The Effectiveness of Cognitive Training on Cognitive Skills in Children Ages 5 to 7-years Old

Submitted by

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Abstract

The purpose of this casual-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on early childhood children ages 5 to 7. The goal was to determine if there is a significant difference in pre-test and post-test scores of working memories, visual processing, auditory processing, processing speed, and logic and reasoning following completion of the LiftOff cognitive training program. The data were collected from a normed and validated standardized cognitive assessment for the pre-intervention and post-intervention assessment results, Woodcock-Johnson III Tests of Cognitive Abilities, and subtests from the Woodcock-Johnson III Tests of Achievement of the 5 to 7-year old children who completed a LiftOff cognitive training program through LearningRx between 2010 and 2019 (n =1,067). Results suggest that the LearningRx LiftOff cognitive training produces significant improvement in cognitive skills, particularly auditory processing, in a relatively brief time for this sample of children. Statistical analyses show that there are statistically significant differences between pre-test and post-test on working memory, processing speed, visual processing, auditory processing, and logic and reasoning with a medium to very large effect size, and that age is only a significant factor in scores for logic and reasoning. The largest effects are in auditory processing and processing speed.

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Chapter 1: Introduction

Children's literacy and reading skills are a top priority for many parents, school districts, special interest groups, and political agendas across the United States. Its impact can be seen by the domino effect that early reading ability has on children. Children who struggle with reading are more likely to be held back a grade in school, become adolescent parents, become high school dropouts, or enter the juvenile justice system (Connor et al., 2014). These difficulties tend to skew children to have negative attitudes about reading and learning.

Hulme and Snowling (2013) posited that the ability to read is a foundational skill of early education and can have serious negative consequences if these students do not master this skill. When a child struggles to learn, many find it an overwhelming obstacle to overcome. Academic struggles, like reading, often become a consistent obstacle through elementary grades (Morgan et al., 2019).

If there is an underlying cognitive issue for a child with learning difficulties, it may be even more challenging (Barnes et al., 2020). Identifying these challenges and how they manifest themselves in a child's learning ability can be a critical piece to addressing their needs. The literature suggests for many students' challenges in school are linked to one or more underlying cognitive deficits.

Problem Statement and Significance of the Study

Many of the efforts that have been made have focused on instructional strategies and reading skills building. Unfortunately, these have not met their goal of improving national student performance and narrowing academic achievement gaps (Wigfield et al., 2016). The ability to identify underlying causes of reading academic difficulties can guide decisions on the best intervention or instructional methods to assist children at risk for future academic difficulties. This problem could be solved if targeted cognitive training can increase low cognitive skills that underlie a child's ability to read.

Research has connected certain cognitive skills to early reading skills. For example, a deficit in working memory (WM) may contribute to difficulties in comprehending text and following multi-step instructions (Viterbori et al., 2015). Reading comprehension requires the ability to build integrated mental pictures; it relies heavily on both the processing and storage functions of working memory (Gathercole & Baddeley, 2014). Geary et al. (2012) noted that research conducted has shown that deficiencies in working memory and processing speed contributes to problems learning math and significant difficulties in the overall learning process. Studies also point to relations between impairments on various tests of WM and distinct types of learning disabilities (Boustanzar & Rezayi, 2017; Zamani & Pouratashi, 2018).

There are several commercial early reading programs available with many falling into the categories of instructional strategy. The focus of this study was to explore the effectiveness of the LiftOff program, a one-on-one cognitive training program, on children ages 5 to 7-years old (Tenpas et al., 2002). LiftOff is a proprietary 12-week cognitive training program for young children offered by LearningRx, a national network of brain training centers. It is an early start learning program that targets major cognitive skills including working memory, long-term memory, visual processing, reasoning, processing speed, and multiple auditory processing skills including blending, segmenting, rhyming, and deletion of sounds.

There is accumulating evidence that certain cognitive programs are effective in older children and adults (Dessey et al., 2020; Jaeggi et al., 2017; Moore & Ledbetter, 2019; Moore et al., 2019). Jaeggi et al. (2017) noted that for a cognitive intervention to be effective, it cannot be a “one-size-fits-all” approach and needs to be designed for each individual to maximize the outcomes. Colzato and Hommel (2021) purported that people are more likely to succeed in a training program that is designed for their skills, abilities, and needs.

Theoretical and Conceptual Framework

Grant and Osanloo (2014), after reviewing and ruling out other theories, concluded that cognitive theory is the best theoretical approach when conducting research on the effectiveness of a child's learning program. Cognitive theory examines how the brain thinks, using different processes and the impact of internal and external factors (Schwarzer & Luszczynska, 2005). Cognitive theory uses developmental psychology and cognitive science (Xu, 2019). Having research that has a strong basis in cognitive theory, has made it much easier to review the literature and determine if it will fit within the purpose of this study.

Specifically considering the efficacy of cognitive training on cognitive skills that support learning, Feuerstein's theory of structural cognitive modifiability is the best framework (Tzuriel, 2020). Feuerstein's theory posits that cognition is not static but malleable as a result of mediated experiences with the world (Haywood, 2020). Feuerstein focused more on the prerequisites of thinking and ways to help people learn how to learn. Tan (2003) supported the concept that different learners have different capabilities to benefit from the mediated experience. Each person displays differences in their cognitive structure, their knowledge base, and their operational functioning.

Researcher's Positionality

I have served as an early childhood education faculty at a 2-year community college for the past 14 years. Due to my experience and education, I have learned that early intervention is critical in education in an effort to help a child maximize the best of their abilities to be successful. I want to contribute to the body of research if there is another early intervention option available.

In addition to my college teaching experience, I own a LearningRx franchise. I have owned and operated my center since May 2017. Since my center does not use the Woodcock-Johnson III –Tests of Cognitive Abilities and Tests of Achievement (WJ III) as its assessment tool, it eliminates the possibility that any of the participants will have received training or have been assessed at my location.

The data for this t study was obtained from a centralized database of client records for a national network of cognitive training centers that administered both the WJ III and LiftOff programs between 2011 and 2020. This data was queried by a member of the research department at the organization. The data was stripped of all identifying information and emailed to me containing the following variables: random ID numbers, clientage in years and months, grade, city, state, zip code, ethnicity, sex, diagnosis, pretest scores, and post-test scores. At the time of starting this research, I had not personally trained a client using the LiftOff program and was unfamiliar with the protocols and training methods associated with it.

For my ethical obligation as a researcher, I reported to the Institutional Review Board (IRB) that I have financial and/or business interests which may be affected by the results reported in this study.

Purpose of the Study

The purpose of this causal-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. My goal was to see if LiftOff is an effective program for increasing cognitive skills that have been shown to improve a child's ability to read and learn therefore providing an early mediation option for children. Tzuriel (2020) concluded that when children are identified early with a deficit in learning and cognitive skills, it would make it easier to develop mediation strategies that would aid in overcoming the difficulties and realizing the child's learning potential.

A generous portion of the research on cognitive training exists around older adults; specifically, those suffering from mild cognitive impairment and Alzheimer's (Bahar-Fucks & Woods, 2013; Giovangnoli et al., 2017; Kallio et al., 2017; Sitzer et al., 2006) and older children with learning difficulties (Buttelman & Karbach 2017; Karbach, 2015; Karch et al., 2013; Knoll et al., 2016). There is a lack of research on children under the age 8.

My desire is that the results of this study fill a gap in the research and will provide initial data vital to objectively evaluate the effectiveness of cognitive training in children ages 5 to 7-years old with one or more cognitive deficits.

Research Questions

With significant research connecting cognitive skills to a child's ability to read and learn (Barnes et al., 2016; Boets et al., 2011; Bonifacci & Snowling, 2008; Dosi & Koutsipetsidou, 2019), my aim was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. The research questions were addressed through the course of this causal-comparative study and were as follows:

R1: Is there a statistically significant difference in pretest and post-test measures of cognitive skills for children ages 5 to 7-years old following completion of the LiftOff cognitive training program?

H_1: LiftOff training program shows significant improvements in cognitive skills in children ages 5 to 7-years old.

H_0: LiftOff training program does not show significant improvements in cognitive skills in children ages 5 to 7-years old.

R2: Does the effect of the LiftOff cognitive training program differ by age and sex?

H_1: There are significant differences in early reading and cognitive test score changes following Liftoff cognitive training based on age and sex.

H_0: There are no significant differences in early reading and cognitive test score changes following Liftoff cognitive training based on age and sex.

Rationale for Methodology

A causal-comparative method was used for this study. A causal-comparative design makes the connection between the dependent and independent variables following action or intervention (Creswell & Creswell, 2017). The objective is to see if the independent variable changes the outcome, or the dependent variable, through a comparison of two or more groups of individuals. This causal-comparative study measured cognitive task performance in the areas of working memory, processing speed, auditory processing, visual processing, logic, and reasoning. The data for this study was gathered from a normed and validated standardized cognitive assessment for the pre-and post-assessment, WJ III Tests of Cognitive Abilities, and subtests from the WJ III Tests of Achievement.

