, this concern most likely did not impact gain scores achieved by the sample as a whole.

Future Directions. This study was the first to study cognitive and academic growth from cognitive based programs for separate diagnostic groups, differing levels of intensity in intervention. It also is the first study to use CHC theory to study cognitive skills training improvements. The results from this initial study indicated that interventions can be successful in improving cognitive skills which are linked to academic performance. Given the current high demand for research based interventions that can used in the classroom, more research is indicated to further generalize and expand the knowledge base in the area of cognitive based interventions. Using a randomized control group design would be ideal for further research in order to address concerns related to this study in regards to lack of generalizability to the overall population. Additionally, steps should be taken to reduce practice effects; strategies might include the use of two different versions of the same measure or ensuring that the length of time between testing is long enough to reduce the possibility or impact of practice effects.

Evaluating the change in state and national standardized achievement tests as a result of participation in cognitive training programs would allow for a real world assessment of academic achievement related to cognitive skills training.

Administering attention rating scales to parents and teachers before and after training for students with Attention Deficit Hyperactivity Disorder would help determine if changes in symptoms were a result of intensive cognitive training. Results from this type of study would have implications for possible modalities of treatment for students with attention difficulties.

An additional area of assessment for future studies may include evaluating follow-up testing at various intervals after training to assess stability of improved scores over time. This would help determine the potential of the intervention to sustain or continue to positively impact the individual after training ceased, or to determine whether follow up sessions, such as the booster sessions discussed in the Schaie (2005) longitudinal study would be needed to maintain initial results.

STUDY STRENGTHS AND CONTRIBUTIONS

The current study addressed gaps in the literature related to cognitive based training programs and their effect on general intellectual ability and specific skills related to reading achievement. The study was based in theory, using the most relavent and accepted theory of intelligence, the Cattell Horn Carroll Theory of Intelligence, as well as using Feuerstein's Theory of Cognitive

Modifiability and the Phonological Core Variable Difference Model of reading disability to underlie and explain results.

Additionally, this study used robust statistical procedures and methods to reliably assess changes in scores from pre to post test, including controlling for regression to the mean between pre and post test scores. The sample was gathered from a large national database, and was representative of 51 cities across the United States of America. Due to the large sample size and distribution from across the nation, limitations in generalizability, particularly those related to possible fidelity issues related to intervention between trainers, though they cannot be ignored, may be minimized due to these factors.

This study contributed to current literature by finding that students with reading difficulties actually had a more substantially impaired working memory before intervention than students with ADHD or No Disability. This is surprising given the amount of literature dedicated to studying working memory deficits in students with ADHD. This finding also gave credibility to the Phonological Core Variable Difference Model of reading disabilities further indicating that working memory is related to reading achievement.

This research furthered the evidence for cognitive training programs as being successful in improving cognitive skills. It also indicated that there is a possibility for cognitive skills interventions to impact academic achievement. Though more research is needed in this area, particularly related to specific cognitive abilities and the impact on specific areas of reading achievement, such as word decoding, fluency, and reading comprehension, this study does indicate that these types of interventions are worthy of further investigation.

This study contributed to the sparse literature involving the potential of cognitive training programs to positively impact general intellectual ability, working memory and reading achievement scores. It is the first study of its kind to have a theoretical basis for evaluating a cognitive training program and lends way to future studies backed by theory and related to improving student ability and achievement.

FINAL THOUGHTS

This study has implications regarding the future of interventions for students who are struggling with reading achievement and/or cognitive skills. It also lends support to future studies aimed at providing cognitive based interventions to improve and promote achievement. With Response to Intervention (RTI) being on the doorstep of many local education agencies in one way or another, this study allows for a different perspective on interventions aimed at improving underlying cognitive abilities. As shown with this research study, cognitive training has the potential to positively impact academic performance. More research is needed in this area to further solidify these findings and to explore the possibility of cognitive interventions being used within classroom settings to effectively promote academic performance for students.

Table 1

Program Description Matrix

Program	**Ttl. Hrs of training**	**Ttl. Hrs w/ cert. trainer**	**Hrs. Read**	**Hrs Read w/cert. trainer**	**Hrs. Cog**	**Hrs. Cog w/cert. trainer**
Think						
Pro	60	60	0	0	60	60
Partner	60	36	0	0	60	36
Read						
Pro	100	100	50	50	50	50
Partner	100	60	50	30	50	30

Table 2

Age (in months) by Gender, Program, and Diagnosis

Variable List	N	Mean	SD	Range
Gender				
Male	616	130	35	162
Female	359	131	35	156
Program				
Read Pro	120	139	32	151
Read Partner	284	134	34	142
Think Pro	146	128	36	162
Think Partner	425	127	35	155
Diagnostic Group				
ADHD	359	137	34	155
Dyslexia	67	127	34	148
No Disability	549	127	34	162

Table 3

Frequencies for Descriptive Variables for Entire Sample

Variable List	N	% of whole
Gender		
Male	616	63.2
Female	359	36.8
Race		
White	821	84.2
Black	59	6.1
Hispanic	34	3.5
Native American	4	.4
Asian	20	2.1
Other	22	1.5
Parent Education		
Did not complete H.S.	4	.4
Completed High School	66	6.8
Completed 2 year degree	60	6.2
Completed 4 year degree	240	24.6
Post graduate degree	226	23.2
Program		
Read Pro	120	12.3
Read Partner	284	29.1
Think Pro	146	15.0
Think Partner	425	43.6
Diagnostic Group		
ADHD	359	36.8
Dyslexia	67	6.9
No Disability	549	56.3

Table 4

Means and Standard Deviations for Dependent Variables

Variable List	N	Mean	SD	Range
Pre-Test Scores				
General Intellectual Ability	615	98.99	11.99	82
Word Attack	959	100.53	11.63	91
Sound Awareness	967	99.70	12.96	89
Working Memory Cluster	505	98.31	12.23	74
Predicted True Scores				
General Intellectual Ability	615	98.99	11.64	80
Word Attack	959	100.53	10.05	78
Sound Awareness	967	99.70	10.57	72
Working Memory Cluster	505	98.32	11.15	67
Post-Test Scores				
General Intellectual Ability	566	113.40	14.12	86
Word Attack	959	105.84	10.59	84
Sound Awareness	967	110.31	13.43	84
Working Memory Cluster	505	108.01	12.78	77

Table 5

Gain Scores on Dependent Variables for Overall Sample

Variable List	N	Mean	SD	Range
Overall Sample				
General Intellectual Ability	566	14.51	8.34	61
Word Attack	959	5.31	7.73	70
Sound Awareness	967	10.61	10.42	71
Working Memory Cluster	505	9.69	10.59	74

Table 6

Pre-test Scores on Dependent Variables by Diagnostic and Intervention Groups

Variable List	ADHD			Dyslexia			No Dx		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Total Sample									
General Intellectual Ability	225	99.08	12.42	40	94.35	10.4	350	99.47	11.12
Word Attack	354	100.80	9.86	65	93.38	8.86	540	101.21	9.99
Sound Awareness	357	100.27	11.11	66	91.95	9.55	544	100.26	9.95
Working Memory Cluster	176	97.19	11.53	35	93.46	9.85	294	99.57	10.87
Read									
General Intellectual Ability	83	92.93	11.56	29	92.93	10.09	144	95.90	10.84
Word Attack	135	93.63	7.97	49	91.21	8.49	212	94.52	7.56
Sound Awareness	138	93.46	8.94	48	90.76	9.56	216	95.25	8.90
Working Memory Cluster	69	93.77	10.67	27	91.79	10.26	123	97.25	10.86
Think									
General Intellectual Ability	142	102.68	11.48	11	99.56	9.68	206	101.96	10.70
Word Attack	219	105.22	8.18	16	100.04	6.44	328	105.53	8.93
Sound Awareness	219	104.57	10.17	18	95.14	8.95	328	103.57	9.20
Working Memory Cluster	107	99.39	11.57	8	99.07	5.75	171	101.23	10.60

