THE EFFECT OF COGNITIVE REHABILITATION THERAPY ON MEMORY AND PROCESSING SPEED IN ADOLESCENTS

by

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Abstract

This research study examines the relative effectiveness of Cognitive Rehabilitation Therapy (CRT) in processing speed and working memory. These areas are targets of interest given current literature related to learning deficits. Research suggests the center of the deficit is related to delays in processing speed and working memory. CRT is one such intervention designed to overcome these deficits in students. In this study 1,277 adolescent children ages 10-19 were studied to determine if CRT had any effect on working memory and processing speed as measured by the Woodcock Johnson COG-III test. A quasiexperimental design was utilized examining scores pre-CRT and post-CRT. Based upon the results of this study, the gain in cognitive functioning as measured by working memory and processing speed in adolescents is statistically significant. These results support the use of CRT as needs based intervention in adolescents.

Dedication

This is dedicated to my loving wife and family. They have stood by me on this educational journey and have made sacrifices so I may reach my dreams. My mentor, Dr. Steven Schneider pushed me to be better than I imagined possible and guided me along the way. I am forever indebted to those who helped me succeed.

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I would like to acknowledge the efforts of my mentor Dr. Steven Schneider. His efforts and guidance have made this possible. I would also like to recognize my committee, Dr. John Flynn and Dr. Jeff Shen, for their diligent review of my research and invaluable input.

Table of Contents

List of Tables

List of Figures

CHAPTER 1. INTRODUCTION

Background of the Problem

Struggling to learning may be a daunting challenge to overcome for many students. For students with difficulties related to cognitive processing this can prove even more challenging. Recognizing and understanding these challenges and how they present can be an important piece to solving this learning puzzle. For many students struggling in school there may be a reason for their challenges related to underlying cognitive deficits. These deficits present significant problems for the students related to achieving at grade level. These students face a daunting struggle to overcome these challenges and many will continue to struggle with learning related to an underlying cognitive deficit.

New interventions are being created and designed specifically to remediate these cognitive impairments. These interventions have been created based upon a medical model developed through working with stroke victims and brain injuries. In the early studies it was observed patients recovering from strokes were able to improve brain functioning through an intervention referred to as Cognitive Rehabilitation Therapy (CRT). CRT also contains interventions like cognitive remediation and cognitive training. They all belong to the larger class of intervention called CRT. Functional Magnetic Resonance Imaging showed significant activation in the brain in patients utilizing CRT, (Laatsch, Pavel, Jobe, Lin & Quintana, 1999). From this success seen in modifying the cognitive functioning in patients with strokes, CRT was thought to potentially provide a benefit to those struggling in school.

Researchers have then turned their attention to children. Adapting the program from the stroke patient now to the student, CRT began to delve into the realm of learning. For students this may prove to be a monumental improvement in interventions for students with problems learning. Currently there is inconclusive data to support the use of CRT as an intervention for cognitive impairment. As a result, further research is needed to determine if there is significant efficacy to support its implementation as part of remediation plan for students struggling.

Statement of the Problem

Currently educational interventions designed to improve cognition are being developed for adolescents with problems learning and achieving below grade level, (Trout, Leinemann, Reid, & Epstein, 2007). The impetus of these new methods focuses primarily on improving areas of cognition known to be integral to learning, such as working memory and processing speed (Maehler & Schurchardt, 2009). Research conducted by Andersson (2010) found processing speed and working memory deficits contributed to problems learning math, as well as significant difficulties in the overall learning process, (Weiler et. al, 2000).

Pilot studies conducted by Boivin, Busman, Parikh, Bagirana, Page, Opoka, and Giordani (2010) as well as Alloway, Rajendran and Archibald (2009) examining Cognitive Rehabilitation Therapy (CRT) showed promise for enhancing processing speed and working memory following CRT in small samples. While these data are encouraging, there are still gaps in the evidence supporting the use of CRT more broadly, due to the variability of research methods and inconsistency of measures, (National Academy of Science 2011). As a result, additional research is required to determine whether CRT has a significant effect on cognition in adolescents.

Purpose of the Study

The proposed research will examine the effectiveness of Cognitive Rehabilitation Therapy (CRT) in adolescents by exploring its effect on working memory and processing speed. Current literature suggests modifying aspects of cognitive functioning, such as working memory and processing speed may enhance learning, (Andersson, 2010). Deficits in one or both of these areas play a role in slowing the learning process in adolescents, (Weiler et. al, 2000). CRT Programs, such as LearningRX, have been developed as a learning intervention, unfortunately its significance as an efficacious treatment for cognitive deficits is yet to be conclusively established (National Academy of Science, 2011).

Significance of the Study

This study is designed to address questions related to the effectiveness of CRT as an intervention for adolescents with learning problems. More importantly, this study will examine integral elements related to learning, as these deficits contribute to poor performance and are typically difficult to modify after age 9, (Andersson, 2010). It is the hope this research will provide additional data required to objectively evaluate the use of CRT for students with deficits in working memory and processing speed. This study will review the efficacy of CRT which is custom tailored to the learning needs of the students. It is theorized by custom tailoring a program for the specific student's needs, greater improvement in learning can be made, (Barr & Tagg, 1995). The information gained from this research may add to the body of literature surrounding the use of CRT to modify cognition in adolescents with problems learning.

Research Design

This study will use a quasiexperimental design methodology. More precisely this study is a secondary analysis of archival data captured in the specific participant population. Data will be collected at baseline to assess current cognitive functioning in the areas of working memory and processing speed for each participant. For this study the key efficacy variables will be working memory and processing speed. These data will again be collected following treatment with Cognitive Rehabilitation Therapy (CRT). These data will be analyzed to address the question of what effect does CRT have on these discrete aspects of cognitive functioning in adolescents. The data will be analyzed via an ANOVA processed in SPSS. The resulting analysis will provide the basis for answering the corresponding research questions.

Sample and Sampling Procedure. This study is a secondary analysis of an existing database of adolescents completing Cognitive Rehabilitation Therapy (CRT) designed to enhance learning. As a result of the utilization of the archival database, there will be no randomization, or stratification based upon age, disability, or baseline cognitive function. Only adolescents completing the LearningRx (CRT) program will be utilized for this study.

Study Design. This study is a quasiexperimental study examining the effect of CRT on memory and processing speed. This study design is appropriate when utilizing archival data, since random assignment and controls are not possible based upon the fact the data are already collected and exist in the archival dataset. This dataset was not analyzed previously to examine the effect of CRT and the variables targeted in the study.

Data Collection. This study is designed as a secondary analysis of an archival dataset. As a result an existing dataset will be analyzed to examine effectiveness of this intervention. Data collected pre-CRT and post-CRT will be examined to determine the efficacy of CRT on these specific quantitative variables as noted above. The corresponding analysis will help determine the effectiveness of CRT in adolescents with problems learning. The Woodcock Johnson-III Tests of Cognitive Ability (WJ III Cog) was utilized to capture short-term memory, long-term memory and processing speed pre-CRT and post-CRT. The WJ III Cog is a validated scale by which psychologist measure cognitive abilities. The Woodcock Johnson is a widely accepted, validated measure of cognitive ability, (Daly, Wright, Kelly and Martens, 1997). The following variables will be measured and collected:

1. Working Memory: For the purpose of this study it is defined as the ability to temporarily hold information for processing complex cognitive functions such as language comprehension, reasoning and learning.

2. Processing Speed: For the purposes of this study is defined as the ability to perform simple or complex cognitive tasks quickly. This skill also measures the ability of the brain to work quickly and accurately while ignoring distracting stimuli.

Data Analysis. For this study the data will be analyzed to explore the effects of CRT on memory and processing speed as defined above. Based upon the study design, the analysis will utilize a repeated measure ANOVA via SPSS to analyze the collected data. The results will determine significance of the intervention in question and the corresponding effects in the participant population.

Research Questions and Hypotheses

The following research questions will be addressed through the course of this study. Both the null and alternative hypotheses are provided below.

RQ1.What is the effect of Cognitive Rehabilitation Therapy on working memory in adolescents?

H_0. CRT has no effect on working memory in adolescents.

H_1. CRT has an effect on working memory in adolescents.

RQ2- What is the effect of Cognitive Rehabilitation Therapy on processing speed in adolescents?

H_0. CRT has no effect on processing speed in adolescents

H_1. CRT has an effect on processing speed in adolescents.

This study is a secondary data analysis of archival data utilizing a quantitative methodology. The data analysis for this study will be completed via a repeated measures ANOVA. This ANOVA will be calculated using SPSS as the primary software program. The archival dataset has been provided in a raw format via Excel spreadsheet and will be imported into SPSS at the time of analysis. The repeated measures ANOVA will be completed with all output generated by SPSS. The Woodcock-Johnson scores for working memory and processing speed will be analyzed independent of the other.

In addition to working memory and processing speed, the following descriptive statistics will be collected:

1. Age
2. Gender
3. IQ

Assumptions and Limitations

This study is a quasiexperimental design and as a result there are limitations based upon this design. One of the primary limitations is there is no random assignment of treatment for the participants. All participants will be provided the same intervention. In this study all participants will receive CRT and there will be no control group. It is hoped the research and expected the data will provide enough information to address the research questions for this study.

The data provided for this study are part of an archival database and as a result the recruitment of participants cannot be modified. Based upon research of existing literature, the variables captured via the Woodcock-Johnson III test contained in the archival dataset represent valid and reliable measures of cognitive functioning necessary to address the research questions in the study, (Lohman, 2003). These data are assumed to representative of the larger population in general and should provide for the generalization of these data to other adolescents.

Another assumption with this sample utilized for this study is they are representative of the larger population. They have been recruited based upon identified cognitive deficits which have negatively impact their achievement in school. These participants are assumed to capable of completing the CRT in the course of the trial and are able to complete a pre and post study cognitive assessment. It is also assumed no language deficit exists which would exclude them from being able to participate in CRT interventions or prohibit them from completing the primary efficacy variable measures in this trial.

The last assumption for this study is related to the measurement of the key efficacy variable. The Woodcock-Johnson III-Cog is assumed to be a valid and reliable measure based upon the data presented by the publisher of the test and related validity and accepted reliability, (Lohman, 2003; Riverside, 2001). It is also accepted the persons administering the WJ-III are properly trained and experienced to conduct such measures.

This study is limited in not having a control group by which to compare the experimental group. With this in mind, the study represents a large scale review of the effect of CRT on working memory and processing speed. This value in data justify this study with given its limitations and identified assumptions.

Definition of Terms

The following terms and definitions will be utilized throughout the course of this research:

Cognitive Rehabilitation Therapy. Any cognitive based intervention designed specifically to rehabilitate cognitive processing disorders. This can include methods such as cognitive training and cognitive remediation. All of the designated interventions are designed to enhance the underlying cognitive processes of the participant presenting with deficits.

Processing Speed. For the purposes of this study is defined as the ability to perform simple or complex cognitive tasks quickly. This skill also measures the ability of the brain to work quickly and accurately while ignoring distracting stimuli

Working Memory. For the purpose of this study it is defined as the ability to temporarily hold information for processing complex cognitive functions such as language comprehension, reasoning and learning.

Expected Findings

The literature regarding the use of CRT is limited. Many of the studies conducted have been pilot studies which showed some improvement in cognitive functioning in participants experiencing problems learning, (Alloway, Rajendran and Archibald, 2009). Based upon these finding, it would be expected there should be similar changes seen in adolescents as well. However, what is not certain is whether these changes are statistically significant or may be attributed to other factors consistent with cognitive development.