Sampling Strategy and Size

The sample involved archived data gathered from a database of clients ages 5 to 7-years old who completed a LiftOff cognitive training program through LearningRx with a mean of 60 hours completed between 2011 and 2020 (n =1067). This was a nonprobability sample based on Creswell and Creswell's (2017) description, which asserted that when the researcher selects participants due to convenience and availability the sample still represent some characteristic that the researcher wants to study.

Data Analysis

Research question 1, was created to assess the effectiveness of the LiftOff program on cognitive skills for children ages 5 to 7- years old. To answer the question, I will compare pre-intervention WJ III scores with the post-intervention WJ III scores using paired-samples t-tests for the pretest to post-test change in standard scores for everyone. A Bonferroni-corrected p-value of $p < .01$ was used for significance testing, and the effect size was assessed using Cohen's d.

To answer research question 2, a factorial MANOVA was used to observe differences by age, differences by sex, and the interaction of sex and age. This analysis showed if there is an association between cognitive training and improvement in cognition and if that is impacted by age, sex, or both. These analyses were then compared the gain scores, post- minus pre-Standard Score, for children ages 5, 6, and 7 to each other. The Tukey post-hoc test was performed to control for multiple comparisons and see the exact differences (Armstrong, 2014). If statistically significant effects are obtained with more than two groups, a post-hoc test was then performed to determine which groups differ. The use of effect sizes is important because it allows for the comparison the magnitude of experimental treatments from one experiment to another. The effect size was assessed using partial eta squared for RQ#2. (Napierala, 2012). A p-value of 0.05 was used in the analysis to answer research question 2.

The results were then plotted appropriately, addressing the differences in the groups if there were any to be found. The data indicated whether the program is effective, and for which group it works best. My hope was that the data analysis addressed where the program would be used most effectively. The statistical analysis supported whether cognition was improved by this program.

Definition of Terms

Key terms that are used in this causal-comparative research study included:

Cognitive development: For this causal-comparative study, cognitive development is defined as a child's development in information processing, perceptual skill, language learning, and conceptual resources about brain development (Haywood, 2020).

Cognitive training: For this causal-comparative study, cognitive training refers to the act of participating in a specific repetitive program or activity over a circumscribed timeframe to enhance a cognitive skill or general cognitive ability (Rabipour & Raz, 2012).

Cognitive skills: For this causal-comparative study, academic achievement can be exhibited using markers in cognitive skills such as the ability to process, learn, think, and reason; and substantive knowledge (Kell, 2018).

Early or emergent reading skills: For this causal-comparative study, early or emergent reading skills may include letter knowledge, phonological awareness, rapid automatized naming (RAN), Word Attack, verbal short-term memory, fluency, and comprehension. (Lohvansuu et al., 2018; NAEP, 2019).

Phonological awareness: For this causal-comparative study, phonological awareness is developmental and typically follows this progress starting in preschool: segmenting sentences into words and moving to kindergarten: rhyming; kindergarten: segmenting words into syllables and deleting syllables, transitioning to first grade: blending, segmenting, deleting, and adding phonemes, and adding in first and second grade: manipulation (e.g., substitution, transposition) of phonemes (Mather & Jeffre, 2016).

Processing speed: For this causal-comparative study, processing speed is defined as the ability to execute both simple and intricate cognitive tasks quickly. This skill also measures the brain's capability to work rapidly yet efficiently while ignoring distracting stimuli (Ebaib et al., 2017).

Working memory: For this causal-comparative study, working memory is defined as the groups of parts of the mind that temporarily retain data and information in an amplified state of readiness for use in continuous information processing (Cowan, 2017).

Summary and Organization of the Remainder of the Study

Research has shown that cognitive development and skills affect a child's ability to read and learn. Reading comprehension requires the ability to build integrated mental pictures, it relies heavily on both the processing and storage functions of working memory (Johann et al., 2020).

One option to improve cognitive skills is through cognitive training. It is important to review specific commercial cognitive training programs and their effectiveness (Jaeggi et al., 2017). For this causal-comparative study, I have chosen to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. While several commercial cognitive training programs are available, LiftOff is specific to children ages 5 to 7-years old (Tenpas et al., 2002).

Chapter 2 presents a review of research related to cognitive skills and how they relate to a child's ability to read and learn. It also provides research related to the practice of cognitive training as a means to increase cognitive skills.

Chapter 3 addresses the research methodology, which involves the population sample a description of the assessment tool, and the data collection and procedures used in the study.

Chapter 4 provides the results of the data collection and the data analysis.

Chapter 5 involves a discussion of the results and how they compare/contrast with the literature, the limitations of this study, the implication of the results for practice, recommendations for future research, and a conclusion of this study.

Chapter 2: Literature Review

Introduction to the Chapter and Background to the Problem

The purpose of this causal-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. This study involved examinig the research on cognitive skills related to learning, including those shown to impact reading skills and academic success. My goal was to see if LiftOff, a program for increasing cognitive skills in children, is actually providing a successful early mediation option for children. The results of this study may provide data vital to objectively evaluate the effectiveness of cognitive training in children ages 5 to 7-years old with one or more cognitive deficits.

Theoretical Foundations and/or Conceptual Framework

Cognitive theory examines how the brain thinks using different processes and the impact of internal and external factors (Schwarzer & Luszczynsk, 2005). Since this causal-comparative study was for the purpose of learning if cognitive training improves cognitive skills that support learning, reading, and overall academic success, this theory was the best fit.

In the early 1900s, cognitive theorists such as Piaget (1896-1980), Vygotsky (1896-1934), and Bruner (1915-2016), provided a solid foundation for learning theory. Piaget, Vygotsky, and Bruner showed that there is a need to develop ways to get to the root of deficits creating obstacles to learning and cognitive development. One way to consider addressing this is through cognitive training and the notion that the brain can change.

Curlik and Shors (2013) noted that it is not only that new pathways are being created between neurons (neurons that fire together, wire together), it is also that there are new neurons occurring as a result of cognitive training. Similarly, Feuerstein's theory of structural cognitive modifiability notes that cognition is not static but malleable as a result of mediated experiences with the world (Haywood, 2020). Bryan (2014) concluded that there is a biological basis behind quality cognitive training that is supported by the research showing that those physical changes in the brain can and do occur throughout a person's lifespan.

Review of the Literature

Cognitive Development and Skills

I examined cognitive development by dividing it out from other developmental domains (e.g., social-emotional, physical, and language). In reality, development cannot be easily categorized in isolation. The four areas of development are closely related, often overlap, and are affected and influenced by development in all other areas (Berk, 2013). For example, oral language acquisition (language development) is foundational to learning, since learning begins with listening and speaking, which happens through interactions with others (social-emotional development). If a child does not have interpersonal interactions with others, it would have a direct impact on their ability to acquire language (Nor & Rashid, 2018).

Cognitive ability or skills in early childhood are a key factor determining a child's future academic success. In early childhood, to learn academic skills children use cognitive skills; therefore, most academic tasks involve the use of those cognitive abilities (Evans & Stanovich, 2013; Peng et al., 2018). Several studies on the correlation between cognitive abilities and academic achievement (Gerst et al., 2017; Sternberg et al., 2008) have concluded that cognitive abilities are foundational structures, and these cognitive abilities are essential and impact academic outcomes. Peng and Kievit (2020) noted that in a bidirectional model a person's achievement academically and cognitive abilities impact each other through development in several ways, and those relevant cognitive abilities and academic achievement should increase proportionately with age. They should parallel each other in predicting over a longer period. Cognitive abilities and academic achievement should improve with targeted cognitive interventions.

Knowledge of brain and cognitive development and how they influence learning is extensive, deep, and still building (Fischer & Bidell, 1998, 2007; Khan & Panth, 2017; Peng & Kievit, 2020; Piaget, 1983). What a child already knows, or background knowledge, affects their ability to make sense of new experiences and insights. This background knowledge affects a child's capacity to remember, process information, categorize, solve problems, read, and understand mathematical concepts and develop language skills (Bjorklund & Ellis, 2014; McAffe & Leong, 1994).

Many characteristics of the brain such as the number of neurons and synapses, brain mass, change steadily as children grow and develop (Bjorklune & Ellis, 2014). At the same time, while they grow, children's other areas such as actions, language, problem-solving, social skills, emotions, and motivation develop. Research shows that as individuals, people grow in complex patterns, evident in not just linear change but cycles of peaks and valleys (Dawson et al., 2005; Molenaar, 2004). Evidence is building showing peak times of brain growth, cognitive development, and learning (Lazonder et al., 2020).

Starting around 5-years old, children build an understanding of concepts by experimenting and interacting in a variety of ways with their environment. Children should be formulating predictions and solving problems by scrutinizing the people and things around them. They begin to think in complex ways and connect new encounters and knowledge to what they already know. At this age, they have an increased ability to present ideas, use symbols, expand beyond literal meanings, and explore abstract ideas (Fleer et al., 2014).

Piaget's theory of cognitive development describes how a child builds a mental model of the world (McLeod, 2018). Piaget's (1936) influences on cognitive development involve a stage theory, detailed observational studies of cognition in children, and a series of creative, simple experiments to expose different cognitive abilities. Piaget described learning as a dynamic process with several stages. His work consisted of three components: schemas, adaptations, and stages of development. Piaget theorized that children construct knowledge through action. He argued that children must engage in tasks actively to develop and learn (Murray, 2020).