Table 7

Post-test Scores on Dependent Variables by Diagnostic and Intervention Groups

Variable List	ADHD			Dyslexia			No Dx		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Total Sample									
General Intellectual Ability	205	113.08	14.83	35	108.57	10.09	326	114.13	13.96
Word Attack	354	106.14	10.56	65	101.22	9.52	540	106.19	10.62
Sound Awareness	357	110.31	13.56	66	106.92	10.84	544	110.72	13.65
Working Memory Cluster	176	107.40	12.81	35	101.57	11.35	294	109.14	12.71
Read									
General Intellectual Ability	73	105.37	14.41	25	105.40	9.00	134	109.19	13.74
Word Attack	135	101.01	10.25	49	99.65	8.92	212	101.80	9.07
Sound Awareness	138	105.44	13.37	48	105.88	11.31	216	107.04	12.90
Working Memory Cluster	69	102.83	11.68	27	99.41	11.59	123	105.34	13.00
Think									
General Intellectual Ability	132	117.34	13.30	10	116.50	8.44	192	117.57	13.08
Word Attack	219	109.30	9.47	16	106.00	9.97	328	109.03	10.60
Sound Awareness	219	113.37	12.61	18	109.72	9.21	328	113.14	13.61
Working Memory Cluster	107	110.36	12.69	8	108.88	6.92	171	111.87	11.81

Table 8

Gain Scores on Dependent Variables by Diagnostic and Intervention Groups

Variable List	ADHD			Dyslexia			No Dx		
	N	Mean	SD	N	Mean	SD	N	Mean	SD
Total Sample									
General Intellectual Ability	205	12.92	7.74	35	13.48	8.12	326	14.99	8.70
Word Attack	356	5.34	8.05	65	7.83	7.15	540	4.99	7.55
Sound Awareness	357	10.03	10.31	66	14.97	7.42	544	10.46	10.69
Working Memory Cluster	176	10.22	10.21	35	8.11	7.36	294	9.57	11.13
Read									
General Intellectual Ability	73	13.00	7.17	25	12.44	7.81	134	13.70	9.06
Word Attack	135	7.37	8.32	49	8.44	6.97	212	7.28	8.10
Sound Awareness	138	11.98	9.88	48	15.12	7.63	216	11.80	10.46
Working Memory Cluster	50	9.05	9.69	27	7.61	7.53	123	8.09	11.38
Think									
General Intellectual Ability	132	14.43	8.01	10	16.09	8.71	192	15.89	8.36
Word Attack	219	4.08	7.63	16	5.96	7.62	328	3.50	6.78
Sound Awareness	219	8.80	10.41	18	14.58	7.02	328	9.57	10.76
Working Memory Cluster	107	10.97	10.51	8	9.80	6.95	171	10.63	10.86

Table 9

Pearson Product Moment Correlations Between Program Demographics, Pre-test Scores, and Gain Scores for Dependent Variables

Variable List	1	2	3	4	5	6	7	8	9	10	11	12
1. Diagnosis		.06	.02	-.03	.03	.12**	.03	.05	.06	-.02	.00	-.03
2. Intensity			.05	-.01	.05	.02	.03	-.01	.05	.02	-.01	.01
3. Type of Program				-.61**	.32**	.22**	.45**	.56**	.12**	.11*	-.13**	-.23**
4. Length of Program					-.20**	-.15**	-.26**	-.29**	-.13*	-.08	.17**	.16**
5. PTS GIA						.69**	.59**	.44**	-.03	-.07	.07	.02
6. PTS Working Memory							.47**	.33**	-.03	-.31**	.05	-.01
7. PTS Sound Awareness								.59**	.13**	.06	-.18**	-.03
8. PTS Word Attack									.12**	.06	-.06	-.31**
9. Gain GIA										.60**	.44**	.31**
10. Gain Working Memory											.23	.15**
11 Gain Sound Awareness												.32**
12. Gain Word Attack												

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Figure 1

Ability-Achievement Continuum

Cognitive	**Academic**
Abilities or processes that develop largely independent of formal, school-related experiences	Specialized abilities that develop more as a function of formal, school-related experiences

Gt Gs Gsm Glr Gv Gf Ga Gc Grw Gq

Adapted from Flanagan,D.P. (2007). *Integration of RTI and New Methods of Cognitive Assessment: A Consensus Approach to SLD Identification.* (Power Point Presentation). St. John's University and Yale Child Study Center, School of Medicine.

Gt = Reaction Time
Gs = Processing Speed
Gsm= Short Term Memory
Glr = Long Term Retrieval
Gv = Visual-Spatial Thinking
Gf = Fluid Reasoning
Ga = Auditory Processing
Gc = Comprehension-Knowledge
Grw = Reading/Writing
Gq = Quantitative Reasoning

REFERENCES

Ackerman, P.L. & Lohman, D.F. (2003). Education and g. In H. Nyborg. (Ed.). *The Scientific Study of General Intelligence, Tribute to Arthur R. Jensen* (pp. 276-292). Amsterdam: Pergamon.

Ackerman, P.L. & Lohman, D.F. (2006). Individual Differences in Cognitive Functions. In P.A. Alexander, & P.H. Winne (Eds.), *Handbook of Educational Psychology* (2nd ed.). (pp.129-159). American Psychological Association: Division 15.

Aiken, L.R. (2004). *Perspectives of Individual Differences: Assessment of Intellectual Functioning* (2nd ed). New York: Springer.

Alloway, T. (2006). *Working Memory and Learning. What is Working Memory?* Retrieved April 4, 2009, from http://www.york.ac.uk/res/wml/FAQ.htm.

American Psychiatric Association (2000). Diagnostic and statistical manual of mental disorders (4th Rev. ed.) Washington, DC: Author.

Anjum, A. (2005). The relationship between the Differential Ability Scales and the Woodcock Johnson III Tests of Cognitive Abilities for children diagnosed with attention deficit hyperactivity disorder. *Dissertation Abstracts International, 65*(9), 4859.

Anthony, J.L. & Lonigan, C.J. (2004).The nature of phonological awareness: Converging evidence from four preschool and early grade school children. *Journal of Educational Psychology*, *96*(1), 43-55.

Baenninger, M. & Newcombe, N. (1989). The role of experience in spatial test performance: A meta-analysis. *Sex Roles, 20*(5-6), 327-344.

Baddeley, A.D. (1992). Working Memory. *Science*, *255*(5044), 556-559.

Baddeley, A. D. (2007). *Working Memory, Thought, and Action.* Oxford: University Press.

Baker, L.A. Vernon, P.A. & Ho, H.Z. (1991). The genetic correlation between intelligence and speed of information processing. *Behavioral Genetics, 21*(4), 351-367.

Ball, K., Edwards, J. D., and Ross, L. A. (2007). The Impact of Speed of Processing Training on Cognitive and Everyday Functions. *The Journals* *of Gerontology Series B: Psychological Sciences and Social Sciences, 62* (Suppl.1), 19-31.