It has been shown children with mild learning disabilities have been able to improve performance through the application of different CRT programs, (Wilner, 2005). It is hypothesized this study will show similar results, however, the CRT programs are different and therefore it is reasonable to anticipate the efficacy of this program will not show the same result as previous research. There are data supporting a change in working memory for participants completing CRT programs, (Alloway et. al, 2009). This research will provide valuable information needed to effectively answer the research questions.

CHAPTER 2. LITERATURE REVIEW

Introduction to the Literature Review

The topic of cognitive rehabilitation therapy as a treatment option in adolescents is characterized by a relative poverty of literature. As a result, the structure of this literature review focuses on the fundamental components which validate the methodology of the study. Areas of interest such as cognitive functioning, brain functioning, pilot studies and data supporting proof of concept (POC) have been reviewed solidifying the choice of methodology to explore a larger scale efficacy study. By examining the functional components within the literature, the methodology can be constructed in a manner necessary to support the study design. In order to do this, the first step begins with an understanding of the predominant cognitive theories.

At the center of learning lies the ability to processing information and internalize it in a meaningful manner. The development of cognitive ability has been studied for many years by people such as Piaget, Feurstein and Sternberg. These cognitive theorists have provided the foundation upon which learning has been built. As fractures have been found within this foundation, there is a growing need for alternative methods to enhance cognitive abilities. The cognitive processes which have shown to have an important role in learning are working memory and processing. Cognitive rehabilitation may provide a much needed advantage to adolescents struggling in school with problems learning by enhancing either or both of these cognitive processing skills, (Alloway et. al, 2009). The cognitive theories of Piaget, Sternberg and Feuerstein will be examined more closely to identify prevailing theories of cognitive development.

One of the most influential learning theorists was Jean Piaget. He developed a learning theory based upon the concept children learn by observing their environments and engaging this environment constructively, (Ormond 1999). According to Piaget, there were four stages of development for each child. These stages were the sensorimotor, preoperational, concrete operational and formal operational, (Piaget 2005). These stages are necessary from the standpoint of the development of learning within each child. Piaget's theory is interesting and provides great insight into the process of learning, however, it seems there is nothing concrete regarding how to modify cognition in an individual struggling to achieve at an appropriate level. His theory lacks a component of cognitive modifiability. Perhaps this suggests one cognitive theory cannot be comprehensive enough to cover all the aspects integral to cognition and learning.

Another leading theorist is Robert Sternberg. At the center of his cognitive theory is the Triarchic theory of intelligence. More specifically, his theory is comprised of three distinct sections. These sections are componential, experiential and practical, (Sternberg 1985). Sternberg's theory represents a significant change from his predecessors in a way which begins to address the bigger question of how these subcomponents work together to shape how the learning occurs. It also suggests a person can have differing levels of competency within each of the three categories.

Sternberg's theory also focuses on the processing ability and delves more into how the information is used to solve problems and used in a practical manner, (Sternberg 1985). His theory represents a very solid basis for analyzing both gifted learners, as well as those struggling to achieve at level. More importantly the theory begins to suggest flaws in certain aspects of cognitive ability may influence the overall perception of intelligence of the individual. With this in mind, the synthesis of a new concept of remediation becomes possible if the defect can be isolated and repaired begins to emerge. This idea is carried forward by Reuven Feurstein.

Feurstein's theory suggests there is a modifiability of cognition within each person. This signals a change in the thought process of other theorists by opening the discussion of how one fixes the inherent defect in the learning process, (Feurstein 1990). He theorizes through environmental enrichment, the cognitive functioning of the individual is able to be modified and improved. This is significant in that is presents a solution to challenges related to cognitive functioning. It also suggests the mind and intelligence is not static, but rather has the capacity to be changed under the right conditions. This challenges those specializing in cognitive psychology and learning with the task of defining precisely how this can be effectively done. It is the hope of this study to address whether CRT is an effective option to modify components of cognitive functioning.

Theoretical Orientation for the Study

The fundamental theory for Cognitive Rehabilitation Therapy has been developed from the efforts to retrain patients who have suffered from brain injuries or strokes. It has been observed in these patients their cognitive ability can be modified through a series of exercises designed to stimulate the brain in regions where deficits have been noted, (Laatsch et. al. 1999). This is related to an older theory known as Structural Cognitive Modifiability which suggests cognition is able to be changed and enhanced to improve the overall cognitive functioning, (Feuerstein 1990). It is thought this study may provide valuable information related to what extent is cognitive functioning enhanced through interventions such as Cognitive Rehabilitation Therapy (CRT).

The medical model of CRT provides the basis for the use in others suffering from cognitive deficits. Previous studies have shown effectiveness of CRT in children with cancer suffering from cognitive impairment, (Butler & Mulhern, 2005). While these data are encouraging, it is still unclear whether similar results will be observed in adolescents not experiencing a medical condition resulting in impairment of their cognitive processing abilities. This research is designed to explore the viability of CRT in a different participant population.

There is a sense of relative uncertainty regarding the use of CRT as an efficacious treatment for cognitive deficits which present as difficulty learning, (National Academy of Science 2011). The use of CRT as an intervention may be more closely related to instructional enrichment (IE) in which the learning paradigm of the student is considered more important than the teaching paradigm, (Lurie &Kozulin1999). This research will address the important aspects of whether CRT is actually capable of modifying aspects of cognition integral to learning such as working memory and processing speed, (Andersson 2010).

CRT has shown significant improvements in patients with damage to the brain. Patients suffering from white matter diseases like Schizophrenia have shown deficits related to processing speed and have also show significant improvement in cognitive functioning post CRT interventions, (McGurk, Twamley, Sitzer, McHugo, G., Mueser, 2007). While the brain of the schizophrenic and a student with problems learning are different, there are similarities in functional areas of the brain in regard to hypoactivation. For example, in the research by McGurk et. al (2007) it demonstrated deficits in processing speed and working memory could be modified through the application of CRT.

Pilot studies in students with problems learning have also shown similar results, (Alloway et. al, 2009). This establishes the idea while the root cause of the hypoactivation may be different for schizophrenia and problems learning, the CRT therapy can increase activation in these specific areas of the brain responsible for cognitive functioning, (Takeuechi, Taki, Hashizume, Sassa, Nagase, Nouchi & Kawashima, 2011). This research establishes the cognitive equivalency model for effects of CRT. Regardless of etiological basis for hypoactivation in the brain, this model allows for the comparison of interventions designed to increase activation in these specific brain regions. There is growing evidence which supports the idea cognitive remediation techniques like CRT effectively change the brain structures responsible for cognitive functions, (Takeuchi et. al, 2011).

Review of Research Literature and Methodological Literature

In the study conducted by Andersson (2010) students with learning challenges struggled in areas of working memory and processing speed. Also noted in his research were both deficits became more pronounced as the child advances through to subsequent grades. The cognitive deficits play an important role in learning by inhibiting the multi-step encoding and delaying recall of learned material, (Andersson 2010). If these deficits can be modified, perhaps the student will be able to overcome the learning problems by utilizing a program custom tailored to his specific cognitive deficits.

Data from previous studies suggest CRT may have a positive effect for the participants, and in particular on working memory, (Alloway et. al, 2009). Processing speed has also been shown to be positively effected in student experiencing cognitive processing issues, (Butler & Mulhern, 2004). Of particular note was the lack of agreement in previous studies due to inconsistent choices of validated measures related to program efficacy, (Trout et. al, 2007).

In order to control for this, this study will utilize measures widely accepted for their validity and reliability related to cognitive functioning, (Lohman, 2003). The Woodcock-Johnson will be utilized to assess the cognitive ability of the participants in this trial. As noted by Lohman (2003), the Woodcock-Johnson has an established validity and reliability in the range of .80-.97 for selected measures. This allows for some degree of confidence regarding primary variables studied in this trial. The evidence from this study may contribute to the current body of literature by providing new data related to the effects of CRT on cognitive functioning in adolescents, since there is limited data to support its usage, (Journal of Science 2011).

Other research completed utilizing CRT for diseases known to have comorbid cognitive impairment, such as schizophrenia, have shown some promise for the use of cognitive remediation. In the study completed by Sartory et. al (2004) the results showed subjects with cognitive dysfunction improved in some areas of executive functioning and processing speed. This is encouraging for a group suffering from hypoactivation of the brain resulting in cognitive impairment. While the study did show improvement, it was not seen in all areas of functioning. Verbal memory was also shown to improve over the course of the three week treatment period. This suggests CRT and other cognitive remediation programs may hold hope for improving overall cognitive functioning.

The role of working memory in learning is well documented, (Andersson, 2010; Mrazik, Bender and Makovicuk, 2011). Working memory serves a critical role in holding short term information needed to solve more complex problems. As deficits are experienced in this area of cognitive function, these challenges present in the form of a marked inability to process information needed to solve problems, (Andersson 2010). This deficit makes learning difficult at best for those experiencing these deficits. These deficits are not limited to children, but can continue into adulthood.

In the study conducted by Mrazik et. al (2011), they examined the relationship of working memory in adults. They found these same deficits in cognitive processing related to working memory persisted into adulthood. More importantly the impact of these deficits extends past the educational realm and showed a significant effect related to functional outcomes in adulthood. These problems continue and learning challenges tend not to be outgrown, but rather plague the learning through their live. Reading comprehension tends to be a significant and continual challenge for those with working memory insufficiency. This deficit creates a problem for career development and overall satisfaction for the adult as the problems related to reading comprehension persist.

Other effects of working memory deficits are also implicated in attention deficit disorder. In fact the working memory deficit may be responsible for the presentation of the attention deficit disorder, (Martinussen & Major, 2011). This signals an increased role of working memory on functioning in the classroom. As a result, it is suggested in the research alternative teaching methods should be employed in the classroom. Maximizing the students' gifts to overcome the deficits is an important methodology to be explored in dealing with cognitive processing disorders like working memory, (Sternberg & Shaughnessy, 2001).

In children with arithmetic disability, there is evidence supporting the existence of working memory deficits, (Van der Sluis, Van der Leij and de Jong, 2005). The difficulty in storing information in the short term and applying it in a meaningful way to solve a problem seems to create an issue in students' arithmetic deficits. This is similar to what Andersson (2010) found when examining problem solving difficulties in children with problems learning. This represents a significant link with working memory and broader problems learning. The effects or working memory deficits are not limited to math and reading, but rather have other broader presentations.

In the study completed by Alloway et. al. (2009) illustrated the relationship between working memory deficits in students with learning disabilities and IQ. As noted in the study, students with working memory deficits also had lower IQ scores. This is reasonable given the level of cognitive functioning required to complete IQ tests. While this is significant, it also highlights the inability to accurately measure IQ in students with cognitive deficits. Testing does not always reflect the intelligence of the student and some students are quite intelligent but do not perform well on test, as was the case of

Robert Sternberg, (Sternberg & Shaunessy, 2001).

While role of working memory in the process of learning is a critical one for many reasons, understanding its activity within the brain is also equally important. In studies designed to examine the neuroactivation pattern in adolescents, the research clearly identified a hypoactivation in the areas of the brain associated with activities targeting working memory, (Weismer, Plante, Jones and Tomblin, 2005). In order to properly assess this activation, functional magnetic resonance imaging (fMRI) was done for these students. The results represent a better understanding of the functional involvement in the activation of specific areas of the brain implicated in learning.