In the first stage, Piaget (1952) defined schemas as being regulated by a central meaning of tightly interconnected actions that are interrelated and repeatable action sequences possessing components. In basic terms, schemas are a way of organizing knowledge.

During the second stage, intellectual growth is a process of adapting to the world. This happens through assimilation, accommodation, and equilibrium. This process takes our existing knowledge and changes it when it does not fit with a current situation to restore balance. Children seek out and process the latest information based on what they already know. They are also able to modify their thinking to make sense of added information and experience. Children's knowledge can grow as they investigate, learn new concepts, and revise their previous way of thinking to integrate the latest information (Piaget, 1952).

Piaget's third component, stages of development, encompasses a child's growing sophistication in their ability to think. Each child goes through these stages in roughly the same order and the child's growth is affected by biological maturation and interaction with the environment. The rate at which a child progresses through each stage is dependent on each child (Piaget,1952).

While no stage can be skipped, some people may never attain the later stages. Because this study only examined children ages 5 to 7-years old, only the second stage of development was discussed.

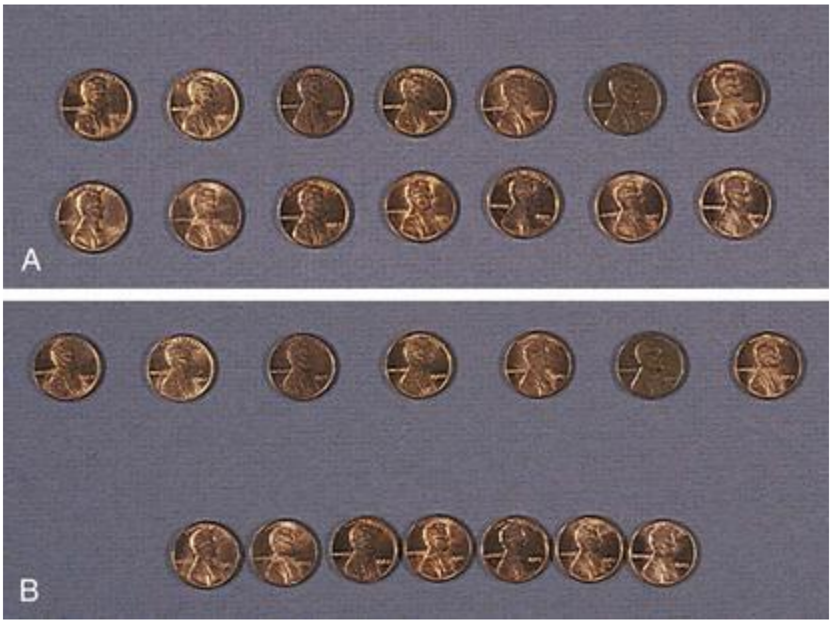
Around age 2, Piaget coined the second period as preoperational and lasts until approximately age 7. During this stage, children begin to notice the attributes and characteristics of the objects they engage with. The researcher asserted that children must actively interact with tasks to develop and learn Piaget, 1952).

Piaget's theory of cognitive development explains the development of cognition with ages and stages. A majority of the viewpoints of the researcher's original theory of cognitive development have been contested; however, the objective characteristics connected to cognitive development are still valid. Some of these related factors are the development of logic and cause-and-effect relationships during childhood (Villasin, 2020).

There are several characteristics of the preoperational stage that might be seen in children ages 5 to 7-years old. As shown in Figure 1. Experimental design to demonstrate preoperational logic, if a clinician lined up two rows of pennies so that a row of four pennies was longer than a row of six pennies and asked a child to point to the row that has the fewest pennies the child would point to the row of six. This is referred to as centration, which is the tendency to focus on only one aspect of a situation at a time (Khalil, 2019). In the example, the child is focusing on one aspect only (length) and cannot manipulate the length and number.

Figure 1

Experimental Design to Demonstrate Preoperational Logic



Note: From Feldman et al. (n.d.).

Next, a child moves into conservation which Piaget found that most children could not move into before age 5. This is understanding that a quantity stays the same even when you change the shape, size, or container it is in. This is often seen when you have two containers of varied sizes that hold the same amount of liquid. A child will typically pick the tallest container when asked which holds more (Khalil, 2020).

Another characteristic Piaget defined is artificialism meaning the assumption that everything that exists is made by a conscious being, such as God or a human (Gruber & Voneche, 1977). This being is in charge of physical qualities and movements. For example, a child sees it as someone making thunder and not an act of nature. Establishing an understanding of how cognitive development develops and grows in children ages 5 to 7-years old enables educators to explore ways to maximize thinking and learning. Researchers can delve deeper into the cognitive skills that make up cognitive development to see what role each plays in a child's ability to think, learn, and perform academically.

Working Memory

Working memory (WM) has a vital role to play in the academic performance of children, due to multiple academic tasks involving multiple sequences of tasks that should be remembered in a brief period (Bergman & Soderquist, 2017). This means that WM uses an integrated system that is enlisted during tasks such as learning, reading and language comprehension, and reasoning (Baddeley, 1992; Tsianos et al., 2010).

According to Mather and Jaffe (2002), WM is the brain structure that delivers temporary storage and manipulation of information that is used for difficult cognitive tasks such as language comprehension, learning, and reasoning. A child who struggles to update WM, effectively plan, move from one concept to another, and show restraint, is unlikely to be able to stay on task in the classroom and do well academically (Ahmed et al., 2019). This might be seen in a classroom as a child who struggles to complete work in class due to a struggle remembering what was covered in the lesson and the directions of what is to be done.

Research has shown ties between WM to academic success and intelligence. The National Science Foundation (2018) study results proposed, regarding student academic performance in algebra, that that the strongest predictors were cognitive skills specifically linked to WM, and also showed that cognitive skills can be improved using cognitive training interventions. Jaeggi et al. (2017) purported that fluid intelligence (the capacity to solve novel abstract problems) is dependent on a student's improvement in WM.

Fried et al.'s (2016) study reported that in a non-Attention Deficit/Hyperactivity Disorder (ADHD) sample, a deficit in WM negatively impacts the academic learning processes associated with the recognition of priority patterns, focus and attention, ability to recognize hierarchies, inhibition of irrelevant stimuli, the meaning of stimuli (analysis and synthesis), and to recognize and select the goals that work best to solve a problem establishing an intention. With these cognitive abilities proving to be critical for learning, any deficits can lead to educational difficulties and low educational achievement.

When adding in the element of an ADHD diagnosis, WM has an even more profound impact. WM deficits have been shown to have a significant impact on the likelihood of increased risk for academic deficits and cognitive dysfunction in children with ADHD (Freid et al., 2016). The researchers also suggested that screening for WM deficits in children diagnosed with ADHD could aid in identifying them at considerable risk for academic and cognitive dysfunction.

Research suggests that basic mathematical skills rely heavily on domain-general cognitive processe such as WM and processing speed (Formosa et al., 2018; Fuchs et al., 2012; Hornung et al., 2014). The different domains associated with WM have been linked with parts related to math cognition and with early math overall. WM deficits have been connected to difficulties in the automatization of the conventional counting sequence, counting, and the acquisition of Arabic numerals (Bull et al., 2008). Both Alloway and Passolunghi (2011) and Gullick and Temple (2011) concluded that WM has a direct influence on mathematical performance in children age 5, and credited this to how it works in retrieving math facts and manipulating verbal and visual information.

In a regression analysis by Formosa et al. (2018), their study showed that verbal WM, visuospatial WM, and processing speed have a significant impact on math cognition. In the study, the researchers found that verbal WM, visuospatial WM, and processing speed directly influence math cognition. Additionally, some studies have discovered that verbal WM capacity is related to the amount of mathematical proficiency, such as how it can sustain active the counting sequence and partial results while counting (Bull & Scerif, 2001; Camos et al., 2018) or how it impacts the recovery and procurement of arithmetic facts (DeStefano & LeFevre, 2004; Geary, 2012; Kaufmann, 2002).

When examining the impact of WM on reading, the research is more direct. The significant role WM has on reading performance is because tasks entail using both information processing and storage synchronously (Bergman & Soderquist, 2017). It is as if someone wanted to understand the text. First, they must visually process the words. Then, they match the words to the phonological, semantic, and orthographic depictions in long-term memory (LTM). This then ends with the combination of these depictions within the framework to develop what is the meaning of the passage.

van den Broek et al. (2016) posited that the aim of WM is to be involved in this process of understanding by allowing short-term memory (STM) to retain relevant information, having information from long-term memory (LTM) retrieved, and combining all the sources of information to form an accurate understanding based off what was described by the text. Regarding van den Broek's position on children reading a text, they should be able to remember information previously taught and then add the information received to their knowledge bank as they proceed to become an effective reader.

A comprehensive literature review by Savage et al. (2007) offered two conclusions related to reading and WM. The first examined foundational reading skills such as decoding, and reading comprehension require WM for advanced reading skills (Peng et al., 2018)**.** Secondly, it was uncertain if the relation between reading and WM was influenced by other domains of WM (e.g., verbal verses visuospatial).