Basso, M. R., Carona, F. D., Lowery, N., & Axelrod, B. N. (2002). Practice effects on the WAIS-III across 3- and 6-month intervals. *The Clinical Neuropsychologist, 16*, 57-63.

Ben-Hur, M. (2000). *Feuerstein's Instrumental Enrichment: Better Learning for Better Students.* Retrieved October 11, 2009, from http://www.newhorizons.org/strategies/ie/hur.htm.

Berliner, D. C. (1988). Meta comments: A discussion of critiques of L.M. Dunn's monograph Bilingual Hispanic Children on the U.S. Mainland. *Hispanic Journal of Behavioral Sciences, 10*(3), 273-299.

Berninger, V. W., Nielsen, K. H., Abbott, R. D., Wijsman, E., & Raskind, W. (2008). Gender differences in severity of writing and reading disabilities. *Journal of School Psychology, 46*, 151-172.

Bharti, S. (2006). *B.Ed. Guide.* New Delhi, India: AnMol Publications.

Biederman, J., Mick, E., & Faraone, S.V. (2000). Age dependant decline of symptoms of attention deficit hyperactivity disorder; impact of remission definition and symptom type [Electronic version]. *American Journal of Psychiatry, 157*(5), 816-818.

Binet, A. (1905). New Methods for the Diagnosis of the Intellectual Level of Subnormals**.** First published in *L'Année Psychologique*, *12*, 191-244. Translated by Elizabeth S. Kite (1916) in *The development of intelligence in children*. Vineland, NJ: Publications of the Training School at Vineland. Retrieved on June 5, 2009 from http://psychclassics.yorku.ca/Binet/binet1.htm.

Bouchard, T. J. Jr., & Segal, N. L. (1985). Environment and IQ. In B.B. Wolman (Ed.) *Handbook of Intelligence, Theories, Measurements, and Applications* (pp. 391-464). New York: Wiley.

Bruner, J.S. (1964). Some theorems on instruction. Reprinted and abridged from "Some Theorems on Instruction illustrated with reference to mathematics" In E.R. Hilgard (Ed.) *Theories of Learning and Instruction,* National Society for the Study of Education, Chicago, 306-335. In E. Stones (Ed) *Readings in Educational Psychology*, London: Methuen & Co. LTD, 1970, p. 112- 124.

Brunswick, E., Goldscheider, L., & Pilek, E (1932a) Zur Systematik des Gedachtnisses. [Systemizing memory.] Beihefte zur Zeitschrift fur angewandte Psychologie, 64, 1-158. In Weinert & Schneider (Eds). *Individual Development from 3 to 12: Findings from the Munich Longitudinal Study*. (1999). New York: Cambridge University Press.

Brunswik, E., Goldscheider, L., & Pilek, E. (1932b). Untersuchungen zur Entwicklung des Gedachtnisses [Studies on the Development of Memory]. Beihefte zur Zeitschrift fur angewandte Psychologie, 61. Leipzig: Ambrosius Barth. In Goswami (Ed). *Blackwell Handbook of Childhood Cognitive Development,* Berlin, Germany: Blackwell Publishing.

Brody, N. (1992). *Intelligence* (2nd ed). San Diego: Academic Press.

Bronfenbrenner, U. (1979). *The Ecology of Human Development: Experiments by Nature and Design*. Cambridge, MA: Harvard University Press.

Bunge, S.A., Klingberg, T., Jacobsen, R.B., & Gabrieli, J.D. (1999). *A resource model of the neural basis of executive working memory*. Communicated by P.S. Goldman-Rakic, Yale University School of Medicine, New Haven, CT. December 30, 1999.

Carroll, J.B. (1987). Jensen's mental chronometry: Some comments and questions. In: S. Modgil & C. Modgil (Eds), *Arthur Jensen: Consensus and controversy* (pp. 297-307 & 310-311). New York: Falmer.

Carroll, J.B. (1993). *Human cognitive abilities: A survey of factor-analytic studies*. Cambridge, England: Cambridge University Press.

Carpenter, D (2009). Testing the Effects of LearningRx: 2009 Control Group Study. (Available from the LearningRx Website, http://www.learningrx.com/doctors-only/2009-control-group-study-29-july-09.pdf).

Cashdan, A. (1969). Handicaps in Learning. Reprinted and abridged from Handicaps in Learning. In J.F. Morris and E. A. Lunzer (Eds) *Development in Learning: Contexts of Education,* Staples Press, (pp. 165-194). In E.Stones (Ed) *Readings in Educational Psychology*. (pp. 378-394). London: Methuen & Co. LTD.

Cattell, R. B. (1941). Some theoretical issues in adult intelligence testing. *Psychological Bulletin*, *38*, 592.

Cattell, R.B. (1963). Theory of fluid and crystallized intelligence: A critical experiment. *Journal of Educational Psychology, 54*, 1-22.

Cattell, R. B. (1983). The role of psychological testing in educational performance: The validity and use of ability predictions. In R.B. Cattell (Ed). *Intelligence and National Achievement,* (pp. 19-69). Washington, DC: Cliveden Press.

Ceci, S.J. (1991). How much does schooling influence general intelligence and its cognitive components? A reassessment of the evidence. *Developmental Psychology, 27*, 703-722.

Central Auditory Processing Deficit Therapies (2003). Retrieved on September 15, 2008 from http://www.concordspedpac.org/CAPD.html.

Chen, H. & Zhu, J. (2008). Factor invariance between genders of the Wechsler Intelligence Scale for Children-Fourth Edition. *Personality and Individual Differences, 45*(3), 260-266.

Clark-Edmands, S. (1975). *Specialized Program Individualized Reading Excellence (S.P.I.R.E.).* Educators Publishing Service.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Earlbaum Associates.

Corter, H.M., McKinney, J.D. (1966). *Cognitive training with retarded children, I. Final Report.* U.S. Department of Health, Education, & Welfare Office of Education.

Cowan, N., Nugent, L. D., Elliott, E. M., Ponomarev, I. & Saults, J. S. (1999). The role of attention in the development of short-term memory: age differences in the verbal span of apprehension. *Child Development, 70*(5), 1082-1097.

Crawford, J.D., Stankov, L. (1996). Age differences in the realism of confidence judgments: A calibration study using tests of fluid and crystallized intelligence**.** *Learning and Individual Differences, 8* (2) 83-103.

Cronbach, L.J. & Snow, R. E. (1977). *Aptitudes and instructional methods: A handbook for research on interactions.* New York: Irvington Publishers.

Deary, I.J. (1993). Inspection time and WAIS –R IQ subtypes: A confirmatory factor analysis study. *Intelligence*, 17, 223-236.

Deary, I.J. (2000). *Looking down on human intelligence: From psychophysics to the brain. Oxford*, U.K.: Oxford University Press.

Dempster, F.N. (1985). Short-term memory development in childhood and adolescence. In C.J. Brainerd & M. Pressley (Eds.). *Basic processes in memory development* (pp.209-248). New York: Springer-Verlag.

Descartes (1637). Discours de la methode. (Discourse on the method). Translated by John Veitch, 1870.

Dewey, D., Crawford, S. G., & Kaplan, B. J. (2003). Clinical importance of parent ratings of everyday cognitive abilities in children with learning and attention problems. *Journal of Learning Disabilities, 36,* 87-95.

Duff, K., Beglinger, L. J., Schultz, S.K., Moser, D.J., McCaffrey, R. J., Haase, R.F. et al. (2007). Practice effects in the prediction of long-term cognitive outcome in three patient samples: A novel prognostic index. *Archives of Clinical Neuropsychology*, *22*(1) 15-24.