These data suggest a biological basis for the hypoactivation in brain. More importantly, it builds the foundation for interventions designed to overcome these deficits by remapping the brain to tap into these areas which have little activation and are not damaged. The research by Weismer et. al (2005) was valuable in the fact it also had normal functioning adolescents as a control to be able see the differences in the brain function. The results showed distinct differences in the brain activation in the normal learning working memory activation, which may help to explain the issues with encoding new information and utilizing it in a meaningful manner. These findings build a case for the distinct functional differences in the brains of students with problems learning. The study also showed a difference in the coordination of the components of the brain between those with working memory deficits and normally functioning adolescents, (Weismer et. al., 2005). This also opens the door to alternative interventions targeting these dysfunctions directly.

Working memory is not the only cognitive skill which is an important target for studying. Processing speed is also an integral part of learning and therefore the focus of efforts to remediate poor functioning. Processing speed is conceptually thought of as how quickly one executes cognitive tasks, (Takeuechi, Taki, Hashizume, Sassa, Nagase, Nouchi & Kawashima, 2011). The role of a processing in the learning process has been established in others studies and continues to be a point of interest to researchers examining ways to overcome inherent deficits.

Specific to the Topic or Research Question

At the heart of the research question exists the issues of cognitive processing. Cognitive functioning is integral to the understanding of the effectiveness of CRT. The research has established a link between learning and working memory as well as processing speed, (Alloway et. al, 2009). In fact, it has been noted these impairments contribute significantly to the inability of the student to master complex processes such as mathematics, (Andersson, 2010). Understanding how these deficits impacts functional outcomes for students is significant. Finding a way to improve the underlying deficits may be the next steps in overcoming these deficits to improve overall learning.

In order to understand the complexity of learning, it is important to explore these components more detail. Research has shown deficits in working memory and processing speed can contribute significantly to a decrease in IQ, (Schazt, Kramer, Ablin & Matthay, 2000). The underlying cognitive processing dysfunction is thought to be primarily to blame for many students struggling to achieve at grade level. In an effort to explore this hypothesis in more detail, research has shown improvement in reading comprehension in students completing CRT, (Mahapatra, Das, Stock-Cutler & Parilla, 2010). These results are encouraging and highlight the need to further understand the delicate interplay of cognitive functioning and the value of CRT as an intervention.

Synthesis of the Research Findings

The previous research related to CRT is compelling for many reasons. One of those being it stimulates the discussion around alternative methods by which to change the current brain functioning in the individual. Whether this be a person struggling with cognitive function due to stroke, traumatic brain injury, cancer, or even first episodes of schizophrenia there is evidence to suggest CRT may be an effective intervention, (Butler & Mulhern, 2006; Laatsch et. al, 1999; McGurk et. al, 2007; Satory et. al, 2006). This opens the floor for debate regarding how to use the current data to shape the next steps in the research of this topic.

At the center of this discussion is the research from Takeuchi et. al 2011, which demonstrates the fundamental argument for the implementation of CRT. In this study the researchers examined the baseline functional magnetic resonance imaging (fMRI) each subject. Then a CRT-like intervention was administered and the fMRI was completed. The results quantify the previous assumptions areas of the brain are in a state of hypoactivation which negatively influences the person's ability to process information in a meaningful way. It also begins to unlock the medical theory behind the neural network enhancements which are gained during the process of CRT. More specifically the results advance the idea that neural plasticity and rehabilitation are integral to overcoming the hurdles associated with cognition. The results specifically showed increased area of activation post CRT in participants.

Critique of Research

The collection of studies utilizing CRT as an intervention for cognitive impairment and processing disorders is varied and represents the significant challenges facing the understanding of its utility. Most of the research completed and published has primarily been done in smaller populations. The data are very useful in understanding some part of the role of CRT. However, the target population of adolescents still seems to be understudied at this point in time. As noted in the literature review, the foundation for the use of CRT in cognitive impaired population begins to take shape.

One of the most important aspects of the previous research is the establishment of clear and consistent variables to target for future studies. Based upon the review of the previous studies, the collective findings support the primary efficacy outcomes in the working memory and processing speed as the target of future research. Other studies have shown durability of these measures across various etiological causes of the cognitive impairment. Whether the cause of the cognitive impairment is cancer, schizophrenia or stroke, many participants have shown some response to CRT as intervention. It seems reasonable to begin to examine other participant populations which may benefit from CRT.

Adolescents are a population which may prove to be helped through interventions like CRT. While there is anecdotal evidence suggesting the role of CRT in cognitive impairment, there are no large scale trials examining this to date. This study proposes to examine the effectiveness of CRT in adolescents and hopefully significantly contribute to the understanding of the role of CRT in cognitive processing disorders. One of the biggest limitations of the previous research is the lack of a true experimental design.

Most the research to this point has been competed in limited participant populations with no control group for comparison. This limits the generalizability of the data findings. Another limitation of the previous studies involves the age ranges of the participants. There are very few studies which select adolescents as their target population. As the theoretical considerations are being reviewed, it seems logical to believe there may be a potential benefit in the adolescent population. Many of the pilot studies choose a younger participant. This may be due in part to the thought that many students who don't receive intervention before the age of 9 continue to struggle to catch up, (Andersson 2010).

Summary

The literature review provides a solid foundation for the conceptualization of CRT as a treatment option for cognitive disorders. While the overall data are notably lacking in concrete evidence supporting it in adolescents, there is sufficient evidence to advance the idea it may be helpful and additional studies are needed to establish it as an efficacious intervention. The previous studies are helpful in understanding how CRT is effective in other populations and builds on the idea of cognitive deficits as a function of brain hypoactivation.

The early cognitive theories provide a good overview of learning theory and illustrate a need to develop methods by which to overcome inherent deficits impeding learning and cognitive development. Through focusing attention on the cognitive processing new methods such as CRT may provide a method by which these processing disorders may be modified thereby paving the way for more efficient learning to occur. Until further research is completed, it is difficult at best to generalize the previous findings related to CRT and its use in the adolescent population. Fundamentally the elements are there. Now the next steps must be taken.

CHAPTER 3. METHODOLOGY

Purpose of the Study

The purpose of this study is rooted in the need for objective evaluations of new methods by which to enhance learning. Cognitive Rehabilitation Therapy (CRT) is being touted as a possible intervention and shows promise in some aspects of cognition; however, it has not been evaluated in larger scale trials such as this one, (Trout et. al, 2007). The individual variables identified for this study are integral to the learning process, (Andersson, 2010). This study will determine if there is statistical evidence to support the use of CRT as an effective intervention in adolescents. Cognitive development in adolescents' increases in capacity as early, then levels out, therefore developing interventions which effectively modify cognitive functioning may prove integral to further improving achievement in adolescents, (Luna, Garver, Urban, Lazar and Sweeney, 2004).

In the study conducted by Andersson (2010) students with learning challenges struggled in areas of working memory and processing speed. Also noted in his research were both deficits became more pronounced as the child advances through to subsequent grades. The cognitive deficits play an important role in learning by inhibiting the multi-step encoding and delaying recall of learned material, (Andersson 2010). If these deficits can be modified, perhaps the student will be able to overcome the learning problems by utilizing a program custom tailored to his specific cognitive deficits.

Data from previous studies suggest CRT may have a positive effect for the participants, and in particular on working memory, (Alloway, et. al, 2009). Processing speed has also been shown to be positively effected in student experiencing cognitive processing issues, (Butler & Mulhern 2004). Of particular note was the lack of agreement in previous studies due to inconsistent choices of validated measures related to program efficacy, (Trout et. al, 2007). In order to control for this, this study will utilize measures widely accepted for their validity and reliability related to cognitive functioning, (Lohman 2003). The evidence from this study may contribute to the current body of literature by providing new data related to the effects of CRT on cognitive functioning in adolescents, since there is limited data to support its usage, (Journal of Science 2011). This study is designed to address questions related to the effectiveness of CRT as an intervention for adolescents with learning problems.

More importantly, this study will examine integral elements related to learning, as these deficits contribute to poor performance and are typically difficult to modify after age 9, (Andersson, 2010). It is the hope this research will provide additional data required to objectively evaluate the use of CRT for students with deficits in working memory and processing speed. This study will review the efficacy of CRT which is custom tailored to the learning needs of the students. It is theorized by custom tailoring a program for the specific student's needs, greater improvement in learning can be made, (Barr & Tagg 1995). The information gained from this research may add to the body of literature surrounding the use of CRT to modify cognition in adolescents with problems learning.

The proposed research will examine the effect of Cognitive Rehabilitation Therapy (CRT) in adolescents by exploring its effect on working memory and processing speed. Programs such as LearningRx offer CRT programs thought to be an effective intervention; however, there is limited data to support its use. This study is designed to evaluate the effects of CRT delivered by LearningRx on working memory and processing speed. This study will utilize a quasiexperimental design, given the lack of ability to randomize participants to a particular intervention, (Gribbons & Herman, 1997). The study is designed to investigate what changes, if any, are experienced in cognitive functioning following CRT intervention.

Research Design

For this study the quasiexperimental design methodology was chosen. More precisely this study is a secondary analysis of archival data captured in the specific participant population. As noted, there is no control group, nor randomization which is consistent with the quasiexperimental methodology, (Gribbons & Herman, 1997). The proposed research will examine the effectiveness of Cognitive Rehabilitation Therapy (CRT) in adolescents by exploring its effect on working memory and processing speed.

This study will examine the effect of CRT on cognitive abilities by comparing the change, from baseline to end of treatment, on working memory and processing speed in adolescents. The intent of this study is to objectively evaluate the CRT program created by LearningRx to modify cognition. Currently there is limited evidence to support its implementation as a student focused intervention for students experiencing difficulties learning.

Within this study, the Woodcock-Johnson III (WJ-III) scores were collected at baseline to assess current cognitive functioning in the areas of working memory and processing speed for each participant. The WJ-III will be collected again at end of treatment to determine what effect, if any, was experienced following treatment with CRT. For this study the key efficacy variables will be working memory and processing speed as measured by the WJ-III. These data were collected following treatment with Cognitive Rehabilitation Therapy (CRT). These data will be analyzed via a repeated measures ANOVA in SPSS to address the question of what effect does CRT have on working memory and processing speed in adolescents. It is hoped the resulting analysis may provide the basis for answering the research questions related to the effectiveness of CRT.

Archival data will be analyzed to examine effectiveness of this intervention. Data collected pre-CRT and post-CRT will be examined to determine the efficacy of CRT on these specific quantitative variables as noted above. The corresponding analysis will help determine the effectiveness of CRT in adolescents with problems learning. The Woodcock-Johnson-III Tests of Cognitive Ability (WJ III Cog) was utilized to capture working memory and processing speed pre-CRT and post-CRT. The WJ III Cog is a validated scale by which psychologist measure cognitive abilities. The Woodcock Johnson is a widely accepted, validated measure of cognitive ability, (Daly, Wright, Kelly and Martens 1997).

The following variables will be measured and collected:

Working Memory: For the purpose of this study it is defined as the ability to temporarily hold information for processing complex cognitive functions such as language comprehension, reasoning and learning.

Processing Speed: For the purposes of this study is defined as the ability to perform simple or complex cognitive tasks quickly. This skill also measures the ability of the brain to work quickly and accurately while ignoring distracting stimuli.