In the resource-sharing model, WM shows a strong relationship with reading comprehension because reading comprehension also requires simultaneous information processing and storage. Comprehension is the process of making meaning and is a primary goal of reading instruction (Soto et al., 2019). It entails being able to connect what you read and hear with what you have experienced. Even pre-readers need to have the ability to comprehend things such as stories they are being read, oral instructions and information, and conversations. Preschool and kindergarten-age children who attempt to comprehend what they are hearing, use the same cognitive process that older children and adults use to read. Comprehension allows children to process what they hear and read which is crucial to future reading success (Razinski et al., 2017). To understand what is being read, processing and storage have to switch back and forth such that information processing effectiveness influences the storage capacity of WM that is available for reading comprehension (Peng et al., 2018).

Additional studies have shown that children with reading difficulties are known to often exhibit problems retrieving stored vocabulary knowledge from the mental lexicon (Dickens, 2017; Dosi & Koutsipetsidou, 2019; Rucklidge & Tannock, 2002), which could mean that WM tests may show a specific problem in word-finding. This is important, because vocabulary is a strong predictor of later reading and literacy ability (Oakhill et al., 2019). It can be noticed in the preschool years that children with larger vocabularies have more developed phonological awareness (Lonigan et al., 2018; McBride-Chang et al., 2005).

Research has shown that vocabulary is also critical in oral reading instruction (National Institute of Child Health and Human Development, 2006). Furthermore, a meta-analysis of studies has shown that some phonological awareness abilities like phoneme deletion are impacted by WM capacity because they require both storage and manipulation of phonemes (Peng et al., 2018).

Processing Speed

Processing speed (PS) can be defined as the velocity in which a subject executes a simple and automated cognitive task (Sheppard & Vernon, 2008)**.** As noted in WM and academic success, a child’s ability to move from one concept to another, sometimes referred to as shifting ability, has an impact on their academic achievement. Processing speed has been shown to account for between 70% and 90% of the age-related variance in fluid intelligence quotients in children and adults (Hermida et al., 2020). The assumption is that an individual’s PS places a limit on the amount of information that can be processed in a given time interval. Studies support the idea that deficiencies in PS may limit a person’s ability to complete more difficult cognitive tasks, including inhibition, maintenance, and shifting operations (McAuley & White, 2011, Rose et al., 2011; Span et al., 2004).

Slower PS could result in lower academic performance because a child cannot complete all the tasks in the time allotted. Parents may see this impact if a child is repeatedly unable to get work completed in class and has to bring it home to finish. A child may also struggle with timed tests and completing them in time. This line of thought leads to the conclusion that as PS increases, on tasks where speed impacts performance, higher PS speed will result in better performance (McAuley & White, 2011, Rose et al., 2011; Span et al., 2004).

Developmental cascade models put forward the idea that children's information PS is an impactful process in cognitive development shown to support gains in inhibitory control, working memory, and related cognitive skills (Clark et al., 2014). McAuley and White (2011) found that PS accounts for significant discrepancies in the developmental course of both WM and inhibition. Their findings suggested that PS might allow quicker evaluation of environmental cues which help determine the appropriateness of certain purposeful behaviors.

Tucker-Drob et al.’s (2019) meta-analysis study indicated that age-related gains in PS are believed to aid in general cognitive efficiency in two ways: more information can be gained within a certain timeframe; and with less time for information to be lost, a greater number of neural networks can be co-activated, thereby increasing the capacity to perform concurrent tasks and represent information from many views. What this means is that if a child is given added information quickly and struggles with slower processing, they will miss the content being taught. Think of a child that repeatedly comments, “You didn’t say that” or “I didn’t hear you say that” when questioned about missing directions or instructions.

It has also been shown that PS within executive functioning is partially responsible for developmental improvements in complex span task performance due to preventing decline and increasing the speed in the repetition of memory items (Gordon et al., 2018). Magimairaj and Montgomery’s (2013) analysis noted the development of an attentional task-switching ability as a means to explain increases in WM aptitude around seven years of age. This ability is seen by a direct relationship between storage capacity (WM) and PS in complex span tasks.

Espy et al. (2006) found that information processing has been shown to develop rapidly from three to five years of age pointing to the need for an effective way to address a deficiency early. Considering that PS is so intricately linked to cognitive task ability, it could be conceived that a significant reason for the varying ability in young children's early task performance and how that relates to academic achievement, may be accounted for by individual differences in PS.

Concerning mathematical performance, some have suggested that PS influences are explained by the availability of resources in WM and EF (Clark et al., 2014). Still others (Bull & Johnston, 1997; Fuchs et al., 2012, 2006) have found its effect is independent of WM capacity. They contend that slow PS may impact the establishment of mathematical conceptual information in LTM, like the automatization of the counting sequence and arithmetic facts. Lépine et al. (2005) found that even when examining WM alone, placing stress on a person’s ability to process information more quickly resulted in more intense relationships regarding measures of mathematics, reading, and non-verbal reasoning.

Studies have shown that children's performance on executive tasks, which includes PS in preschool, has a direct correlation with their mathematics achievement well into elementary school (Clark et al., 2010; Douglas & LeFevre, 2017). In classroom instruction of basic math facts, not only is remembering math facts important but the speed at which they are recalled is also a key factor in measuring whether a child has mastered them. Processing speed and language proficiency are strong predictors of children's mathematics performance across the preschool years (Clark et al., 2014).

Rohde and Thompson (2007) showed that PS, a cognitive skill closely related to attention, is an incremental predictor of general intelligence when forecasting for the mathematical subtest of the SAT. There is also noteworthy evidence that children who have a slower ability to process information have poorer mathematics achievement (Bull & Johnston, 1997; Geary et al., 2012). Studies by Lijffijt et al. (2005) and Karulunas and Huang-Pollack (2013) allude that slow PS clarifies the reason for much of the deficit in WM in children with ADHD compared to their typically-developing peers.

A progressive increase in reading speed is the benchmark of common reading acquisition**.** As children age, the ability to name familiar objects and how quickly they name them are related to reading ability (Roembke et al., 2019). Ozernov-Palchik et al. (2017) conducted a longitudinal study that acknowledged a correlation between how quickly kindergarten children could name familiar digits and letters and how they would perform on word recognition tasks.

Wong (2020) incorporated research conducted by Spring and Davis (1988) that found children who read more digits are able to read more words and more words correctly. Wong's findings mirror other research that children with dyslexia may show deficits in eye movement performance or/and in visual perceptual skills. The results indicated that 56.67% of children in the study presented visual deficits in eye movement, and 46.67% showed visual deficits in visual perception. Processing speed deficits, when present, could function both to impair reading difficulties and to lessen a child's ability to make up for them (Bonifacci & Snowling, 2007).

In a review of the literature around rapid naming, Savage (2004) reported that many studies have found deficits in the automaticity of rapid serial naming and fluency measures for children with reading disabilities. Some have argued that single deficits in phonological processing are unlikely to explain entirely dyslexia, and PS deficiencies are an additional risk factor (Lovett et al., 2017; Pennington et al., 2012). A growing body of research suggests that children with dyslexia have PS deficiencies (Arnett et al., 2017; Doyle et al., 2018; Willcutt et al., 2005).

A study by Shanahan et al. (2006) found that PS is a shared cognitive risk factor in both children with a reading disability and those diagnosed with ADHD. One large-scale study that examined reading disorders and ADHD (Willicutt et al., 2005) learned that PS measures are consistently lower among children with combined ADHD and reading disability than those children with only one disorder.

Auditory Processing (AP) and Phonological Awareness (PA)

AP is an overarching term that captures a person's abilities such as auditory discrimination, temporal ordering, spectral resolution, and discrimination and performance in degraded listening conditions (American Speech-Language-Hearing Association [ASHA], 1996). There is a large body of research around auditory processing and how it relates to children's reading ability. Early theories proposed an association between AP and phonic decoding skills focusing on the ability to read by mapping letters onto sounds (Tallal, 1980, 1984). van Rijthoven et al. (2018) found that children's semantic knowledge plays a significant role in both phonological awareness and rapid naming, which fits prior research specific to children with dyslexia.

Several studies have stated that children with AP struggles will have simultaneous deficits in language skills (Gillam et al., 2017; Gokula et al., 2019; Sharma et al., 2009; Wible et al., 2005). Through speech, children learn to arrange and communicate their thoughts and ideas. They systematically learn the rules for ordering sounds and using language in conventional practices. Children eventually transition from oral language to written language. Children with language delays may have difficulty in isolating, distinguishing, or processing language sounds (ASHA, 1996).

In addition to AP, PA , or phonological sensitivity, is defined as the ability to recognize, isolate, and manipulate basic speech units, and begins development early in life, before reading instruction (Law et al., 2017). At approximately age 3, children begin to develop PA with gradual improvement as they age (Gillon, 2005). Hearing these differences in the parts of oral language can be challenging for some children since it is asking them to focus on the sounds of speech separately from meaning. A strong predictor of later writing, reading, and spelling is a young child's PA (U.S. National Early Literacy Panel, 2008).

PA develops as a progression from straightforward skills such as listening and advancing to much more complex skills such as manipulating individual sounds in words. PA can be facilitated, and this can lead to reading improvements (Schuele & Boudreau, 2008). PA starts by simply listening to sounds in the environment. Developing these beginning listening skills helps children to later focus on the separate sounds in words.