Edelson, S.M., Rimland, B. (2008). The Efficacy of Auditory Integration Training. Summaries and Critiques of 28 Reports (January 1993-May 2001). Retrieved on September 15, 2008 from http://www.autism.com/families/therapy/aitsummary.htm.

Elliot, C.D. (1990). *Differential Abilities Scales.* San Antonio, TX: Pearson Education Inc.

Elliot, C.D. (2007). *Differential Abilities Scales, 2nd Edition*. San Antonio, TX., Pearson Education Inc.

Evans, J.J., Floyd, R.G., McGrew, K.S., & LeForgee, M.A. (2001). The relations between measures of Cattell Horn Carroll (CHC) Cognitive Abilities and Reading Achievement during Childhood and Adolescence. *School Psychology Review*, *31*(2),246-262.

Eysenck, H.J. (1987) Intelligence and reaction time: The contribution of Arthur Jensen. In: S. Modgil & C. Modgil (Eds), *Arthur Jensen: Consensus and controversy* (pp. 285-295 & 308-309). New York: Falmer.

Eysenck, H.J. (1991). Race and intelligence: An alternative hypothesis. *Mankind Quarterly*, *32* (1/2), 123-126.

Eysenck, H.J. & Eysenck, S.B.G. (Eds.) (1991). Improvement of IQ and behavior as a function of dietary supplementation: A Symposium. *Personality and Individual Differences: Special Issue.*

Falleti, M.G., Maruff, P., Collie, A. & Darby, D.G. (2006). Practice effects associated with repeated assessment of cognitive function using the Cogstate battery at 10-minute, one week and one moth test-retest intervals. *Journal of Clinical and Experimental Neuropsychology, 28,* 1095-1112.

Feuerstein, R. & Rand,Y. (1977). *Redevelopment of Cognitive Functions of Retarded Early Adolescents. Instrumental Enrichment.* Hadassah Wizo Canada Research Institute. In H. Sharron (Ed). The Israeli Studies. *Changing Children's Minds,* (pp.207-211) London: Souvenir Press.

Feuerstein, R., Rand, Y., Hoffman, M. & Miller, R (1980). *Instrumental Enrichment.* Baltimore, MD: University Park Press.

Flanagan, D.P. (2007). *Integration of RTI and New Methods of Cognitive Assessment: A Consensus Approach to SLD Identification.* (Power Point Presentation). St. John's University and Yale Child Study Center, School of Medicine.

Flanagan D. P., & Harrison, P.L. (2005). *Contemporary Intellectual Assessment: Theories, Tests, and Issues*. Guilford Press.

Flanagan, D. P., McGrew, K. S. & Ortiz, S. O. (2000). *The Wechsler Intelligence Scales and Gf-Gc theory: A contemporary interpretive approach.* Boston, MA: Allyn & Bacon.

Flanagan D. P, & Ortiz, S.O. (2001). *Essentials of Cross Battery Assessment.* New York: Wiley.

Flanagan, D.P., Ortiz, S.O., & Alfonso, V.C.(2002). *Essentials of Cross-Battery Assessment* (2nd ed.). New York: Wiley.

Flanagan, D.P., Ortiz. S.O., Alfonso, V.C., & Mascolo, J.T. (2006). *The Achievement Test Desk Reference: A Guide to Learning Disability Identification* (2nd ed). New York: John Wiley & Sons.

Flanagan, D.P., Ortiz, S.O., Alfonso, V.C. (2007) *Essentials of Cross Battery Assessment, 2nd Edition.* Hoboken New Jersey: John Wiley & Sons, Inc.

Flavell, J.H., Miller, P., & Miller, S. (1993). *Cognitive Development* (3rd Ed.) Englewood Cliffs, NJ: Prentice Hall.

Fox, B., Routh, D.K. (1984). Phonemic Analysis and Synthesis as Word Attack Skills:Revisited. Journal of Educational Psychology 76(6), 1059-64.

Furr, R.M., & Bacharach, V.R. (2007). Psychometrics: An Introduction. Los Angeles, SAGE.

Gaub,M. & Carlson, C.L. (1997). Gender differences in ADHD: A meta-analysis and critical review. *Journal of the American Academy of Child and Adolescent Psychiatry, 36*, 1036-1045.

Geiser, C., Lehmann, W., & Eid, M. (2008). A note on sex differences in mental rotation in different age groups. *Intelligence, 36*(6), 556-563.

Gerth, J.M., Barton, S.A., Engler, H.F., Heller, A.C., Freides, D., & Blalock, J. (1994). *Non-Pharmacological Techniques in the Treatment of Brain Dysfunction.* In S.M. Edelson & B. Rimland. [Electronic Version] *The Efficacy of Auditory Integration Training.* Retrieved on October 25, 2009 from http://www.autism.com/families/therapy/aitsummary.htm.

Glass, J.(1968). Educational piltdown man, *Phi Delta Kappa,* November, 148-151.

Graham, N.C. (1968). Memory span and language proficiency. Journal of Learning Disabilities, I (11), 644-648. In E. Stones (Ed) *Readings in Educational Psychology* (pp. 408-414). London: Methuen & Co. LTD.

Goswami, U. (2002). *Blackwell Handbook of Child Cognitive Development.* Oxford: Blackwell.

Hagen, R.A. (1983). Early intervention with vulnerable children: Results of a demonstration project. Paper presented at the Annual Meeting of the American Psychological Association (91st, Anaheim, CA, August 26-30, 1983).

Haier, R. J. (2003). Positron Emission Tomography Studies of Intelligence: From Psychometrics to Neurobiology. In H. Nyborg (Ed.) *The Scientific Study of General Intelligence, Tribute to Arthur R. Jensen* (pp.41-51). Amsterdam: Pergamon.

Halper, D.G., & LaMay, M.L. (2000). The smarter sex: A critical review of sex differences in intelligence. *Educational Psychology Review, 12* (2) 229-246.

Halperin, J.M., Trampush,J.W., Miller, C.J., Marks, D.J., Newcorn, J.H. (2008). Neuropsychological outcome in adolescents/young adults with childhood ADHD: Profiles of persisters, remitters, and controls. *Journal of Child Psychology and Psychiatry, 49*, 958-966.

Harlow, H.F. (1949). Learning to Think. Reprinted and abridged from The formation of Learning Sets, *Psychological Review*, *56*, 51-65. In E.Stones (Ed) *Readings in Educational Psychology*. (pp. 6-16). London: Methuen & Co. LTD.

Herrold, K. & O'Donnell, K. (2008). *Parent and Family Involvement in Education. 2006-07 School Year, From the National Household Education Surveys Program of 2007* (NCES 2008-050). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education. Washington, DC.

Heywood, H.C., Arbitman-Smith, R., Bransford, J.D. & Declos, V. (Vanderbilt University). Towery, J.R. (Louisville, Kentucky). Hannel, I.L. & Hannel, MV. .(Phoenix, Arizona) (no date). *Cognitive Education with Adolescents: Evaluation of Instrumental Enrichment.* In H. Sharron (Ed) *Changing Children's Minds*. Nashville, Louisville and Phoenix Results, 214-218. London: Souvenir Press, 1987.

Hitch, G. J, &, Towse, J. (1995). *Working memory: What develops* In, W. Schneider & F. E. Weinert, (Eds.), *Memory performance and competencies: Issues in growth and development*, (pp. 3 – 22), Northvale, NJ: Erlbaum.