Target Population and Participant Selection

New interventions designed to improve cognition are being developed for adolescents with problems learning and achieving below grade level, (Trout et. al, 2007). For this study the primary population will be adolescents who are experiencing difficulty learning as identified by his parent and/or guardian. The larger population is comprised of students in school and has been narrowed down to those experiencing difficulty learning. For this study the sample population will consist of adolescent students experiencing problems learning and students ages 10-19, as defined by the APA criteria, (APA, 2002). Previous research suggests there are underlying cognitive deficits which contribute to the student performing below grade level most of these students fail to overcome these deficits if addressed after the age of 9, (Andersson 2010).

The archival dataset provides just over 3,000 students participating in CRT provided by LearningRx. Of these 3,000, approximately 1,000 are in the adolescent age range for this study. This represents a significantly larger subpopulation being studied. The literature providing the support for the use of CRT has been comparably smaller and recommendations of prior research suggests increasing the sample size to determine the significance of CRT interventions, (Trout et. al, 2007). Other studies have also recommend larger sample sizes would provide a more complete picture of the effect of CRT on cognition which supports the sample size contained within the archival dataset, (National Academy of Sciences, 2011).

This study will be utilizing archival data and therefore there will be no random sampling or recruitment challenges for this research study. Participant recruit has already been completed and is part of the archival dataset. Participants in this study were self-identified presenting with problems learning as noted by the parents and/or guardians who voluntarily sought CRT services through Learning Rx.

Measures

The primary measure chosen for this study is the Woodcock-Johnson III-Tests of Cognitive Ability (WJ III Cog). This tool is designed to assess the cognitive abilities of participants across different domains such as working memory and processing speed. The WJ III Cog is widely used in practice and is regarded as a valid and reliable tool to measure cognitive ability, (Lohman 2003). The WJ III Cog is administered by the trained administrator and the results are interpreted in manner by which to provide a clear understanding of current cognitive functioning. The test has been normed for ages 2-90 years of age. The insight gained via this test allows for understanding the current level of achievement, as well as determining if the participant is developing appropriately. This data can be helpful in determining the participant specific needs related to cognitive ability.

Data were collected pre-CRT and post-CRT will be examined to determine the efficacy of CRT on working memory and processing speed. The Woodcock Johnson-III Tests of Cognitive Ability (WJ III Cog) was utilized to capture short-term memory and processing speed pre-CRT and post-CRT. The WJ III Cog is a validated scale by which psychologists measure cognitive abilities. The Woodcock Johnson is a widely accepted, validated measure of cognitive ability, (Daly, Wright, Kelly and Martens 1997). According to the publishers, the WJ III follows the exact same norms seen within the larger population, (Riverside 2001).

There is strong reliability and validity for the Woodcock Johnson. More precisely the reliability coefficient for the WJ III has been calculated at .97 and for the cognitive battery it was calculated at .90 demonstrating this scale is valid for the intended purpose in this research study, (Hersen and Gross 2008). The data for this study come from an existing archival database. The publisher of the Woodcock Johnson also provided reliability and validity for the WJ III-COG in the range of .80-.90 for most all the components of the scale. The validity and reliability of the WJ III-COG has been supported by other studies and remains a valuable scale for cognitive functioning, (Lohman 2003).

Research Questions and Hypotheses

The following research questions and hypotheses will be explored during the course of this trial.

Res q1-What is the effect of Cognitive Rehabilitation Therapy on working memory in adolescents?

Res q2- What is the effect of Cognitive Rehabilitation Therapy on processing speed in adolescents?

H_0: CRT has no effect on working memory in adolescents.

H_1: CRT has an effect on working memory in adolescents.

H_0: CRT has no effect on processing speed in adolescents

H_1: CRT has an effect on processing speed in adolescents.

Expected Findings

The literature regarding the use of CRT in the adolescent population is limited. Many of the studies conducted have been pilot studies with younger participants which showed some improvement in cognitive functioning in participants experiencing problems learning, (Alloway et. al, 2009). Based upon these findings, it would be expected there should be similar changes seen in adolescents as well. However, what is not certain is whether these changes are statistically significant.

It has been shown children with mild learning disabilities have been able to improve performance through the application of different CRT programs, (Wilner 2005). It is hypothesized this study will show similar results, however, the CRT programs are different, and therefore it is reasonable to anticipate the efficacy of this program will not show the same results as previous research. There are data supporting a change in working memory for participants completing CRT programs, (Alloway et. al, 2009). It is hoped the data from this study will provide valuable information needed to effectively answer the research questions.

It is the hope this study may serve a very important role by answering the question as to whether CRT has a statistically significant effect on cognition as measured by processing speed and working memory. Considering the theoretical construct of cognitive modifiability described by Feurstein (1990), this study will objectively evaluate whether the change in processing speed and working memory is possible and statistically significant, which may contribute to the current limited literature related to the efficacy of CRT, (Trout et. al, 2007). Currently the literature is limited regarding data examining CRT in the adolescent population and some argue after the age of nine, cognition cannot be modified, (Andersson 2010). It is the hope of this study would provide data necessary to understanding the role of CRT in education.

Data Analysis

This study is a secondary data analysis of archival data utilizing a quantitative methodology. Demographic data will be analyzed prior to running the ANOVA to ensure appropriate inclusion in the subset of data to be used to address the research questions. These data include age, grade, gender and primary presenting learning challenges upon entering the CRT program. These data will be reported in order to gain insight into the composition of the sample and to hopefully provide a broader understanding of relevance of findings to other professionals and clinicians.

The data analysis for this study will be completed via a repeated measures ANOVA, (Huck & McLean, 1975). This ANOVA will be calculated using SPSS as the primary software program. The archival dataset has been provided in a raw format via Excel spreadsheet and will be imported into SPSS at the time of analysis. The repeated measures ANOVA will be completed with all output generated by SPSS. The Woodcock-Johnson scores for working memory and processing speed will be analyzed independent of each other. In addition to working memory and processing speed, the following descriptive statistics will be collected:

1. Age
2. Gender
3. IQ

Ethical Considerations

For this trial, the ethical consideration related to participation in this study has been considered there are no major ethical concerns. All subjects will have their data de-identified and therefore will not risk disclosure of identifying information. There is no threat of disclosure of participants' names or other personal information. All participants will be given active therapy and no one will receive sham, or non-therapeutic intervention. As a result, this minimizes the risk of participation in the course of the study. All participants are voluntarily completing the CRT and are free to discontinue at any time with no threat of negative repercussions or consequences.

The legal guardian for each participant voluntarily agreed to undergo treatment via CRT provided by Learning Rx for the purposes of this study. The owner of the dataset has agreed to allow the use of the dataset for additional review during the course of the trial. Safeguards have been put in place which includes the confidential handling of the dataset by this researcher only. The limited exposure to other reduces the likelihood of disclosure of personal information inadvertently. Prior to analysis of the data, all identifying information was removed and only the de-identified dataset will be utilized for this study.

CHAPTER 4. DATA COLLECTION AND ANALYSIS

Introduction

This section of the dissertation contains the details related to the sample utilized for this study. The following sections will provide in depth information related to participant selection, inclusion/exclusion criteria, as well as the results and analysis of the data collected in this study. This study was a secondary data analysis of archival data utilizing a quantitative methodology. The data analysis for this study was completed via a repeated measures ANOVA, (Huck & McLean, 1975).

This ANOVA was calculated using SPSS as the primary software program. The archival dataset was provided in a raw format via Excel spreadsheet and then imported into SPSS at the time of analysis. The repeated measures ANOVA was completed with all output generated by SPSS. The Woodcock-Johnson III Cog scores for working memory and processing speed were analyzed independently of the other. In addition to working memory and processing speed, the following descriptive variables were used to describe the population being studied:

1. Age
2. Gender
3. IQ

The following research questions and hypotheses were evaluated during the course of this trial.

RQ1-What is the effect of Cognitive Rehabilitation Therapy on working memory in adolescents?

RQ2- What is the effect of Cognitive Rehabilitation Therapy on processing speed in adolescents?

The following are the hypotheses tested via the repeated measures ANOVA.

H_0. CRT has no effect on working memory in adolescents.

H_1. CRT has an effect on working memory in adolescents.

H_0. CRT has no effect on processing speed in adolescents

H_1. CRT has an effect on processing speed in adolescents.

Description of the Sample

This study sample population consisted of adolescent students experiencing problems learning ages 10-19 inclusive, as defined by the APA criteria for adolescents, (APA 2002). Participants for this study were sampled from an archival dataset of students participating in CRT through LearningRx. The archival dataset provided just over 2,900 students completing CRT. This represents a significantly larger sample being studied as compared to previous pilot studies of the efficacy of CRT. Since this study utilized an archival data, therefore there was no random sampling or recruitment challenges for this research study. Participant recruitment was completed prior to the archival dataset compilation. Participants in this study were self-identified presenting with problems learning as noted by the parents and/or guardians who voluntarily sought CRT services through Learning Rx.

Data collected pre-CRT and post-CRT and were examined to determine the relative effectiveness of CRT on working memory and processing speed. The Woodcock Johnson-III Tests of Cognitive Ability (WJ III Cog) was utilized to assess working memory and processing speed pre-CRT and post-CRT. The data were supplied in raw format and contained 2,963 participants. Only those participants meeting inclusion criteria were included in the final dataset used for analysis. The inclusion criteria utilized for this study are as follows:

1. All participants must be adolescents.
2. Their age at pretest must be between the age of 10-19 years old inclusive.
3. Participants must have a valid WJ III-Cog score for both pre-CRT and post-CRT to be eligible for analysis.
4. All participants must have completed the entire CRT program.

Based upon the entry criteria, there were 598 participants included in the working memory analysis. For the processing speed analysis, there were 1,277 meeting all necessary entry criteria. The following are the observed demographics for the working memory subpopulation and represented in Table 1.

Table 1.

		Gender-Working Memory			
		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Female	225	37.6	37.6	37.6
	Male	373	62.4	62.4	100.0
	Total	598	100.0	100.0	

Of the 598 participants eligible for inclusion in the working memory analysis, the ratio of males to females is approximately 60% males and 40% females. This is consistent with the rate of observed rates of difficulty learning in the general population, (National Center for Learning Disabilities, 2012). This indicates the representative sample is similar to the larger population and therefore provides for good overall general applicability.

In order to better describe the population of participants being included in this study, IQ and age were all demographic data collected for the sample population studied in this trial. These aspects of this population are described in Table 2 below. There was no exclusion for IQ score and all participants were exposed to active CRT intervention. This age of the sample was consistent with the age of adolescence as defined by the APA, (APA 2002).

Table 2.

Age, IQ and Sample Size

	N	Range	Minimum	Maximum	Mean	Std. Deviation
Age	598	9.2000	10.0000	19.2000	13.379766	2.5138894
PreIQScore	597	144	0	144	94.33	16.065
Valid N (listwise)	597					

Processing Speed Sample. The sample utilized to assess the effectiveness of the second variable, processing speed, was collected utilizing the same 2,963 participants from the larger sample population. The same inclusion criteria detailed earlier were used to determine the appropriate subpopulation for analysis. There were a total of 1,277 participants included in the final sample for analysis. Table 3 details the demographic information for this sample. All participants included met the age requirement with the range being 10-19.9 years old. The mean IQ was 88.51 with a range of 0-149. IQ scores were examined in this population only as a point of reference. It was noted in the distribution six participants did not have a valid IQ score and consequently each was excluded from the IQ range and calculations.