Next, children will start noticing and discriminating rhyme and alliteration. For preschool and kindergarten children, rhyming involves recognizing the sounds in word endings. Rhyming is one of the first skills to develop in PA (Grofčíková & Máčajová, 2020). Children also develop alliteration which asks children to decipher parts of words that are smaller than a syllable and at the beginning of words (Symmons, 2020). Research shows that a child grasps larger units of words that can be segmented, such as syllables, onsets, and rimes, develops first, whereas an understanding of smaller units or phonemic awareness, is believed to develop only after exposure to print (Goswami, 2002).

As PA skills progress, children learn to manipulate phonemes in many different ways. Children will blend and segment phonemes, or substitute one phoneme for another. Research has shown that PA skills tend to be the most potent predictor of success in learning to read (Mott & Rutherford, 2012).

Forty to 60% of the later reading achievement of kindergarten children is attributed to pre-reading PA (Law et al., 2017). Young children on average can distinguish words that rhyme, regardless of if other phonological skills have not developed (Lonigan et al., 2018). Children begin by representing and manipulating more holistic units of speech such as syllables before they become able to segment phonemes (Gillon, 2017).

There is a growing body of research that has added to the evidence that there is a relationship between measures of AP, phonology, and literacy achievement in preschoolers (Boets et al., 2011). These researchers investigated pre-reading in children and showed a clear relationship between a measure of AP and speech-in-noise perception. Law et al. (2017) found that their auditory measure uniquely predicts discrepancies in first and second-grade reading. This suggests that basic AP skills impact on reading development is not limited to the time point before reading instruction but extends through the preliminary stages of reading development (Law et al., 2017).

A study by Gokula et al. (2019) found that children who struggle with word reading do poorer as a group on visual attention, AP, receptive language, phonological processing, and digit memory when examining children with developmentally appropriate word reading skills. However, Leppanen et al. (2010) suggested that an early AP deficit may not be solely sufficient to contribute to reading difficulty.

After children have a suitable grasp of the sounds used in language, they progress to being able to relate printed symbols with their corresponding sounds or phonics. PA and AP lay the groundwork for phonics to happen. Familiarity with the letters of the alphabet and understanding that the phonemes align are solid predictors of how easy or difficult a child can learn to read (U.S. National Reading Panel, 2000).

Visual Processing (VP)

VP is the ability to recognize, examine, and think about images (Gibson et al., 2015). Cavanagh (2012) defined visual cognition to mean being able to create visual images that represent surfaces and objects retain the base data of the visualization but change which areas belong together and how they are arranged in depth. Some expand VP to include one's ability to attend to and distinguish something's details and characteristics, such as color, shape, size, orientation, and color (Yang et al., 2013; Kulp et al., 2004). Visualization is also a term that has been used to describe the ability to recognize mental patterns and visually manipulate them to conjure up how they might appear when altered in some way such as rotated, changed in size, partially obscured (Flanagan et al., 2013).

The literature shows spatial orientation to be one of the most impactful VP abilities among all visual-spatial abilities (Wang et al., 2014; Yilmaz, 2009; Zhang, 2016). The ability to visualize is the most commonly studied spatial ability linked with mathematics achievement (Mix & Cheng, 2012). One such study found that by measuring spatial visualization and verbal skills of kindergarteners, the two could predict the level of arithmetic in the first grade as well as arithmetic growth up to the third grade (Zhang et al., 2014)

Visual processing is a necessary process to develop for a child to be able to discriminate between letters, characters, symbols, and written numbers (Meng et al., 2011; McBride-Chang et al., 2005). For children to understand written language, they need to comprehend how words, sounds, and sentences work together in writing. An adequate predictor of future writing, spelling, and reading ability in young children is their view toward print. The ability of a reader to understand that a letter represents one or more sounds is inherent in their ability to decipher letter symbols (U.S. National Early Literacy Panel, 2008).

There is increasing agreement among researchers that children with learning difficulties specific to math have fundamental deficiencies in numerical understanding and domain-general functioning, such as language and spatial skills, compared to children with no learning difficulty (Geary, 2004). Several longitudinal studies have explored how developing math proficiency in childhood is impacted by spatial skills. Zhang et al. (2018) found deficiencies in the same set of cognitive skills, including spatial, language, and counting skills were found to underlie math learning difficulties (MLD). van Garderen and Montague (2003) found that children with MLD had impairments in spatial visualization compared with children who do not struggle with math. Children with weakness in spatial ability may not be able to use spatial strategies in mathematical problem solving or get the full benefit from classroom instruction (Krawec, 2014). Barner et al. (2016) showed that children with lower visuospatial WM do not experience gains from math instruction using a visuospatial strategy. Children with higher visuospatial WM did better in math than the control group with typical math instruction.

Holmes et al. (2008) assessed how a child’s performance in visual and spatial STM tasks and how it is linked to whether preschooler develops numerical competence and that visual STM is critical in later years of schooling. Fanari et al. (2019) observed that early numeracy competency significantly aligned over time with later math skills. Research has shown that one of the strongest predictors of academic success in mathematics is a child’s level of early numerical ability (Jordan et al., 2006; Lyons et al., 2014; Passolunghi et al., 2007, 2008).

Research results show that active visual-spatial WM has an impact on math performance from the incredibly preliminary stages of math learning (Fanari, et al., 2019). Yang and Meng (2020) found that VP in kindergarten explains unique differences in early mathematics in first grade. Studies indicate that children with high visual-spatial ability are more likely to interpret an increased amount of math problems into pictures and use spatial descriptions as well as exhibit stronger flexibility in translating a story/word problem into a math problem. This means children can identify and extract math equations from the word problems, and visually process number relationships (Sigmundsson et al., 2010; Zhang & Lin, 2015).

When researching VP and reading, Yang and Meng (2020) discovered that VP in kindergarten significantly predicts Chinese character reading in first grade when controlling for inhibitory control, prior reading proficiency, age, sex, sustained attention, and nonverbal IQ. Visual processing directs the way visual information is extracted from printmaking it simpler for young children to distinguish characters from each other (Aghababian & Nazir, 2000).

The ability to name pictures is one of the earliest milestones in language development and is thought to be a precursor of the child's developing visual word recognition system (Araujo et al., 2016). It is common for people with VP deficits to often be diagnosed with dyslexia (Ramus et al., 2003) and/or dyscalculia (Emmons & Anderson, 2005). Yang and Meng (2020) pointed out that as children learn to read Chinese the spatial orientation threshold between two lines is higher in children with dyslexia than in in typically developed children. Wolf et al. (2000) found that readers with dyslexia have longer naming latencies and also are more likely to have more errors in response to familiar items, such as objects, letters, and digits. A large body of neuroscience research shows that many people with dyslexia also show low-level problems in VP (Farmer & Klein, 1995; Klein, 2002). It is the reason that research would show a correlation that interventions targeting VP are successful in improving learning (Gibson et al., 2015).

Logic and Reasoning

One of the significant attributes that distinguish humans from other species is the ability to reason. Sometimes referred to as process skills, these are the skills children use to learn. One of the most noted aspects of human reasoning is deductive reasoning, meaning the ability to make logically valid inferences (Markovits, 2018). This is the crux of developing and testing hypotheses as well as key in comprehension.

Cattell’s investment theory suggests that the ability to reason underlies the attainment of academic achievement since a better ability to reason assists in using analogies and abstract schema which aid in organizing and solidifying academic knowledge (Peng & Kievit, 2020). Earlier research proposed that children younger than age 6 cannot identify logical inconsistency; however, a study by Doebel et al. (2016) signified that even children at age 4 can if the statement they are assessing are presented in an open-communication setting that encourages thought of the source's knowledge reliability. Children can remember when sources were not consistent and avoided learning new information from those inconsistencies, which suggests that the ability to think logically and reason in early childhood promotes children's social learning.

Logic and reasoning include skills and abilities like connecting, problem-solving, observing and exploring, communicating, and representing, and organizing information (Bertan et al., 2009). Problem-solving involves producing ideas, taking risks to try something new, and using materials in unusual and distinctive ways (Björklund et al., 2020). This affects our world in ways such as medical and technological advances. Children can decide which materials to use, guess what they might need, and test their ideas.

There have been studies which have examined the significance of strengthening a child's ability to problem-solve to prevent potent difficulties in the future, develop problem-solving skills, and conditions of problem-solving skills (Anlıak & Dincer, 2005; Dereli-İman, 2014; Kesicioglu, 2015). One of the academic disciplines where problem-solving skills are critical can be seen in the STEM-related fields (science, technology, engineering, and mathematics, Sahin, 1999).

Science in early childhood education is to develop the ability to observe, estimate, recognize, communicate, interpret, discover, think independently, and problem-solving (Sahin, 1999). Bahar and Aksut's study (2020) investigated the effects of activity-based science teaching practices on preschool children ages 5 and 6 years old and their ability to gain problem-solving skills. The results indicated that the average of children's post-test total scores in the experimental group is significantly higher than the average of children's post-test total scores in the control group.