Horn, J.L. (1965). *Fluid and crystallized intelligence: A factor analytic and developmental study of the structure among primary mental abilities.* Unpublished doctoral dissertation, University of Illinois, Champaign.

Horn, J.L. (1970). Organization of data on life-span development of human abilities. In L.R. Goulet & P.B. Baltes (Eds.) *Life-span developmental psychology: Research and theory* (pp. 434-466). New York: Academic Press.

Hulme, C., Thompson, N., Muir, C. & Lawrence, A. (1984). Speech rate and the development of short-term memory. *Journal of Experimental Child Psychology, 38*, 241-253.

Huff, E.G., Dancer, J., Evans, S.D., & Skoch, A.C. (2006). Validity and reliability of the Test of Early Reading Ability-Second Edition with preschool age children. *Perceptual Motor Skills, 102*(1), 288-290.

Hume, D (1739-1740) *A Treatise of Human Nature: Being an attempt to introduce the experimental method of reasoning into moral subjects.* In D.F. Norton & M.J. Norton (Eds). Oxford University Press, 2000.

Humphreys & Davey (1988). Continuity in intellectual growth from 12 months to 9 years. Intelligence, 12, 183-197.

Husain, M. & Millimet, D.L. (2009). The Mythical "Boy Crisis"? *Economics of Education Review, 28*(1), 38-48.

Hyde, J.S., & McKinley,N.M. (1997). Gender differences in cognition: Results from meta-analyses. In P.J. Caplan, M. Crawford, J.S. Hyde, & J. T. E. Richardson (Eds.). *Gender Differences in Human Cognition* (pp.30-51). New York: Oxford University Press.

Individuals with Disabilities Education Improvement Act of 2004, Pub. L. No.108-446, § 614 (b) (6) (B).

Individuals with Disabilities Education Improvement Act of 2004, Pub. L. No.108-446, § 602 (3) (A).

Irvin, G.H. & Hoedt, K.C. (1979). Study of the remediation of deficiencies in auditory perception. *Ohio Journal of Science, 79*(4), 174-177.

Irwing, P., Hamza, A., Khaleefa, O., & Lynn, R. (2008). Effects of Abacus training on the intelligence of Sudanese children. *Personality and Individual Differences, 45*(7) 694-696.

Jaeggi, S. M., Buschkuehl, M., Jonides, J., & Perrig, W. J. (2008). Improving Fluid Intelligence with Training on Working Memory. *Proceedings of the National Academy of Sciences of the United States of America, 105(*19), 6829-6833.

Jaušovec, N., & Jaušovec, K. (2008). Spatial rotation and recognizing emotions: Gender related differences in brain activity. *Intelligence, 36*, 383-393.

Jensen, A.R. (1969). How much can we boost IQ and scholastic achievement? *Harvard Educational Review,* 39, 1-123.Jensen, A. R. (1982). Reaction time and psychometric g. In: H.J. Eysenck (Ed.), *A Model for Intelligence*, Berlin: Sringer-Verlag.

Jensen, A. R. (1998). *The g factor.* Westport, CT: Praeger.

Jensen, A. R. (2003). Do age-group differences on mental tests imitate racial differences? *Intelligence,* 31(2), 107-121.

Jensen, A. R., & Munro, E. (1979). Reaction time, movement time, and intelligence. *Intelligence, 3*, 121-126.

Jaušovec, N., & Jaušovec, K. (2008). Spatial rotation and recognizing emotions: Gender related differences in brain activity. *Intelligence, 36*, 383-393.

Layng, T.V., Twyman, J.S., & Stikeleather, G. (2004). *Selected for Success: How Headsprout Reading Basics Teaches Beginning Reading.* In D.J. Moran & R.W. Malott (Eds.). *Evidenced – Based Educational Methods* (pp.171-197). San Diego, CA: Elsevier Academic Press.

Karatekin C. (2004). A test of the integrity of the components of Baddeley's model of working memory in attention-deficit/hyperactivity disorder (ADHD). *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 45(*5), 912-926.

Kaufman, A.S., & Kaufman, NL. (1985). Kaufman Test of Educational Achievement. Circle Pines: MN: American Guidance Service.

Kaufman,A.S., & Kaufman, N.L.(1993). Kaufman Adolescent & Adult Intelligence Scale, 4th Edition. Pearson.

Kaufman, A.S. & Kaufman, N.L. (2004). Kaufman Assessment Battery for Children, 2nd Edition. Pearson.

Kaufman, A. & Lichtenberger, E.O. (2005) (Eds). Assessing Adolescent and Adult Intelligence, (3rd ed.) Hoboken, New Jersey: John Wiley & Sons.

Kazdin, A.E. (2000). *Encyclopedia of Psychology Vol. 6*. Oxford University Press.

Kettle, H. 1992. *Evaluation of the Instrumental Enrichment Program*. Research report 91-05. School Board. Vancouver, B.C., Canada.

Kerr, M.M. & Nelson,C.M. (2005). *Strategies Addressing Behavior Problems in the Classroom*. (5th ed.). Pearson.

Kimble, G.A., & Wertheimer, M. (Eds.). (1998). *Portraits of Pioneers in Psychology: Volume III.* Lawrence Erlbaum Associates.

Klingberg, T., Fernell, E., Olesen, P.J., Johnson, M., Gustafsson, P., Dahlstrom, K., Gillberg, C.G., et al. (2005). Computerized training of working memory in children with ADHD – a randomized, controlled trial. *Journal of American Academy of Child Adolescent Psychiatry, 44*(2), 177-186.

Klingberg, T., Forssberg, H., & Westerberg, H. (2002). Training of Working Memory in Children with ADHD. *Journal of Clinical and Experimental Neuropsychology, 24*(6), 781-791.

Kozulin, A., R. Kaufman, and L. Lurie. (1997). Evaluation of the Cognitive Intervention with Immigrant Students from Ethiopia. In A.Kozulin (Ed.). *The Ontogeny of Cognitive Modifiability,* (pp.89-130). Jerusalem: ICELP.

Kreiger, S. M., Kaplan, M. E. (1990). Improving Inattention and Reading in Inattentive Children through MLE: A Pilot Study. In M.C. Mehi (Ed.). *International Journal of Cognitive Education and Mediation Learning* 1(3) (pp. 185-192). *The Cognitive Difficulties of First Year Physics Students at the University of Western Cape and Various Compensatory Programmes* (Capetown, South Africa: University of Capetown, 1985).

Lacene, K. (2004). WAIS III working memory and processing speed indexes in adults with attention deficit hyperactivity disorder. Unpublished thesis dissertation. Canada: University of Alberta.

Lassiter, K.S., Matthews, T.D., & Feeback,G. (2007) An examination of the TONI utilizing Gc-Gf theory: A comparison of the CTONI and WJ III. *Psychology in the Schools, 44*(6), 567-577.

LearningRx Website (n.d.). Think Rx program description. Retrieved November 3, 2009 from http://learningrx.com/thinkrx.htm

Leont'ev,A.N. & Gal'Perin, P.Ia (1965). Learning theory and programmed instruction. Reprinted and abridged from AN Leont'ev and P.Ia. Gal'Perin Learning Theory and Programmed Instruction in Soviet Education, VII (10), 7-15.

Lindblad, S.G. (1996). Gender, age, and level of achievement differences on the woodcock-johnson revised tests of cognitive abilities and tests of achievement-early development battery. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 56*(9-B), 5196.

Linn, M.C. & Petersen, A.C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development, 56*, 1479-1498.