Table 3.

Descriptive Statistics-Processing Speed

	N	Range	Minimum	Maximum	Mean	Std. Deviation
AgeAtPreTest	1277	9.9000	10.0000	19.9000	13.484573	2.5396212
PreIQScore	1271	149	0	149	88.51	18.646
Valid N (listwise)	1271					

The gender distribution for the sample was similar to that of the working memory group. The ratio of males to females was approximately 60% male to 40% female. This reflects the data which support the prevalence seen in the general population, (Center for Learning Disabilities, 2012). The gender distribution is represented in Table 4 below.

Table 4.

Gender-Processing Speed

		Frequency	Percent	Valid Percent	Cumulative Percent
	Female	503	39.4	39.4	39.4
Valid	Male	774	60.6	60.6	100.0
	Total	1277	100.0	100.0	

It was observed these distributions also closely resemble those found in the larger population. These facts provide for the ability to generalize the findings to the larger population. The next section will examine the results of the analysis. The analysis of the each variable is broken down by percentile rank and age equivalence. These values of each variable provide a better understanding of relative change not appreciated via a raw score. Each of these variables will be analyzed in the next section.

Summary of the Results

Working Memory. The variable of working memory was analyzed into two sections. The first section will examine the percentile rank of the Woodcock-Johnson results. The second section of the analysis will examine the age equivalency. Each of the variables was analyzed utilizing a repeated measures ANOVA via SPSS. The following tables represent the results of this analysis. Both the percentile rank and age equivalency were chosen for the primary reason they make the results more meaningful. Examining raw score changes does not provide a meaningful value needed to determine relative effectiveness.

The dependent variables for the purposes of this study were measured pre-CRT and then again post-CRT. These values were compared to determine the significance of any change noticed. In Table 6 the data for the mean pretest percentile score and the posttest percentile are represented. The pretest percentile rank was 39.913, which equates to approximately the 40^{th} percentile rank. This means for all students taking the WJ-III Cog examining the variable of working memory, 60% of all participants scored higher than the sample chosen for this study. By comparison, average for this test would be the 50^{th} percentile. This would represent the scores being in the middle of the distribution and 50% scored higher and 50% scored lower. The 40^{th} percentile rank clearly establishes this sample is below average in terms of cognitive functioning as measure by working memory.

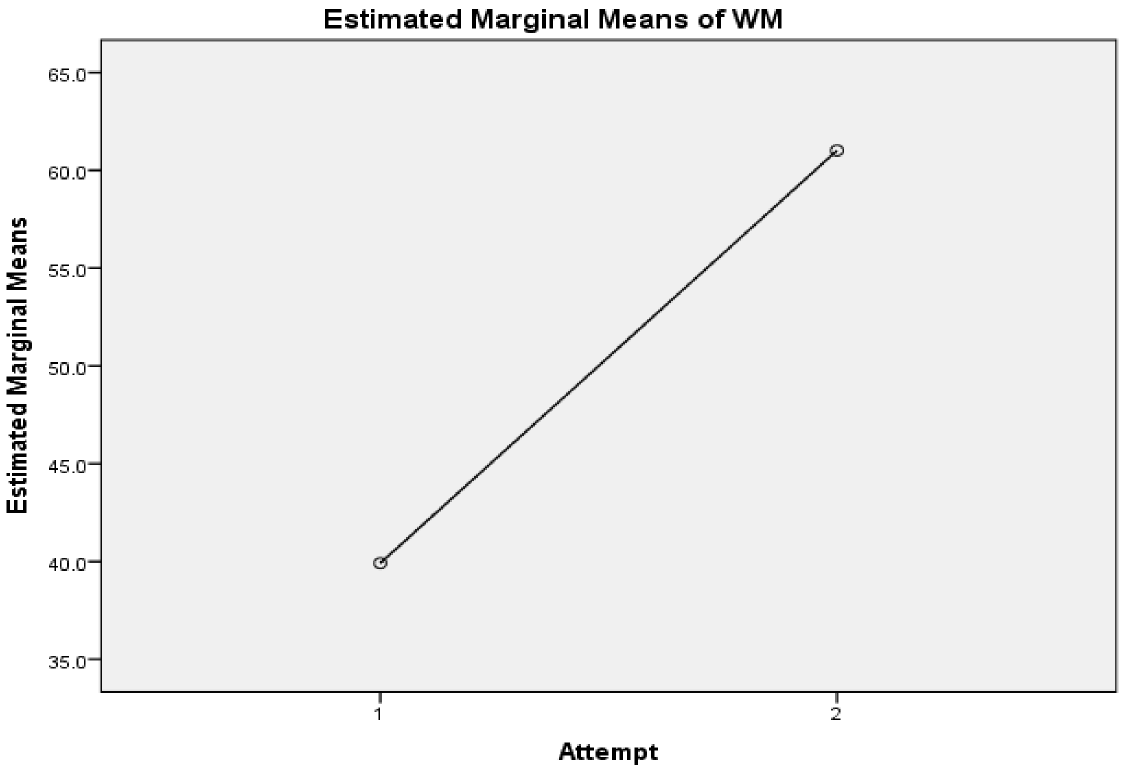
Also contained within Table 5 is the mean for the post-CRT working memory measured by the WJ-III Cog. For this sample the result showed an increase of working memory proficiency. The post-CRT score improved to the 61st percentile. The exact mean value was 61.009. The increase from pretest working memory to posttest working memory is illustrated in the graph in Figure 1. The significance of this change will be discussed in later sections of this chapter.

Table 5.

Descriptive Statistics-Working Memory

	Mean	Std. Deviation	N
PrePercentile	39.913	27.3734	598
PostPercentile	61.009	27.5411	598

Figure 1.



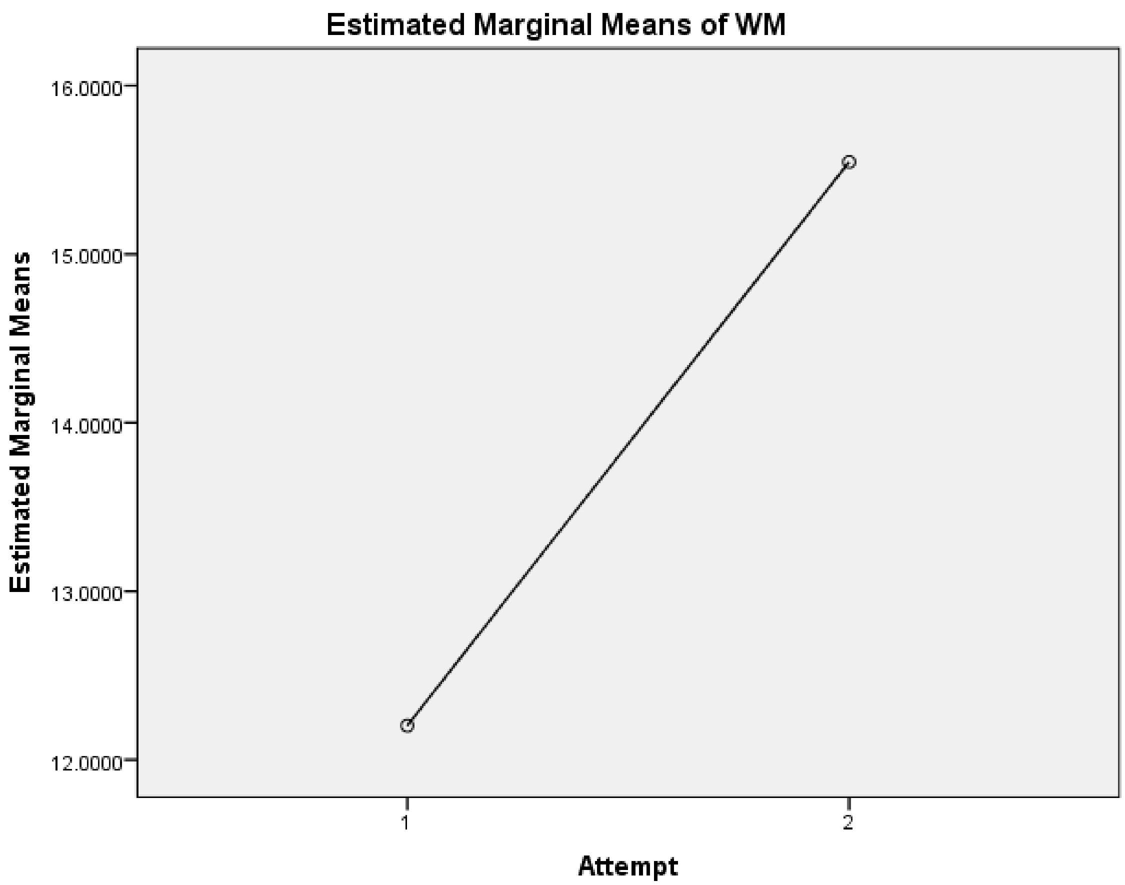
The same methods were utilized to examine working memory in terms of age equivalency. In this measure, the age equivalency measure the level of functioning of working memory observed in each subject. For example, a 15-year-old student with normal functioning working memory should score an age equivalence of 15 or higher. If the value of this measure is below the chronological age, this would clearly highlight an observed deficit in working memory. The data in Table 6 represents the observed change in mean age equivalency after completing CRT. The mean age equivalence prior to CRT was 12.2 years. By comparison, the average chronological age of the sample was 13.37 years old. Again, these data reflect the students have an age equivalency below their actual age. This clearly illustrates the population is achieving below average. In this case, average achievement would be equal to the actual age as noted previously.

The observed change in post-CRT working memory age equivalence is represented. For this sample, the post-CRT value was 15.54 years old. This illustrates an increase of 3.34 years on average for the sample. Figure 2 illustrates this comparison as noted in this analysis. The significance of this will be determined later in this chapter.

Table 6. Descriptive Statistics-Age Equivalency Working Memory

	Mean	Std. Deviation	N
PreAgeEquivScore	12.202174	4.2780354	598
PostAgeEquivScore	15.547157	4.6349575	598

Figure 2.


Estimated Marginal Means of WM
Estimated Marginal Means
16.0000
15.0000
14.0000
13.0000
12.0000
1
2
Attempt

Processing Speed. The same methods by which the data for working memory were described were applied to the variable of processing speed. Table 7 captures the mean percentile pre-CRT and post-CRT. For this sample, the mean before completing CRT was 31.49. This illustrates 68.51 % of students taking this test scored better than this sample in this study. This places the cognitive ability of processing speed for the sample in the lower 1/3rd of all students. By comparison after completing CRT, the scores for the same sample increased by over 15 percentile points to 46.51. This increase raises the mean percentile rank close the average mark of the 50th percentile.