Makashevska and Kamchevska (n.d) drew conclusions around cognitive development related to math and sciences in early childhood by developing logic and reasoning a child can be more active in the process of creating and learning, encouraging children in the learning process and using active learning, like discovery and problem solving, impacts cognitive development. The most important desire in the learning process of young children is the intrinsic desire to learn about the world. How children develop logic and reasoning is driven by the ability to blend different topics including math and science. Learning science and math is dependent on sources and information taken from the daily life of the child. To improve the impact of education, it is important to consider the rate of how logical-mathematical and natural-science development in each child.

Math problems use a cognitive process called relational reasoning or the ability to simultaneously scan several options between multiple components of a problem (Singly &

Bunge, 2014). Under this framework, understanding mathematics requires the ability to form abstract depictions of quantitative and qualitative connections between variables (Halford et al., 1998). This can be observed in a child's ability to solve story word problems. This requires children to conclude theoretical connections between real-world situations and corresponding numerical operations and symbols to solve the problem. Early algebra is another example of where relational reasoning can be seen. This happens when students are asked to solve for one or more unknown numbers. To solve for the missing variable, a child needs to remember the connection between numbers on both sides of the equal sign to decide which operand is needed (Hawes & Ansari, 2020).

A study by Green et al. (2017) was conducted to assess whether fluid reasoning or the ability to analyze recent problems, see patterns and relationships, and apply logic lends itself to future math success throughout primary and secondary schooling by comparing fluid reasoning to other cognitive skills (verbal and spatial) that earlier had been linked to math development. The results showed that fluid reasoning may have more impact on math development than spatial and linguistic skills. Students with strong basic spatial and numerical skills may not even be proficient in applying logical reasoning abilities to solve new or novel problems.

Since the ability to logic and reason can affect one's ability to organize information, it should be no surprise that it can affect reading comprehension. When examining comprehension, it has been argued that comprehension forms a contrasting scheme for reasoning that is parallel rather than analogous to problem-solving. Being able to construct a mental image of a scene may require more analytical problem solving as the situation or content becomes more complex such as in science-based content (Fuchs et al., 2018).

Logic and reasoning can also affect comprehension in making inferences, which is a large part of reading. Texts are rarely ever completely specific; therefore, the reader has to fill in the gaps. Inferencing asks the reader to make logical steps in determining a conclusion based on premises stated in the text. Graesser and Kruez (1993) noted that skilled readers can construct causal inferences that make sense of actions otherwise not connected to the story. The ability to make inferences partly predicts reading comprehension, as one with poor comprehension is deficient in inferencing skills (Cain & Oakhill, 1999). Young children can make more complex inferences when prompted or questioned rather than spontaneously like their older counterparts (Casteel & Simpson, 1991).

Several studies have found that those children who are better at comprehending incorporate information across stories and can make inferences when a word or phrase, take their reference from another word (Oakhill & Garnham, 1998; Yuill & Oakhil, 1988, 1986). Yuill and Oakhill (1991) provided three theories on differences in skill levels regarding inference-making: a) the amount of overall content and knowledge, b) processing limitations (PS) impede a person’s ability to make inferences and incorporate text information with previous knowledge, and c) a lack of skill and ability to know when it is appropriate to draw inferences, which requires the use of logic and reasoning. Oakhill et al. (2003) concluded that initial comprehension skills are a strong predictor of later comprehension. Additionally, the researchers noted that there are three distinct predictors of comprehension skills that tie back to logic and reasoning skills: answering inferential questions, understanding story structure, and detecting inconsistencies in the text.

Cognitive Training

Cognitive training or brain training is built on the foundation of neuroplasticity, a change in neural structure and function in response to experience or environmental stimulation (Shaw et al., 1994). This notion has become more prominent due to recent discoveries around neuroplasticity, indicating that cognitive health may be improved and have long-term effects by participating in specific exercises that are designed to target basic cognitive processes (Gibson et al., 2013).

The idea of training or retraining to think faster and perform at higher levels through brain training is becoming a multi-million-dollar industry (Sparks, 2012). Estimated sales in this sector are shown to be increasing at a rate of 20% to 25% each year. In 2013, sales surpassed $1.3B worldwide with expected projections to exceed $6B by 2020 (Cookson, 2014; Katz, 2014). SharpBrains reported that between 2005 and 2009, the cognitive training industry increased 31% to $295M with more than half of the money spent in the United States (Sparks, 2012). Because of this surge in popularity, it has become the focus of intensive academic research. The theory of cognitive training is that it improves cognitive abilities by using the repetitive practice of standardized cognitive tasks in specific cognitive skills (e.g., memory, attention, or visual processing, Colzato & Hommel, 2021).

Despite the notoriety, as well as the financial success of brain training, cognitive training effectiveness is still under debate. Even within the scientific field, there is no consensus. In 2014, scientists from two separate groups published open letters regarding the effectiveness of brain-training interventions, or “brain games,” for improving cognition. In the first written statement, “A Consensus on the Brain Training Industry from the Scientific Community,” 70 scientists argued that brain games do not provide a researched support means to improve cognitive skills or to ward off cognitive decline (Max Planck Institute for Human Development and Stanford Center on Longevity, November 27, 2020).

It was also noted that there is overwhelming evidence of overall and long-lasting positive effects on the way people’s minds and brains age, which have remained vague and have rejected the claim that things such as “brain games” give customers an avenue founded in science to reduce or reverse cognitive declines when there is no current compelling scientific evidence showing that they do. A few months later, the second group of more than

100 scientists responded, criticizing the open letter, saying it lacked form and substance, as well as arguing that there was plenty of evidence for the "brain training effect" and highlighted that because of this research, therefore the first letter could not make the statement that it was a consensus view. Group two noted, while acknowledging that separate research studies are limited, many of the controlled trials show gains that hold stable for a specific amount of time, present gains included a variety of cognitive and real-life activities, make use of control strategies specifically designed to offset for the "placebo," and detail positive changes in real-life markers of cognitive health and effects (Alescio-Lautier et al., 2014).

One contributing factor to this ongoing debate is the lack of defining what is meant by effectiveness. For brain training to be considered effective, it must be able to enhance the performance of untrained tasks by making improvements in underlying cognitive abilities (Lindenberger et al., 2017). Evidence has shown that cognitive training can strengthen skills on a trained task in the short run; however, the current discussion is around whether there is evidence for long-term benefits of training in one domain, such as VP, yields improvements in other domains, such as PS and WM, and the transfer effect to real-life daily tasks, such as driving and remembering to take medications. The effectiveness of many commercial brain training products is debatable; there is data suggesting that some programs produce clear improvements in cognitive abilities. Moore et al. (2017) pointed out that with all of the studies in cognitive training, 8 years old was the youngest age examined for the effectiveness of a brain training program.

Cognitive Training Programs

Diamond and Lee (2011) concluded that several types of training improve cognitive abilities and emotional control, in particular, programs that train executive function. When reviewing computerized brain training, some of the largest academic randomized control trials have argued that there is evidence for cognitive improvement and transfer to everyday cognitive ability (Wolinsky et al., 2016; Zelinski et al., 2011). In 2017, Mewborn et al. conducted meta-analyses of cognitive training and a pilot study that explained the benefits of improving cognitive abilities specifically highlighting transfer to untrained measures. One large-scale trial did report negative results in younger adults (Owen et al., 2010).

A different product showed that it improves WM capacity in both children and adults. This program involved training on WM tasks 5 days per week over 5 to 6 weeks. Implementing this particular computerized brain training software showed improvements in children diagnosed with ADHD and healthy adults in measures of WM as a result of training (Klingberg, 2010; Klingberg et al., 2005).

Another product that advertises increased brain fitness, increased ability to learn, and improved test scores for children showed that after training for 19–28 sessions of 20 minutes over four weeks, children with language-based learning impairments showed considerable improvement in auditory perception (Semrud-Clikeman & Ellison, 2009). Wolinsky et al. (2013) found that after cognitive training in middle-aged and older adults, there was substantial evidence of both maintenance of and even improvement that occurred in the visual processing speeds of participants.

Jaeggi et al. (2008) learned that cognitive training could improve fluid intelligence (Gf). Their data provided evidence that there is the potential to improve Gf with appropriate cognitive training and the degree of gains is dependent on the amount of training time.

As part of the Mackey et al. (2011) study involving students in an afterschool program, students participated for 75 minutes per day, 2 days per week, for 8 weeks involved engagement in numerous computer-based games and activities to test reasoning skills and processing speeds. It showed significant gains in both.

Miley et al. (2020) conducted a 6-month follow-up study on clients who had received cognitive training and found that the effects on a variety of cognitive measures were in the small to moderate range from initial assessment to six-month follow-up, suggesting that the "dosing" of 70 hours of targeted cognitive training is sufficient to endure lasting improvement.

Moore et al. (2019) found that a clinician-delivered model combined with a digital-delivered model compared to a clinician-only delivery model produces comparable results in gains. This was the only clinician-delivered cognitive training program with research for children as young as eight years of age that targets multiple cognitive skills involving processing speed, working memory, long-term memory, auditory processing, attention, visual processing, and logic and reasoning. There were multiple studies for this program demonstrating that the effects of training are significant across multiple cognitive constructs using multiple measures of standard neuropsychological tests, functional magnetic resonance imaging, and parent rating scales (Carpenter et al., 2016; Gibson et al., 2015; Jedlick 2017; Ledbetter et al., 2016; Moore et al., 2019; Moore et al., 2018).