Luckey, A.J. (2007). *Effectiveness of LearningRx Cognitive Skills Training Programs: A Statistical Analysis of Cognitive Growth.* Unpublished Paper.

Lui, M. & Tannock, R. (2007). Working memory and inattentive behaviour in a community sample of children. *Behavioral and Brain Functions, July*, 3-12.

Lynn, R. (1991). Race differences in intelligence: A global perspective. *Mankind Quarterly, 31*, 255-296.

Lynn, R. & Owen, K (1994). Spearman's hypothesis and test score differences between Whites, Indians, and Blacks in South Africa. *Journal of General Psychology, 121*, 27-36.

Madell, J.R. (1999). Auditory integration training: one clinician's view. *Language, Speech, and Hearing Services in Schools. 30*(4), 371-377.

Mahncke, H.W., Connor, B.B., Appelman, J., Ahsanuddin, O.N., Hardy, J.L., Wood, R. A., et al (2006). Memory enhancement in healthy older adults using a brain plasticity-based training program: A randomized, controlled study. Proceedings of the National Academy of Sciences of the United States of America, June 27.

Marachi, R. (2006). Statistical Analysis of Cognitive Change with LearningRx Training Procedures. Retrieved September 20, 2008 from http://www.learningrx.com/chandler/doctors-only.htm.

Marks, G. N. (2008). Accounting for the gender gaps in student performance in reading and mathematics: evidence from 31 countries. *Oxford Review of Education, 34*(1), 89- 109.

Martinussen, R., Hayden,J., Hogg-Johnson, S., & Tannock, R. (2005). A meta-analysis of working memory impairments in children with attention-deficit hyperactivity disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 44*, 377-384.

Martinussen, R. & Tannock, R. (2006). Working Memory Impairments in Children with Attention Deficit Hyperactivity Disorder with and without co morbid language learning disorders. *Journal of Clinical and Experimental Neuropsychology, 28*(7), 1073-1094.

Marusiak, C.W. & Janzen,H.L. (2005). Assessing the working memory abilities of ADHD children using the Stanford-Binet Intelligence Scales, Fifth Edition. *Canadian Journal of School Psychology, 20* (1-2), 84-97.

Mayes, S.D., & Calhoun, S.L. (2007). Wechsler Intelligence Scale for Children-Third and Fourth Edition: Predictors of Academic Achievement in

Children with Attention-Deficit/Hyperactivity Disorder. *School Psychology Quarterly, 22*(2), 234-249.

Merton, R.K. (1988). The Matthew Effect in Science: Cumulative Advantage and the Symbolism of Intellectual Property. *ISIS,* 606-623. Retrieved May 26, 2009 from http://garfield.library.upenn.edu/merton/matthewii.pdf.

Mcarthur, G.M., Ellis, D., Atkinson, C.M. & Coltheart, M. (2008). Auditory processing deficits in children with reading and language impairments: Can they (and should they) be treated? *Cognition, 107*(3), 946-977.

McCall, R.B., Appelbaum, M.I., & Hogarty, P.S. (1973). Developmental changes in mental performance. *Monographs of the Society for Research in Child Development, 38* (3), 1-83.

McGee, M. (1979). Human spatial abilities: Psychometric studies and environmental, genetic, hormonal, and neurological influences. *Psychological Bulletin, 86*, 889-918.

McGrew, K.S. (2005). The Cattell-Horn Carroll theory of cognitive abilities: Past, present and future. In D.Pl. Flanagan, J.L. Genshaft & P.L. Harrison (Eds). *Contemporary intellectual assessment: Theories, tests, and issues* (pp. 136-182). New York: Guilford.

McGrew, K.S. & Flanagan, D. (1998). *The Intelligence Test Desk Reference (ITDR): Gf-Gc Cross-Battery Assessment*. Allyn & Bacon.

Morris, R.D., Shaywitz, S.E., Shankweiler, D.P., Katz, L., Steubing, K.K., Fletcher, J.M., Lyon, G.R., Francis, D.J., & Shaywitz, B.A. (1998). Subtypes of reading disability: Variability around a phonological core. *Journal of Educational Psychology, 90*, 347-373.

Naglieri, J. A. (2003). Current advances in assessment and intervention for children with learning disabilities. In T. E. Scruggs and M. A. Mastropieri (Eds.) *Advances in learning and behavioral disabilities Volume 16: Identification and assessment (pp. 163-190). New York: JAI.*

Nettelbeck, T. (1998). Jensen's chronometric research: neither simple nor sufficient but a good place to stat. *Intelligence,* 26, 233-241.

Nettelbeck, T. (2003). Inspection time and g. In H. Nyborg (Ed.) *The Scientific Study of General Intelligence, Tribute to Arthur R. Jensen* (pp.77-91) Amsterdam: Pergamon, Nettelbeck, T. & Lally, M (1976). Inspection time and measured intelligence. *British Journal of Psychology, 67*, 17-22.

Neisser, U., Boodoo, G., Bouchard, T., Boykin, A., Brody, N., et al (1996). Intelligence: Knowns and unknowns. *American Psychologist, 51,* 77-101.

Neubauer, A.C. (1997). Intelligence and RT: A modified Hick paradigm and a new RT paradigm. *Intelligence, 15*, 175-193.

Newcombe, N. (1982). Sex-related differences in spatial ability. In M. Potegal (Ed.), *Spatial abilities: Developmental and physiological foundations* (pp. 223-243). New York: Academic Press.

Nyborg. H. (2003a). Sex differences in g. In H. Nyborg (Ed.) *The Scientific Study of General Intelligence, Tribute to Arthur R. Jensen* (pp. 187-222). Amsterdam: Pergamon.

Nyborg, H. (2003b). The scientific study of general intelligence: Tribute to Arthur R. Jensen.

Nyborg, H. & Jensen, A. R. (2000). Black –White differences on various psychometric tests: Spearman's hypothesis tested on American armed services veterans. *Personality and Individual Differences, 28*, 593-599.

Olesen, P.J., Westerberg, H., and Klingberg, T. (2004). Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience, 7*(1), 75-79.

Pallant, J. F. (2007). *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS. (3rd Edition).* Australia: Allen & Unwin.

Perkins, D.A. & Grotzer, T. A. (1997). Teaching intelligence. *American Psychologist, 52*, 1125-1133.

Pesta, B.J., Bertsch, S., Poznanski, P.J., & Bommer, W.H. (2008). Sex differences on elementary cognitive tasks despite no differences on the Wonderlic Personnel Test. *Personality and Individual Differences, 45*(5), 429-431.

Piaget, J. (1961). The genetic approach to psychology of thought. Reprinted and abridged from The Genetic Approach to Psychology of Thought *Journal of Educational Psychology*, *52*, 151-161 in E. Stones (Ed) *Readings in Educational Psychology* (pp.60-67). London: Methuen & Co. LTD.

Piaget, J. (1971). *Biology and knowledge.* Edinburgh: Edinburgh University Press.

Piaget (1973). Problemes de psychologie genetique [Problems of the genetic psychology]. New York: Grossman.

Piaget, J. (1995). *Sociological Studies*. London: Routledge.

Pike, A., Iervolino, A.C., Eley, T.C., Price, T. S. & Plomin, R. (2006). Environmental Risk and Young Children's cognitive and behavioral development. *International Journal of Behavioral Development, 30* (1), 55-66.

Plato (1974). *Meno,* translated by Benjamin Jowett.