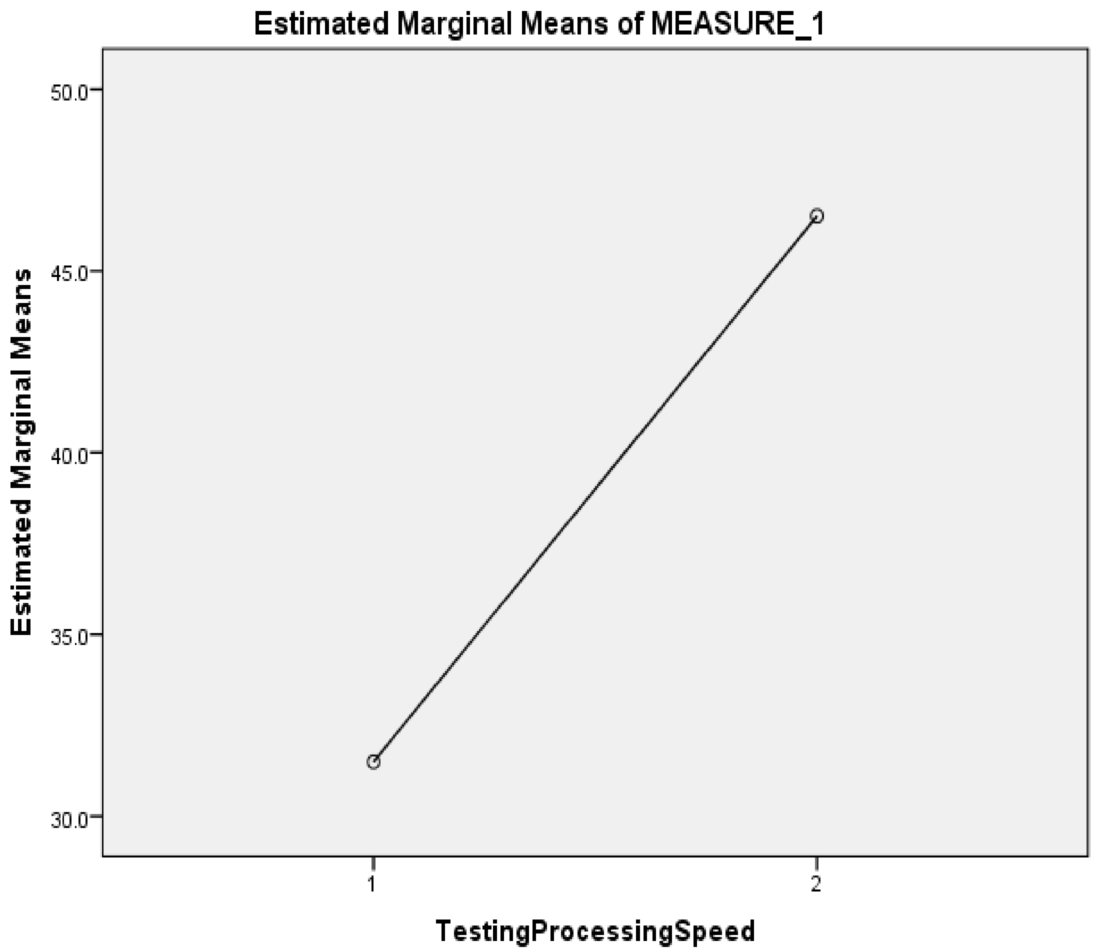
Table 7.

Percentile Rank Pre-Post CRT

	Mean	Std. Deviation	N
PrePercentile	31.498	26.9868	1277
PostPercentile	46.510	30.0163	1277

The observed change in processing speed is noted in figure 3. The significance of this change will be discussed in more detail in later sections of this study. It is clear from the data presented there was an increase in overall mean for the variables measured.

Figure 3.



The age equivalency was examined for processing speed as well. These variables are pre-CRT age equivalency and post-CRT age equivalency. For this sample, the mean age equivalency for this sample was 12.04 years. To put this value into perspective, the actual chronological mean age for the samples was 13.48 years old as noted in Table 8. The pre-CRT age equivalency illustrates nearly a -1.5 years below actual age in terms of cognitive functioning as measure by processing speed. This confirms the sample of students are achieving below average for this particular measure.

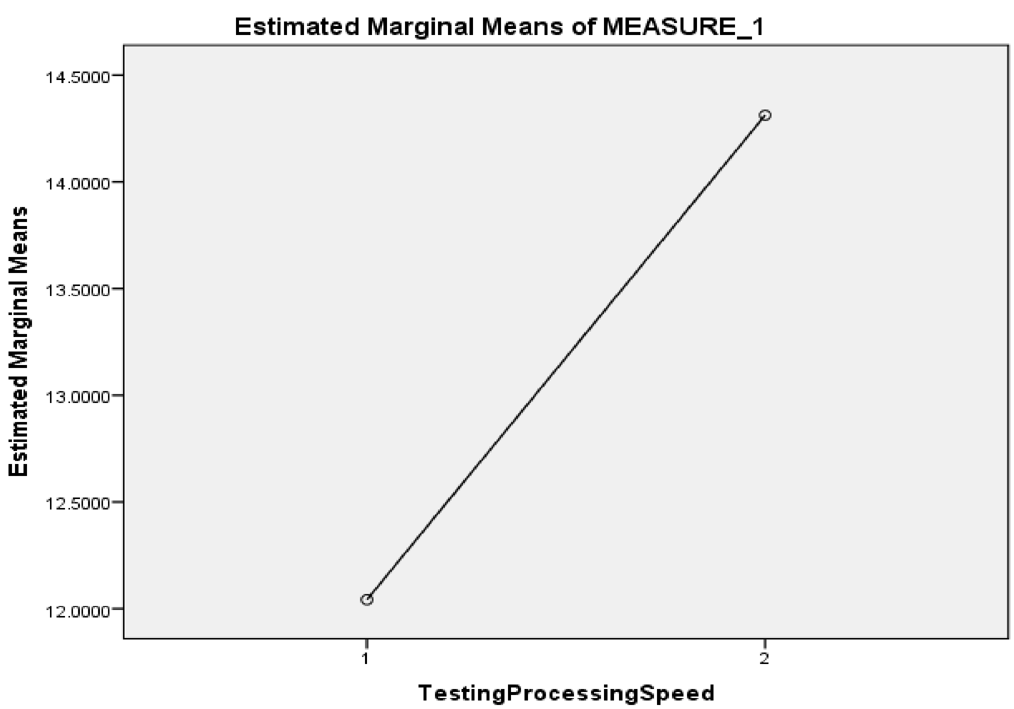
Table 8.

Descriptive Statistics-Processing Speed

	Mean	Std. Deviation	N
PreAgeEquivScore	12.043339	4.0886311	1276
PostAgeEquivScore	14.311677	4.9166812	1276

The post-CRT mean age equivalency was 14.31 years. This represents an increase in age equivalency of 2.27 years. This increase is also illustrated in Figure 4 below.

Figure 4.



Details of the Analysis and the Results

ANOVA-Working Memory. In order to determine if the observed changes in working memory were significant, a repeated measures ANOVA was completed in SPSS. In Table 26 the ANOVA for the percentile scores are represented. The ANOVA illustrates with a *p value* <.001 there is an effect of CRT on working memory. When the mean scores were compared before and after CRT, the results point to a significant effect of CRT on working memory. The power was observed at 1.00 with the *p value* of < .001 as illustrated in Table 10. Based upon this statistical analysis, it is noted that the null hypotheses stating the mean before CRT=mean post CRT must be rejected in this case. This is true when considering the significance level being less than .001. The probability of rejecting the null when in fact it is true is 1 in 1,000 cases. These results were seen both for working memory as measure in terms of age equivalency noted in Table 25 and percentile rank illustrated in Table 26. The effects were durable across both measures of this variable.

Tests of sphericity were run for this sample as well. However, due to the limited number of levels within the dependent variable, this test is not needed. It is only applicable when more than two levels of the dependent variable are being compared, (Howell, 2010). Any discussion of sphericity is not required for this study based upon the design of the trial. Sphericity is only required when there are at least 3 measurements of the variable in question, (Hinton, Brownlow & McMurray, 2004).

The results of the repeated measures ANOVA for working memory are presented in Tables 9 and 10. Table 9 represents the working memory score ANOVA as represented by the age equivalency calculation. As noted in the previous section of this chapter, the change in mean age equivalence was +3.34 years. The statistical analysis clearly indicates the increase in age equivalence was statistically significant. Within this calculation, it is noted that the *p value* is <.001. Based upon this calculation the null hypothesis must be rejected. The analysis shows the means are not the same for the participants completing CRT with regard to working memory. This indicates there is a statistically significant difference between these values as measured by age equivalency.

Partial ETA Squared was calculated as part of the ANOVA for each variable in the study. Partial ETA Squared is a calculation which allows for the estimation of effect size. This calculation allows for the interpretation of the results in regard to the degree of variance which can be attributed to the intervention (CRT) on the dependent variable measured (Cognition). This affords a deeper understanding of the magnitude of difference observed in the means compared. Guidelines typically establish values of .01 = small effect, .06 = moderate effect and > .14 = large effect of the intervention being studied on the variable in question, (Cohen, 1998). This ANOVA in Table 9 illustrates a large effect related to CRT on working memory in the participants of this study. The ETA value of .524 shows this large effect observed in this study.

Table 9.

Measure: Working Memory-Age Equivalent

Source	Attempt	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Attempt	Linear	3345.485	1	3345.485	658.306	.000	.524	658.306	1.000
Error Attempt	Linear	3033.930	597	5.082					

a. Computed using alpha = .05

Working memory was also measured in terms of percentile rank. As mentioned in previous sections of this chapter, the percentile rank assesses where the participants performance ranks in relationship to all other taking the WJ Cog III assessment. It was observed the pre-CRT percentile rank for these participants was at the 40th percentile (39.9 actual). Following CRT the observed percentile rank was now at the 61st percentile (61.009 actual). This represents an increase of over 21 percentile points in working memory.

The ANOVA for this measure is contained in Table 10. The statistical analysis shows the *p value* is <.001 in terms of the difference between mean percentile pre-CRT as compared to post-CRT. This analysis indicates the null hypothesis must be rejected. These data support the idea there is a difference between the means after CRT and furthermore these means are statistically significant. The Partial ETA Squared was also calculated and showed a large effect, .502 for this variable.

Table 10.

Measure: Working Memory-Percentile Rank									
Source	Attempt	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Attempt	Linear	133067.155	1	133067.155	600.745	.000	.502	600.745	1.000
Error Attempt	Linear	132237.665	597	221.504					

a. Computed using alpha = .05

ANOVA-Processing Speed. The variable of processing speed was analyzed following the same methods executed for working memory as reported previously. SPSS was utilized to evaluate the statistical significance of any change observed. Processing speed was examined in terms of age equivalency and percentile rank. Tables 11 and 12 represent the ANOVA for processing speed.

There was an observed change in processing speed following CRT for these participants. The pre-CRT age equivalency was 12.04 years old. Following CRT, the mean increased to 14.31 years old. This represents and age equivalency increase of +2.27 years of age. Table 12 displays the ANOVA for this observed change. Based upon the statistical analysis completed, it shows the change observed was statistically significant. The *p value* is <.001 for this variable. This leads to the conclusion the null hypothesis must be rejected, as there is a statistically significant difference between the means.

Table 11.

Measure: Processing Speed-Age Equivalency

Source	Processing Speed	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
ProcessingSpeed	Linear	3282.740	1	3282.740	698.637	.000	.354	698.637	1.000
Error(Processing Speed)	Linear	5990.940	1275	4.699					

a. Computed using alpha = .05

The data related to processing speed was also analyzed from the perspective of percentile rank. As previously reported, there was an observed change in mean percentile rank for the sample when comparing pre-CRT scores to post-CRT scores. The pre-CRT percentile rank was 31.5 and the post-CRT percentile rank is 46.5. This represents a change of +15.0 percentage points. An ANOVA was run via SPSS to determine if this change was statistically significant. Table 12 details the results of the analysis. Just as in working memory, the Partial ETA Squared values were calculated for processing speed. These values are represented in Tables 11 and 12. In both measures, the ETA observed indicated a large effect size, .354 and .344 respectively.