Musick's (2015) research showed that in a clinician-delivered cognitive training program, compared to the control group in nine of the twelve cognitive areas, produced results, with some as high as 3 years-worth of growth from the pre-test assessments at the beginning of the study and the post-test assessments after the training and study.

Lack of Clarity Regarding the Meaning of Transfer

There is a lack of clarity regarding what *transfer* actually means. Simons et al. (2016) reported that the confusion regarding transfer seems connected to the vague definitions of *far transfer* and *real-world benefits*. The researchers concluded that far transfer, as defined originally for studies of education (Barnett & Ceci, 2002) and later broadened to include studies of cognitive aging (Zelinski, 2009), is typically referring to an improvement in a measure that is in different cognitive domains than that targeted by the training program (e.g., processing speed, visual processing), a definition that includes real-world measures (e.g., driving) as well. Transfer tasks that have many parts that align with the practiced task are believed to demonstrate near transfer, while tasks that have fewer parts that align are said to demonstrate far transfer (Simons et al., 2016).

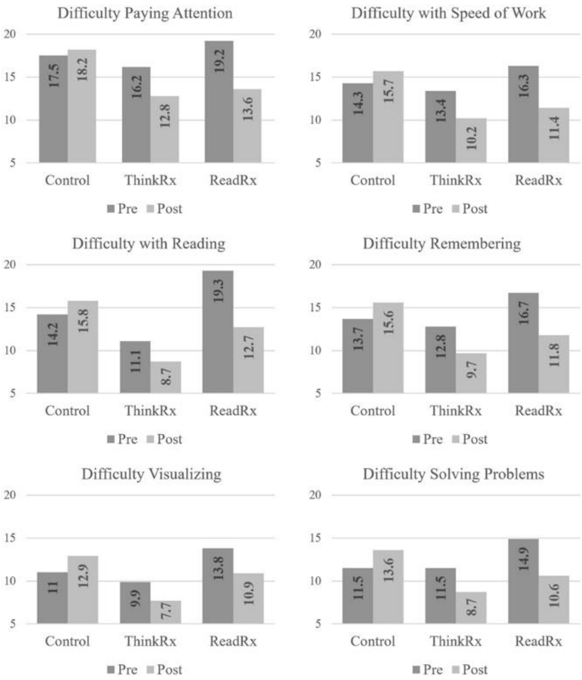
Additionally, Simons et al. (2016) found few studies that examined real-world applications and objectively measured improvements, rather laboratory tasks or neuropsychological testing were used as outcome measures. It was uncovered that when studies have measured real-world tasks, the measures have tended to be self-report and subject to demand characteristics and expectation effects. These programs may be training to the test and may or may not have any impact on real-life activities

Moore et al. (2019) noted that their research showed that transfer to untrained tasks is not due to training for the test but rather is multifaceted and qualitatively varies from the assessment tasks. Corbett et al.'s (2015) study found that there are positive results reported for older adults who trained over a longer period, which included generalization to real-world measures.

In a program evaluation of two clinician-delivered cognitive training programs, one focusing on math and the other er on reading, results showed significant improvement on achievement tests in the content area related to their program. More importantly is that those who completed the cognitive training reading or math intervention programs took achievement tests unrelated to their program (Moore, 2015). Jedlicka (2017), in a study of 178 children with learning disabilities, concluded that there are transfer effects in both clinician-delivered treatment groups using a parent-reported rating of academic skills, cognition and oppositional behavior in addition to significant gains in cognitive measures, using the WJ III of visual and auditory processing, long-term and working memory, fluid reasoning, processing speed, and attention (see Figure 3).

Figure 2

Pre-Training and Post-Training Parent Ratings in Academic Skills



Note: From Jedlicka (2017).

Musick (2015) learned that students who completed a computer-based or one-on-one clinician-delivered cognitive training showed significantly greater improvement on the Texas Assessment of Knowledge and Skills in Mathematics in their raw scores and in the percentage correct out of questions answered, getting the expected transfer of cognitive skill training to math performance that they initially thought would be the result. In another study, Hill et al. (2015) found that using a computerized cognitive training program in a laboratory setting with 322 middle school students there were significant gains in all cognitive measures and math performance after 3 weeks of training. In the second study of three groups, clinician-delivered, computer-based, and controlled study hall in a school, over 15 weeks of training, showed significantly higher scores for the two groups compared with controls on working memory, logic, and reasoning, and three of four math attitude measures.

LiftOff

There are numerous commercial early reading programs available with several falling into the category of instructional strategy. There is accumulating evidence that certain cognitive programs are effective in older children and adults (Dessey et al., 2020; Jaeggi et al., 2017; Moore & Ledbetter, 2020; Moore et al., 2019). Jaeggi et al (2017) suggested that optimal cognitive training outcomes can only be achieved through individualized interventions.

LiftOff is a proprietary 12-week cognitive training program for young children offered by LearningRx, a national network of brain training centers. It is an early start learning program that is individualized for each client, which targets major cognitive skills involving working memory, long-term memory, visual processing, reasoning, processing speed, and multiple auditory processing skills—including blending, segmenting, rhyming, and deletion of sounds. The strong focus on auditory processing skills is the cornerstone of the program, defining it as an early reading development program delivered through a cognitive training approach. The 166-page curriculum includes 456 variations of 20 foundational tasks sequenced by difficulty, speed, and complexity (Tenpas et al., 2002).

The LiftOff program is delivered one-on-one by a cognitive trainer in 90-minute sessions 3 days per week over 12 weeks. It is a hands-on intervention that incorporates a variety of manipulatives like blocks and letters, shape and number cards, speeded drill sheets, handwriting sheets, and a hacky sack that are used in training procedures all paced by a metronome beat. An example of three procedures is shown in Figure 3.

Figure 3

Cognitive Training LiftOff Drills

Visual Memory Sounds Comprehension Blocks

Note: LearningRx (2020). For photo release, see Appendix A.

The metronome is used to increase the intensity of the training tasks and to help improve attention and processing speed. During each training session, trainers give immediate feedback to provide correction and encouragement as students master each task. Trainers track progression through the curriculum using a web-based application that ensures the intervention is followed with fidelity.

The curriculum was created by Dr. Ken Gibson, a behavioral optometrist specializing in pediatric vision therapy as a precursor to ThinkRx and ReadRx, the cognitive training, and reading remediation programs offered at LearningRx centers. Although there is a robust body of research supporting LearningRx programs (Gibson et al., 2015; Jedlicka 2017; Ledbetter et al., 2016; Moore et al., 2019; Moore et al., 2018), no study to date has specifically examined the LiftOff curriculum.

Summary

Cognitive skills are complex and difficult to isolate in lieu of other developmental areas. Many studies have attempted to examine specific cognitive skills and how they impact reading, learning, and academic success. Of these, WM, PS, VP, AP, and logic and reasoning were the focus of this review of literature. All have been connected to some level of impact on reading, learning, and/or academic success. Having so many cognitive skills connected to a child's ability to learn in various academic areas leads to the question of whether there is a way or ways to strengthen and improve those cognitive areas.

An additional examination has been given to the controversy surrounding the effectiveness of cognitive training or brain training. Much of the research seems to agree on the ability to improve cognitive skills at least to a specific task; however, there is much disagreement on improved ability in other tasks and if there is transfer to real-life tasks. Between defining what effectiveness and transfer present as with brain training, more research is needed. Moreover, there is a lack of research on the effectiveness of brain training targeting children ages 5 to 7-years old.

The purpose of this causal-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. If shown to be effective, this could provide a viable alternative RTI for young children struggling to read and learn.

Chapter 3: Methodology

Introduction

A child's reading and math ability upon entering elementary school are both strongly predictive of academic achievement in later grades (Duncan et al., 2007; Pace et al., 2019). Research and randomized controlled trials examining multiple instructional strategies and interventions over the past few decades have led to a significant portfolio of evidence-based best practices to provide a framework for reading instruction, intervention, and the early identification of at-risk readers (Petscher et al., 2020). Hulme and Snowling (2013) proposed that learning to read is a key objective of early education, and any difficulties in learning to read may result in serious adverse consequences.

In reviewing academic trends from 2010-to to 2017, Kuhfeld et al. (2020) concluded that there are three key findings:

- There were stable trends between 2010 to 2014 followed by small declines in entry-to-school reading and math skills.
- There was modest narrowing of the racial/ethnic achievement gaps.
- There is no evidence that state-funded pre-K enrollment is associated with districts' trends in academic skills between 2010 and 2017.

One of their most significant findings was that academic skills at school entry were mostly flat between 2010 and 2014 followed by small declines between 2014 and 2017, particularly in math.

In 2019, the National Education Assessment Program (NAEP) in comparison to 2017, indicted that in 2019 reading scores were lower for fourth-grade students at the 10th, 25th, 50th, and 75th percentiles. The average reading score for fourth-grade students in 2019 was approximately one point lower compared to 2017, the previous assessment year. Muhlend et al.’s (2020) report also noted that it has been close to 10 years since research has seen sturdy growth in either reading or math, other than a slight exception of eighth-grade reading.