Plomin, R. (2003). Molecular Genetics and g. In H. Nyborg (Ed.) *The Scientific Study of General Intelligence, Tribute to Arthur R. Jensen* (pp. 107-122). Amsterdam: Pergamon.

Plomin, R., DeFries, J.C., & Fulker, D.W. (1988). *Nature and nurture during infancy and early childhood.* New York: Cambridge University Press.

Plomin, R. & Petrill, S.A. (1997). Genetics and intelligence. What's new? *Intelligence, 24* (1), 53-77.

Polczyk, R., & Necka, E. (1997). Capacity and retention capability of working memory to modify the strength of the RT/IQ correlation: a short note. *Personality and Individual Differences, 23*, 1089-1091.

Poock, M.A.J. (2005). Validation of the attention battery of the Woodcock Johnson Third Edition Tests of Cognitive Abilities (WJ III, COG) for children with attention deficit hyperactivity disorder. Unpublished doctoral dissertation, Indiana State University.

Presseisen, B.Z.(1992). *Implementing Thinking in the Schools Curriculum*. Paper presented at the Annual Meeting of the International Association for Cognitive Education (3rd, Riverside, CA, February 9, 1992).

Rand, Y., Tannenbaum, A., & Feuerstein, R. (1979). Effects of Instrumental Enrichment on the psychoeducational development of low-functioning adolescents. *Journal of Educational Psychology, 71*(6), 751-763.

Rapport, M.D., Alderson, R.M., Kofler, M.J., Sarver, D.E., Bolden, J., Sims, V.(2008). Working Memory Deficits in Boys with Attention-Deficit/Hyperactivity Disorder (ADHD): The Contribution of Central Executive and Subsystem Processes. *Journal of Abnormal Child Psychology, 36,* 825-837.

Rapport, M.D., Bolden, J., Kofler, M.J., Sarver, D.E., Raiker, J.S., Alderson, R.A. (2009). Hyperactivity in Boys with Attention-Deficit/Hyperactivity Disorder (ADHD): A Ubiquitous Core Symptom or Manifestation of Working Memory Deficits? *Journal of Abnormal Child Psychology, 37*, 521-534.

Rapport, M.D., Chung, K.M., Shore, G., Denney, C.B., & Isaacs, P (2000). Upgrading the science and technology of assessments and diagnosis: Laboratory and clinic-based assessment of children with ADHD. *Journal of Clinical Child Psychology, 29,* 555-568.

Rath (2001). *Phonemic Awareness Quiz for Reading Teachers* (pp. 96-97). Riverside Publishing Company. In *CHC Theory* Retrieved October 15, 2009 from http://alpha.fdu.edu/psychology/chc_theory.htm.

Riverside Publishing Company (2001a). Compuscore [computer software]. Itasca, IL.

Riverside Publishing Company (2001b). *Psychological Processes power point presentation.*

Roid, G.H. (2003). *Stanford Binet Intelligence Scales, Fifth Edition,* Itasca, IL:Riverside

Rosnow, R. L., & Rosenthal, R. (1996). Computing contrasts, effect sizes, and counternulls on other people's published data: General procedures for research consumers. *Psychological Methods, 1,* 331-340.

Ruiz, C.J. (1985). Cognitive modifiability and irreversibility. Publication No. 4 University of Guyana, Venezuela.

Rumsey, R.K. (2004). Executive functioning in boys and girls with attention deficit hyperactivity disorder with and without a co morbid reading disability. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 64*(11-B), 5820.

Sameroff, A.J., Lewis, M., Miller, S.M. (2000) *Handbook of Developmental Psychopathology, 2nd Edition.* New York: Springer.

Sanders, S., McIntosh, D.E., Dunham, M, Rothlisberg, BA., & Finch,H. (2007). Joint confirmatory factor analysis of the Differential ability Scales and the Woodcock Johnson Tests of Cognitive Abilities-Third Edition. *Psychology in the Schools, 44*(2), 119-138.

Sattler, J. (2001). *Assessment of Children, Cognitive Applications*, (4th Ed.). San Diego, CA: Jerome M. Sattler, Publisher, Inc.

Schaie, K.W. (2005). *Developmental influences on Adult Intelligence. The Seattle Longitudinal Study*. Oxford New York: Oxford University Press.

Schneider, W. (2002). Memory development in childhood. In U.Goswami (Ed). *Blackwell Handbook of Childhood Cognitive Development, (*pp. 236-256). Berlin, Germany: Blackwell Publishing.

Schrank, F. A., McGrew, K.S., & Woodcock, R. W. (2001). Technical Abstract (Assessment Service Bulletin no. 2). Itasca, IL:Riverside Publishing.

Schumann-Hengsteler, R. (1992). The development of visuo-spatial memory: How to remember location. *International Journal of Behavioral Development, 15*, 445-471.

Schwebach, A.J. (2007). Cognitive profiles of children with attention-deficit/hyperactivity disorder. *Dissertation Abstracts International: Section B: The Sciences and Engineering 68* (3-B), p 1956.

Share,D.L. & Stanovich, K.E. (1995). Cognitive processes in early reading development: Accommodating individual differences into a model of acquisition. *Issues in Education: Contributions from Educational Psychology, 1*, 1-57.

Sharron, H. (1987). *Changing Children's Minds. Feuerstein's Revolution in the Teaching of Intelligence.* Great Britain: Souvenir Press (E & A) Ltd.

Shaywitz, B.A., Holford, TR., Holahan, J.M.., Fletcher, J.M., Stuebing, K.K., Francis, D.J., & Shaywitz, S.E. (1995). A Matthew Effect for IQ but Not for Reading: Results from a Longitudinal Study. [Electronic Version]. *Reading Research Quarterly*, *30*(4), 894-906.

Siders, A.; Kaufman, A. S. Reynolds, C. R. (2006). Do Practice Effects on Wechsler's Performance Subtests Relate to Children's General Ability, Memory, Learning Ability, or Attention? *Applied Neuropsychology*, *13*(4), 242-250.

Silcock, P. (1999). *New Progressivism*. Philadelphia: PA: Falmer Press.

Singer, J. & Jensen, M. R. (no date). *Cognitive Modifiability Project Yale University*. Narrative Progress Report: Executive Summary. In H. Sharron

(Ed). *Changing Children's Minds (*pp. 212-213). Yale University Cognitive Modifiability Project, London: Souvenir Press, 1987.

Skemp, R. (1965). Concept formation and its significance in mathematics teaching and syllabus reform. Reprinted and abridged from *Concept Formation and its Significance in Mathematics Teaching and Syllabus Reform* in E. Stones (Ed) Readings in Educational Psychology (pp. 230-241). London: Methuen & Co. LTD.

Skemp, R. R. (1970). *The Psychology of Understanding Mathematics.* Hammondsworth: Penguin Books.

Skinner, B.F. (1954). The Science of Learning and the Art of Teaching, *Harvard Educational Review, 24*, 86-97. In E. Stones (Ed) *Readings in Educational Psychology*. (pp. 301-312). London: Methuen& Co. LTD.

Smith, E.E., Geva, A., Jonides, J.,Miller, A., Reuter-Lorenz, P., Koeppe, R.A. (2001). The neural-basis of task switching in working memory: Effects of performance and aging. *Proceedings of the National Academy of Sciences, 98*(4), 2095-2100.

Snow, R.E., & Yalow, E. (1982). Education and intelligence. In R.J. Sternberg (Ed.) *Handbook of human intelligence* (pp. 493-585). Cambridge: Cambridge University Press.