Table 12.

Measure: Processing Speed-Percentile

Source	Processing Speed	Type III Sum of Squares	*df*	Mean Square	*F*	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Processing Speed	Linear	143895.094	1	143895.094	667.8	.000	.344	667.833	1.000
Error(Processing Speed)	Linear	274934.411	1276	215.466					

a. Computed using alpha = .05

The ANOVA supported the conclusion the observed 15.0 percentage point increase is statistically significant. The measured *p value* is <.001, therefore allowing for the null hypothesis to be rejected. This leads to the conclusion there is a difference in the mean after completing the CRT program and the analysis provides a great deal of confidence and reduces the risk of rejecting the null in this case. The larger implications of these results will be discussed in more detail in the next chapter.

Conclusion

During the course of this study, the following hypotheses were addressed in this study:

H_0. CRT has no effect on working memory in adolescents.

H_1. CRT has an effect on working memory in adolescents.

H_0. CRT has no effect on processing speed in adolescents

H_1. CRT has an effect on processing speed in adolescents

The repeated measures ANOVA provided the statistical evidence needed to answer the defined research questions. In the case of the null hypothesis for working memory, it was concluded the null should be rejected. This decision was based upon the fact the changes from baseline in working memory were statistically significant. With a *p value* of $<.001$ it was determined the effects of CRT on working memory were significant. The H_1 was accepted for this variable.

The second research question related to processing speed was also addressed in this course of this study. The same statistical methodology was applied to the variable of processing speed. The ANOVA showed the change in mean from pre-CRT to post-CRT processing speed scores was statistically significant. With a *p value* $<.001$ it was concluded the null hypothesis should be rejected and the H_1 was accepted for this variable. The bigger implication of these conclusions will be reviewed in Chapter 5 of this study.

CHAPTER 5. RESULTS, CONCLUSIONS AND RECOMMENDATIONS

Introduction

This chapter of the study discusses the results, conclusions, implications and recommendations for further research uncovered during the course of this study. While Chapter 4 discussed the results and details of the statistical analysis of the study, this chapter builds upon this and delves deeper into the implications and possible application of the research. This chapter provides additional detail which directly adds to the richness and understanding of the study's scientific importance. This is achieved in part by addressing the observations which surfaced following the analysis. These final pieces of the study are discussed in more detail in this chapter than was presented in chapter 4.

The process of learning may prove challenging for some more than others. In order to shift the learning paradigm in a positive direction, it is important to challenge current schools of thought. It has been theorized there were challenges facing children with semi-permanent learning difficulties which shows resistance to remediation after the age of 9, (Andersson 2010). It is thought these students face challenges related to cognitive functioning and somehow these hurdles cannot be removed in order to achieve grade level results. Finding interventions which prove to be efficacious has been challenging at best.

Thought leaders like Reuven Feuerstein hypothesized cognition can be influenced via enrichment of the environment to stimulate cognitive development, (Feuerstein, 1990). The shape of cognitive functioning is beginning to evolve and move a different direction. In diseases known to result in cognitive deficits such as Schizophrenia, stroke and Multiple Sclerosis these conditions have a signature of marked cognitive hypoactivation, (Butler & Mulhern, 2005; Satory et. al, 2004; Takeuechi,et. al, 2011 **).** In previous research, the chasm created by these deficits has been bridged for some participants via interventions such as CRT. The pilot studies provided evidence to support further study to understand its effects on specific aspects of cognition in different populations, (McGurk et. al, 2007). This study took a closer look at the role of CRT in examining the modifiability of cognition in the adolescent.

Summary of the Results

The purpose of this study is dictated by an important need for objective evaluations of new methods being utilized to enhance learning. Cognitive Rehabilitation Therapy (CRT) is an alternative intervention which shows promise in some aspects of cognition; however, it had not been evaluated in larger scale trials such as this one, (Trout et. al, 2007). This study addresses the limitations noted in previous research by increasing the sample size being studied. Based upon the increase sample size, this research is afforded the opportunity to determine whether any changes observed with greater power than many of pilot studies completed prior.

The individual variables identified for this study are integral to the learning process, (Andersson, 2010). This study examined working memory and processing speed to establish whether there is statistical evidence to support the use of CRT as an effective intervention in adolescents. Cognitive development in adolescents' increases in capacity as early, then levels out, therefore developing interventions which effectively modify cognitive functioning may prove integral to further improving achievement in adolescents, (Luna, Garver, Urban, Lazar and Sweeney, 2004). It is important to first understand how this study is designed.

For this study the quasiexperimental design methodology was chosen. More precisely this study is a secondary analysis of archival data captured in the specific participant population. As noted, there is no control group, nor randomization which is consistent with the quasiexperimental methodology, (Gribbons & Herman, 1997). The proposed research will examine the effectiveness of Cognitive Rehabilitation Therapy (CRT) in adolescents by exploring its effect on working memory and processing speed.

There are limitations present within this study as well. One major limitation is the lack of a control group. In order to further provide a comparison between active treatment and placebo, a non-treated group would have provided this treatment group for further comparison. Another limitation of this study was the lack of collecting multiple dependent variable measurement during treatment. This additional data would have provided for additional data analysis to possibly identify a time point at which cognitive improvement occurred. This information would provide insights into exposure durations necessary for cognitive modification to occur. A further limitation was the study lacked randomization. If there were multiple treatment arms, random assignment could have occurred.

The data presented in chapter 4 highlight the efficacy of CRT utilized in adolescents completing the LearningRx program. The variables of working memory and processing speed were analyzed and did in fact show changes at the end of treatment as compared to baseline. The data illustrated a marked increase in both working memory and processing speed in terms of percentile rank and age equivalence as measured by the Woodcock-Johnson III-Cog test. These results open the discussion in understand how CRT fits into a remediation program designed to help improve overall cognition functioning for students suffering difficulties learning in traditional educational environments.

The variable of working memory was measured and was observed as the pre-CRT percentile rank for these participants being at the 40th percentile (39.9 actual). Following CRT the observed percentile rank increased to the 61st percentile (61.009 actual). This represents an increase of over 21 percentile points in working memory. As noted in the previous section of this chapter, the change in mean age equivalence was +3.34 years. The statistical analysis clearly indicates the increase in age equivalence was statistically significant.

The same methods were applied to processing speed and there was an observed change in processing speed following CRT for these participants. The pre-CRT age equivalency was 12.04 years old. Following CRT, the mean increased to 14.31 years old. This represents and age equivalency increase of +2.27 years of age. As previously reported, there was also an observed change in mean percentile rank for the sample when comparing pre-CRT scores to post-CRT scores. The pre-CRT percentile rank was 31.5 and the post-CRT percentile rank is 46.5. This represents a change of +15.0 percentage points. Both of these measures of processing speed were statistically significant, signally a positive effect of CRT on processing speed and cognition.

Discussion of the Results

The roles of working memory and processing speed have been well established when considering the learning process as noted earlier in this dissertation. Primarily this study was designed to understand the effect of rehabilitation techniques on cognition and to address whether cognition can be modified via these techniques within the specific age range of the sample. This study illustrates cognition is able to be modified and in fact, a statistically significant change in working memory following CRT was observed. This signals a potential alternative intervention for students struggling to achieve at grade level.

One very significant signal detected during this research was the fact working memory and processing speed could be modified, even in older students. This is a deviation from the phenomenon observed by Andersson (2010). In this research it was noted that students needed to have interventions earlier in order to positively impact the learning process. Students who did not have interventions implemented prior to age 9, continued to struggle in both math and reading and had little chance to improve their learning ability. This research clearly shows this is not the case. This study is in agreement with some of the pilot studies examining memory and processing speed in which there were gains seen in smaller participant populations, (Mrazik, M., Bender, S., & Makovichuk, C., (2010). It points to cognitive ability being very responsive to the correct stimulation and having the capacity for modifiability.

The same evidence was seen following CRT in other participant population. In the research conducted by Laatsch et. al (2004) participants showed increased brain activity following CRT. This data is important in that it builds the foundation for a new theory hypothesizing cognitive dysfunction is secondary to brain hypoactivation. By establishing the relationship via fMRI data depicting less brain activation prior to CRT, then observing an increase cognitive functioning post CRT, it appears to point to a distinct component or structural defect implicated in cognitive dysfunction. This signals the existence of a divergent pathway to remediate difficulties learning. In some cases there was little hope for changing the underlying cause and prognosis was related to limited outcomes. More importantly, these alternative treatments highlight the inherent ability to modify these deficits to increase cognitive functioning.

Currently many other approaches to difficulties learning embrace similar ideas to what the research completed by Andersson (2010) discovered. Essentially this equates to believing much of one's cognitive ability is solidified and therefore resistant to remediation. The goal appears to be quantitative decrease of workload instead of a qualitative cognitive increase. This is the approach many schools systems take when dealing with students struggling to learn. Many schools have adopted a methodology to modify the volume and quantity of workload instead of working to modify the student.

Many times the development of an IEP consists of reducing the quantity of work in order to bolster the grades of the student (Jung, Gomez, Baird, & Keramidas, 2008). The IEP is intended to design a specialized program to educate the student according to his specific needs by providing either accommodations or modifications. However, it seems there are mixed results and students still failed to reach their educational goals.

The IEPs may help improve report cards; unfortunately it may mask the underlying problems and not work to enhance the fundamental learning process.

It has been suggested a more student centric learning paradigm should be embraced, (Barr & Tagg, 1995). As the results of this study suggest CRT should be considered in the student centric remediation plan. Clearly it is effective in improving working memory and processing speed which have been implicated as integral components of learning. It makes sense to begin to leverage newer methodologies to change the student instead of only changing the work they are expected to do.

These quantitatively focused remediation plans address achievement in terms of grade achievement not underlying cognitive functioning. More precisely the level of learning is measured in terms of grades and not based upon internal changes experienced within the cognitive functioning of the student. This results in the reduction in amount of information which is assigned to the student to learn. The primary belief behind this is the learning difficulty is related to too much to be learned. Some of this paradigm may be based upon the idea an adolescent's cognitive ability levels off as he gets older, (Luna et. al 2004). Based upon the findings of this study, that conclusion seems to be inaccurate, or at least lacking in conceptualizing cognition in terms of modifiability. The predominant feeling is cognition is set the older the student becomes.

In fact, quite the opposite was found. The detailed analysis of this study showed both variables of cognitive functioning were significantly improved following the administration of CRT. This finding is consistent with the literature review and previous research reviewed when designing this study. In particular, it affirms the theory put forth by Feuerstein (1990) which notes cognitive ability can be improved following immersion in a highly rich and stimulating environment. This research observed improved cognition following a change in the environment in which learning occurred. Perhaps this suggests a biological signal in response to the environment of the participant.

As stated previously, research conducted by Laatsch et. al (2004) explains a possibly biological basis for this improvement in cognitive function. It is believed the same results were seen in this study as in the Laatsch trials. Unfortunately, fMRI was note used in this study, so conclusively the claim cannot be verified, however, it is theorized the increase in cognition is related to possible activation changes similar to what Laatsch observed. In order to understand this, it is necessary to briefly revisit this research.