Snyderman, M. & Rothman,S. (1987). Survey of expert opinion on intelligence and aptitude testing. *American Psychologist, 42*, 137-144.

Spearman, C. (1927). The abilities of man: *Their nature and measurement.* New York: Macmillan.

Stanovich, Keith E. (1986). Matthew Effects in Reading: Some Consequences of Individual Differences in the Acquisition of Literacy. *Reading Research Quarterly, 21*(4), 360–407.

Stanovich, K.E. (1988). Explaining the difference between the dyslexic and garden variety poor reader: Phonological-core variable-difference model. *Journal of Learning Disabilities, 21*, 590-612.

Stanovich, K.E. (1995). Matthew effects in reading: Some consequences of individual differences in the acquisition of literacy. *Reading Research Quarterly, 21*(4), 360–407.

Stanovich, K.E., & Siegel, L.S. (1994). Phenotypic performance profile of children with reading disabilities: A regression-based test of the phonological-core variable-difference model. *Journal of Educational Psychology, 56*, 24-33.

Sternberg, R.J. (1987). “Intelligence” in Gregory, R.L. (Ed) *The Oxford Companion to the Mind*. Oxford; Oxford University Press.

Sternberg, R.J. & Berg, C.A. (1986). Quantitative integration: Definitions of intelligence: A comparison of the 1921 and 1986 Symposia. In R. J. Sternberg & DK Detterman (Eds.), *What is intelligence? Contemporary viewpoints on its nature and definition*. (pp. 155-162). Norwood, NH: Ablex.

Sternberg, R.J. & Detterman, D.K. (1986). *What is intelligence? Contemporary viewpoints on its nature and definition.* Norwood, NH: Ablex.

Swanson, H. L., & Howell, M. (2001). Working memory, short-term memory, and speech rate as predictors of children’s reading performance at different ages. *Journal of Educational Psychology, 93*, 720-734.

Tabachnick, B. G., and Fidell, L. S. (2007). *Using Multivariate Statistics , 5th ed*. Boston: Allyn and Bacon.

Talyzina, N. F. (1968). The Stage Theory of the Formation of Mental Operations, *Soviet Education, X (*3), p. 38-42. In E. Stones (Ed) *Readings in Educational Psychology* (pp.155-162).. London: Methuen & Co, LTD.

Talyzina, N. F. (1981). *The Psychology of Learning: Theories of Learning and Programmed Instruction*. Moscow: Progress Publishers.

Terman, L. M. (1916). *The Measurement of Intelligence: An Explanation of and a Complete Guide for the use of the Stanford Revision and Extension of the Binet-Simon Intelligence Scale*. Boston: Houghton Mifflin Co.

The New Oxford Annotated Bible, New Revised Standard Edition with Apocrypha. (2007). Oxford, New York: University Press.

Thapar,A., Petrill, S.A., & Thompson, L.A. (1994). The heritability of memory in the Western Reserve Twin Project. *Behavior Genetics, 24*, 155-160.

Thompson, Forth, (2005). Cognitive-Training Programs for Older Adults: What Are they and Can they Enhance Mental Fitness? *Educational Gerontology, 31*(8) 603-626.

Thorndike. EL. (1927). *The measurement of intelligence*. New York: Bureau of Publications, Teachers College, Columbia University.

Thorndike, R.L., Hagen, E.P., & Sattler, J.M. (1986). *The Stanford Binet Intelligence Scale: Fourth Edition technical manual.* Chicago: IL: Riverside.

Torgesen, J.K. (2000). Individual differences in response to early interventions: The lingering problem of treatment resisters. *Learning Disabilities Research and Practice, 15*(1), 55-64.

Urie Bronfenbrenner (n.d.) Retrieved on August 21, 2008 from http://www.des.emory.edu/mfp/302/302bron.PDF.

U.S. Department of Health and Human Services (1985). The impact of Head Start on children, families, and communities: Head Start synthesis project (Contract No. 105-81)-C-026. Washington, DC: CSR. (ERIC Document Reproduction Service No. ED 263984).

Vellutino, F.R., Scanlon, D.M., & Lyon, R.G. (2000). Differentiating between difficult-to-remediate and readily remediated poor readers: More evidence against the IQ-achievement discrepancy definition of reading disability. *Journal of Learning Disabilities, 33,* 223-238.

Voyer, D., Voyer, S., & Bryden, M.P. (1995). Magnitude of sex differences in spatial abilities: A meta analysis and consideration of critical variables. *Psychological Bulletin, 117*, 250-270.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes.* Cambridge, MA: Harvard University Press.

Vygotsky,L.S. (1994). *The Vygotsky reader.* Oxford, UK: Blackwell.

Wechsler, D. (1949). *The Wechsler Intelligence Scale for Children*. New York: Psychological Corp.

Weiner, I.B., Freedheim, D.K., Schinka, J.A., & Velicer, W.F. (2003). *Handbook of Psychology*. New York: John Wiley & Sons.

Wendling, B.J. & Mather, N. (2009). *Essentials of Evidence Based Academic Interventions.* New York: John Wiley & Sons.

Westerberg, H., Jacobaeus, H., Hirvikoski, T., Clevberger, P., Ostensson, M.L., Barfai, A., Klingberg, T. (2007). Computerized working memory training after stroke- A pilot study. *Brain Injury, 21*(1), 21-29.

Willcutt, E.G., Doyle, A., Nigg, J., Faraone, S., & Pennington, B.F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. *Biological Psychiatry, 57*, 1336-1346.

Willcutt, E.G., Pennington, B.F., Olson, R.K., Chabildas, N., & Hulslander, J. (2005). Neuropsychological analyses of co morbidity between reading disability and attention deficit hyperactivity disorder: In search of the common deficit. *Developmental Neuropsychology, 27*(1), 35-78.

Winzer, M.A. (1993). *The History of Special Education: From Isolation to Integration*. Gallaudet University Press.

Witmer, L. (1907) Clinical Psychology. *Psychological Clinic,* 1, 1-9.

Wolfe, M.E. (2006). Executive function processes: Inhibition, working memory, planning, and attention in children and youth with attention deficit hyperactivity disorder. *Dissertation Abstracts International: Section B: The Sciences and Engineering, 66* (12-B), 6940.

Woodcock, R.W., McGrew, KS. & Mather, N. (2001). *The Woodcock-Johnson® III*. Itasca, IL: Riverside.

Wozniak, R. H. (1999). Introduction to memory: Hermann Ebbinghaus (1885/1913). *Classics in the history of psychology* [electronic source] Retrieved on November 3, 2009 fromhttp://psychclassics.yorku.ca/Ebbinghaus/wozniak.htm.

Wright, J. (n.d.) *The Savvy Teachers Guide: Reading Interventions that Work*. Keywords: a memorization strategy. PDF Retrieved on August, 23, 2009 from http://www.jimwrightonline.com/pdfdocs/keywords.pdf.

Wu, K.K., Anderson, V. & Castiello, U. (2006). Attention Deficit/Hyperactivity Disorder and Working Memory: A task switching paradigm. Journal of Clinical and Experimental *Neuropsychology, 28*(8), 1288-1306.

Yerkes, R. M. (1921). Psychological examining in the United States Army. *Memoirs of the National Academy of Sciences, 15*, 1-890.

Zigler, E. Balla, D. & Hodapp, R.M. (1984). On the definition and classification of mental retardation. *American Journal of Mental Deficiency, 89*, 215-230.

Zigler, E. & Hodapp, R.M. (1986). *Understanding Mental Retardation.* Cambridge, New York: Cambridge University Press.