Laatsch studied patients with strokes instead of students with difficultly learning. While the samples were not the same, the same increase in cognitive functioning was observed in both this study and the previous pilot studies. Other research examining CRT in different participant populations noted the same phenomenon in Multiple Sclerosis, Schizophrenia and cancer, (Butler & Mulhern, 2005; Satory et. al, 2004**;** Takeuechi, et. al, 2011**).** These findings support the development of a new theory related to cognitive hypoactivation as a root cause of difficulty learning.

This was another observation of this trial which was unexpected. All of the participants presented with difficulty learning in school. Many had tried other accommodations, but still continued to achieve below grade level. What this signals is there is an additional step needed in the process of modifying learning. This study contributes to the understanding of cognitive hypoactivation as the cause of cognitive impairment, not cognitive inability. The results of this study show these participants are capable at achieving at or above normal following CRT.

If there was a permanent structural deficit, this would have been a negative study showing no effect of CRT. It showed very robustly the opposite. This underscores the necessity of understanding the relative etiology of the cognitive impairment and shifting focus away from only the clinical presentation, i.e. grade level failure. Essentially educators need to focus treating the cause instead of merely addressing the symptoms of cognitive impairment. This study adds to the literature needed to further this understanding and new theory. Prior to this study, there was little research designed to detect this difference.

Utilizing the previous studies and combining the results of this study, it is reasonable to conclude CRT may be an effective part of a remediation program designed to improve cognitive functioning in adolescents. More importantly and perhaps counter intuitively so, it suggests hyper-stimulation may be a more appropriate method by which to strengthen cognitive functioning in those struggling to learn. This is opposite of what many schools to as part of an individualized education plan (IEP).

Discussion of the Conclusions

The results of this research indicate there is a positive effect on cognition for adolescents completing CRT. The analysis showed the changes observed are significant enough to be attributable to CRT and not chance alone. Treating cognitive deficits with CRT seems to make sense from the perspective of treating the underlying cause of the challenge learning. One clear advantage to the use of CRT is it is effective in an age group which was previously thought to level out in terms of further cognitive development, (Luna et. al, 2004).

Furthermore, in previous studies results indicated students who did not receive remediation prior to age 9 continued to struggle to achieve at grade level, (Andersson, 2010). This previous research seemed to suggest cognitive development and functioning had a tender age, after which improvement was not likely for the student. This research smashes through this perceived hurdle. It achieves this by illustrating the underlying integral components of problem solving, namely working memory and processing speed, can be significantly improved following CRT. This study is consistent with other research completed previously in participants with cognitive deficits secondary to other neurodegenerative diseases, (Butler & Mulhern, 2005; Laatsch et. al, 2004; Satory et. al, 2004**;** Takeuechi, et. al, 2011). These results could signal a change in the teaching methodologies designed to help student achieve at grade level by focusing on the cause and moving away from only symptomatology.

The emerging theory identified in this research surround the idea of hypoactivation of the brain as the primary reason for inefficiency in cognitive processes. When examining the pre-CRT cognitive skill sets, it is obvious these were below normal. Following CRT these processes increased. This suggests traditional tools used to measure intelligence may not be sensitive enough to detect changes occurring within the student. Previous research observed a similar effect in other populations, (McGurk et. al, 2007). By focusing on adolescents, this study represents a significant solution to a problem noticed, but seldom treated appropriately. Perhaps cognitive ability is not being measured utilizing an appropriate tool.

If grades are utilized as the direct measure of cognitive ability, it may provide only a one dimensional analysis of the underlying cognitive functioning of the students. In this study, IQ was not used as a primary efficacy variable, but was examined in a post hoc analysis. The pre-CRT mean IQ was 88 illustrating the participants were in the low average category. Following CRT it increased to over 100 which place the participants in the high average IQ range. What this suggests is there may be an increased ability related to taking an exam. Essentially, it suggests following CRT, participants performed better on tests which rely on recall and processing. It may illustrate an increased ability to apply retained information for the purposes of taking a test.

IQ was not chosen as a variable for the original hypotheses based upon questions of relative validity as a measure of intelligence. It also does not begin to describe the functional changes observed using the Woodcock Johnson III-Cog scale. The conclusion based upon this observation is a better method by which to assess the students' ability while in a remediation program is needed. Standardized testing may fall short of highlighting the cognitive functioning of the student.

With the sensitivity of IQ and grades in question as a general measure of cognitive ability, the recommendation from this study would be to evaluate relative change within each participant during completion of a remediation program and avoid comparison to relative normal ranges. Just as this research completed baseline assessments, so too would the recommendation for school programs to assess the baseline cognitive function and them craft a customized rehabilitation plan to suit the needs of the student. While this is the intent of many IEP plans, many focus on achievement, i.e. grades, as the measure of success. Unfortunately, this is not adequate to detect changes in variables like working memory and processing speed. Incorporating cognitive process evaluation as a baseline measure will allow for more robust discussions related to the effectiveness of IEPs and/or rehabilitation programs. These insights allow for a more specific targeting of the deficits which affect the students' ability to achieve on standardized tests.

For many students the standardized tests may not adequately gauge change in cognition, however, WJ III Cog scores may provide a diagnostic advantage for educators and parents to determine appropriate levels of response to specific interventions within each student. The WJ III Cog allows for a more sensitive tool by which to measure cognitive changes. These advantages allow for a more comprehensive conceptualization of the internal modifications occurring secondary to the changes in environment. Feurstein (1990) suggests enhancing the stimulatory component of the environment would positively enhance the cognitive abilities of the student. This overcomes the hypoactivation and facilities cognitive changes in response to the increase stimulation. This research illustrates the same outcomes hypothesized by Feuerstein.

Limitations

This study was designed to examine an archival data to test the hypotheses related to the efficacy of CRT on elements of cognition. One glaring limitation of the study was the lack of a control group. All participants were exposed to the active treatment. By not having a control group, it does not allow for a between group ANOVA to be conducted. The difficulty of having a control group not receiving an active intervention is many participants and family have already experienced this with unsatisfactory results. This may lead to a difficulty in recruitment if a non-treated control group was used. Regardless of this fact, the results are still significant. Having a control group would have provided another level of analysis to address questions regarding a potential placebo effect. While there are numerous cases showing poor outcomes related to non-treatment of learning disabilities, it is still an observed limitation in this study design.

Another observed limitation was related to the number of measurements of the dependent variable. Having multiple time points in which the dependent variable was measured would allow for another level of analysis. It may provide an insight into an observable threshold establishing a sensitive exposure point necessary for modification to occur. The repeated measures ANOVA was the proper design for this trial, however providing more measures would further add to the understanding change thresholds of cognition.

During the course of this study, a new theory of structural hypoactivation emerged. The historical research substantiates this theory; however, this study was limited in so far as it didn't contain an fMRI evaluation to examine pre-CRT and post-CRT brain activity in conjunction with measuring working memory and processing speed. If this study contained this measure, it is thought additional information could have been learned regarding the relationship between structural activity and cognition.

Recommendations for Future Research or Interventions

The data from this study support the use of CRT as part of a remediation plan for students struggling to achieve at grade level. The data suggest CRT has a positive effect on both working memory and processing speed. One recommendation would be to examine other variables of cognition like visual spatial memory to see if other variables of cognition are positively impacted as well. This could lead to a more comprehensive profiling of cognitive attributes which are correlated with functional outcomes.

For example, it would of interest to observe whether the gain in working memory and processing speed are independently affected by CRT, or whether they are correlated with other cognitive processes. These findings may prove beneficial in identifying likely cognitive processes to target and apply to a broader population. This concept works toward the idea of student specific learning programs based upon the cognitive fingerprint established at baseline. This could advance the educational efforts significantly if the cognitive code could be broken as it surrounds the concept of cognitive impairment secondary to structural hypoactivation.

Future researchers should consider studying the effects of CRT in participants over specific set time points to determine if there is a time point in which the effects of cognitive improvement begin to take shape. This would be helpful in establishing mean exposure times needed to show appreciable gains in cognitive functioning. With this information it may be possible to effective craft remediation plans appropriate in length to maximize cognitive improvement. It may also provide a treatment algorithm needed to determine mean exposure times. Examining and intermittent exposure schedule to CRT would provide insight into whether cognitive improvement in as additive process. It would answer the question as to whether there is a ceiling to the cognitive improvement observed.

Another recommendation would be to conduct a longitudinal study. The results of this current study don't address how long the positive effects can be seen. While the data support the conclusion CRT is effective, what still remains to be seen is whether these improvements are transient or permanent in nature. A longer study may provide more detail regarding the long-term cognitive improvement. It would also be recommended future studies examine acute treatment with CRT as compared with variable interval schedules of CRT. There may be an additive effect of CRT in subsequent cycles of CRT as compared to an acute treatment phase.

Conclusion

The results of this study highlight a number of critical points not observed in other studies. The most important of these points being the evidence cognition is capable of being modified. Finding the proper method by which to modify cognitive function is the lynchpin of the rehabilitation process. Contrary previous theories, cognition can be positively influenced in an older student as observed in the adolescent participant population. This is a powerfully positive outcome.

Many of schools and teachers attempts to improve learning via IEPs consisted primarily of modifying or accommodating the students learning plan by reducing the amount of work needed given the length of time required for the student to process the task. While this approach was well intentioned and consistent with hypothetical cause of the cognitive dysfunction, it fell short of the needs of the student. The primary underlying condition contributing to the presentation of a student struggling to learn is more than the outcome. To conceptualize this in a different way, the symptom is not the cause.

This study confirms the work done by Laatsch (2004) which showed cognitive function is linked to brain activity. Many of the smaller pilot studies approached this problem in a different manner. These studies began employing the new concept of CRT to improve the underlying cognitive function. These studies contributed to the foundation and thought of using CRT more broadly for other populations suffering from cognitive deficits. This study used these studies as a conceptual launching pad to explore

CRT in an underserved population.

The adolescent population seems to get lost in the transition at times. From late elementary to middle school and later high school and college, this population experiences many shifts in environmental context and therefore lacks continuity of instruction. As a direct consequence, they may more likely to blend in to the educational background and not get the help they need. CRT is a program which now shown to be effective in treating the cause of difficultly learning. In this study all variables were shown to be statistically significantly improved following CRT intervention. This represents a new tool to be utilized in an effort to fix the problem, not just smooth out the bumps to create an appearance of achievement.

The strength of the study is derived in the sample size used for analysis. Previous research studies were much smaller with most in the range of 5 to 50 participants, (Butler & Mulhern, 2005; Laatsch 2004; Satory et. al, 2004**;** Takeuechi, et. al, 2011). This study looked at 598 participants for working memory and 1277 for processing speed. The results of this large sample translate into an ability to confidently interpret the positive effect of CRT on cognition. This study definitely answers the question as to whether CRT works. The answer is an emphatic “yes”. There are also some more subtle conclusions which should be addressed.

The previous literature published on this topic is very limited. This study will significantly add to the quality of research published on this topic. It will also add to the understanding related to the topic of difficulty learning as a function of cognitive hypoactivation. The background research points to the strong likelihood many of the cognitive deficits observed are related to inactivity of the brain. This conclusion significantly changes the previous theory being, there are limitations within the individual which prohibit them from achieving at grade appropriate levels. A further study utilizing fMRI to substantiate this claim would be recommended.

This new theory presents a multi-tier approach to learning. As an unexpected result of this study, there is now evidence to support the use of CRT to remediate this function deficit. Now the clinical presentation, difficulty learning, can be tied to a structural deficit, hypoactivation. This study goes one step further to establish CRT can effectively modify this deficit. This provides another approach to creating brighter futures for many students.

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