How a child performs in the early elementary year’s areas such as language, mathematics, literacy, self-regulation, cognition, approaches to learning, and social-emotional adjustment has typically maintained the remainder of the primary and secondary years (Pace et al., 2019). When a child struggles to learn, many find it an overwhelming obstacle to overcome. Academic struggles, including reading, often become more consistent in the elementary grades (Morgan et.al, 2019).

If there is an underlying cognitive issue for a child with learning difficulties, it may be even more challenging. Identifying these challenges and how they manifest themselves in a child’s ability to learn and read can be a critical piece to addressing their needs. There may be a reason for many students’ challenges in school that is tied to one or more underlying cognitive deficits.

Research suggests that early identification of reading struggles is important for diminishing the negative outcomes, which include reduced educational achievement (Ozernov-Palchik et al., 2017). If there is a deficit in reading, it poses significant difficulties for the students regarding being successful at grade level. These statistics are important because it has been shown that not being able to read at grade level in third grade is among the biggest predictors of later school dropout (Lesnik et al., 2010).

Problem Statement

Research suggests that early identification of reading struggles is important for diminishing negative outcomes, which include reduced educational achievement (Ozernov-Palchik et al., 2017). If there is a deficit in reading, it presents a sizable problem for the student with being successful at grade level. This means early detection of reading deficiencies and early academic intervention, or instruction can be crucial to reducing the number of children below grade level by third grade.

Many of the efforts that have been made focus on instructional strategies and reading skills building with little improvements in national student performance and the academic achievement gaps (Wigfield et al., 2016). Identifying underlying causes of reading academic difficulties can guide decisions on intervention or instructional methods to assist children at risk for future academic difficulties. The problem to solve is if targeted cognitive training can increase low cognitive skills that underlie the ability to read.

Research has connected certain cognitive skills to early reading skills. For example, a deficit in WM may contribute to difficulties in comprehending text and following multi-step instructions (Viterbori et al., 2015). Reading comprehension requires the ability to build integrated mental pictures; therefore, it relies heavily on both the storage functions and processing of working memory (Gathercole & Baddeley, 2014).

Geary et al. (2012) noted that research shows deficits in WM and PS contribute to problems learning math and significant difficulties in the overall learning process. Studies also point to relations between impairments on various tests of WM and distinct types of learning disabilities (Boustanzar & Rezayi, 2017; Zamani & Pouratashi, 2018).

Research Questions

With significant research connecting cognitive skills to a child's ability to read and learn, this research aims to examine the effectiveness of a program that focuses on strengthening cognitive skills in children ages five to seven years old. The following research questions were addressed throughout this casual-comparative study:

R1: Is there a statistically significant difference in pretest and post-test measures of cognitive skills for children ages 5 to 7-years old following completion of the LiftOff cognitive training program?

H_1: LiftOff training program shows significant improvements in cognitive skills in children ages 5 to 7-years old.

H_0: LiftOff training program does not show significant improvements in cognitive skills in children ages 5 to 7-years old.

R2: Does the effect of the LiftOff cognitive training program differ by age and sex?

H_1: There are significant differences in early reading and cognitive test score changes following Liftoff cognitive training based on age and sex.

H_0: There are no significant differences in early reading and cognitive test score changes following Liftoff cognitive training based on age and sex.

Research Methodology

A casual-comparative quantitative design was used for this study due to the emphasis on numbers and figures in the collection and analysis of data. This methodology allows the researcher to use the data collection and analysis to make general conclusions (Eyisi, 2016). A quantitative research design provides the opportunity to use control groups, which enables a comparison of the data from the two groups (e.g., pre-intervention and post-intervention). Using a quantitative research design helped to reduce researcher bias because data were collected from a secondary archived source.

Research Design

The purpose of a causal-comparative design is for the researcher to find links connecting dependent and independent variables following action or intervention (Salkind, 2010). The objective is decided if the independent variable changes the outcome, or the dependent variable, through a comparison of two or more groups of individuals. It was determined that the quantitative, causal-comparison design was best suited for this study because the data were analyzed through statistics. The data were obtained from participants who were enrolled in a specific brain training program, and archival data were used.

Through this causal-comparative study I measured cognitive task performance in the areas of working memory, processing speed, auditory processing, visual processing, and logic and reasoning in children ages 5 to 7. This assessed the difference between pre- and post-intervention assessment measures with the same group. In these situations, it can infer causal relationships (Salkind, 2010). I also compared the change scores for these children to each other as well as the effects of sex.

The data collected was taken from a normed and validated standardized cognitive assessment for the pre-and post-assessment, the WJ III Tests of Cognitive Abilities and subtests from the WJ III Tests of Achievement of students age 5 to 7 who had completed a LiftOff cognitive training program through LearningRx completed between 2010 and 2019 (n =1,067). Since the data were collected from archived records, it was impossible to know if reporting errors were made in the original records. However, the large sample size mitigates the impact a few errors may have on the overall results (Anderson et al., 2017).

Study Population and Sample Selection

The sample selection was a nonprobability sample based on Creswell and Creswell's (2017) description of when the researcher selects the individuals due to their availability, convenience, and having a specific characteristic that the researcher is studying. It consisted of 1,067 children between the ages of 5 and 7-years old who completed the LiftOff cognitive training program at one of seventy learning centers in the United States between 2011 and 2020. LearningRx is a national network of clinics that offer a comprehensive clinician-delivered cognitive training curriculum for children and adults as well as intensive reading and math interventions for children and adolescents. The primary clientele of LearningRx centers are children with learning disabilities or academic struggles, including dyslexia, attention deficit hyperactivity disorder, and speech and language delays (Moore et al., 2019).

Instrumentation

It is important to use an assessment tool that has been proven reliable and valid (Sullivan, 2011). The WJ III Cognitive Abilities and Tests of Achievement is a normed, validated, and reliable assessment tool of both cognitive abilities and achievement among children and is significantly used across the globe because of its distinguished features (Abu-Hamour et al., 2012). The worldwide use of the WJ III upholds its value.

When using a true growth score, which explains the time gap between testing sessions, developmental growth that would typically take place over time is accounted for giving a clear understanding of actual growth attained through LiftOff procedures (Jaffe, 2009). Data was gathered for all of the following subtests, use of standard scores:

a. Working Memory Test. The Numbers Reversed subtest of the WJ III Tests of Cognitive Abilities measures working memory by asking the student to remember a span of numbers and repeat them in reverse order from how they were presented (Mather & Woodcock, 2001).
b. Processing Speed Test. The Visual Matching subtest of the WJ III Tests of Cognitive Abilities measures perceptual processing speed by asking the student to discriminate visual symbols. In three minutes, the student identifies and circles pairs of matching numbers in each row of six number combinations ranging from single-digit to three-digit numbers (Mather & Woodcock, 2001).
c. Auditory Processing Test. The Sound Awareness subtest of the WJ III Tests of Achievement measures four phonological awareness skills: sound rhyming, sound deletion, sound substitution, and sound reversal. The test administrator presents a series of language sounds, and the participant must manipulate the sounds and produce a response. (Mather & Woodcock, 2001).

d. Visual Processing Test. The Spatial Relations subtest of the WJ III Tests of Cognitive Abilities measures visual processing skills by asking the student to match individual puzzle pieces to a completed shape (Mather & Woodcock, 2001).

e. Logic and Reasoning Test. The Concept Formation subtest of the WJ III Tests of Cognitive Abilities measures fluid reasoning by requiring the student to use inductive logic and apply rules to sets of shapes that share similarities and differences. The student must indicate the rule that differentiates one set of shapes from the other (Mather & Woodcock, 2001).

Validity and Reliability

The WJ III Tests of Cognitive Abilities and Tests of Achievement are a normed, validated, and reliable assessment tool of both cognitive abilities and achievement among children and are significantly used across the globe because of its distinguished features (Abu-Hamour et al., 2012). The reliability metrics for WJ III Numbers Reversed subtest has median reliability for 5-years old’s of 0.92; 6-year-old’s is 0.89, and 7-year-old’s is 0.84; the Visual Matching subtest has median reliability for 5-year-old’s of 0.91; 6-year-old’s is 0.91, and 7-year-old’s is 0.89; the Sound Awareness subtest has median reliability for 5-year-old’s of 0.85; 6-year-olds is 0.93, and 7-year-olds is 0.93; the Spatial Relations subtest has median reliability for 5-year-old’s of 0.90; 6-year-olds is 0.83, and 7-year-olds is 0.78; and the Concept Formation subtest has median reliability for 5-year-old’s of 0.94; 6-year-old’s is 0.94; and 7-year-old’s is 0.96 (Woodcock et al., 2001a).

Data Collection Procedures

The data for this casual-comparative study was obtained from a centralized database of client records for a national network of cognitive training centers. The dataset was compiled through a standard query of records performed by a member of the research department at the organization. The data was stripped of all identifying information and saved in an EXCEL spreadsheet. No identifying codes were used, and no information was traceable back to the identity of the clients.

The dataset emailed contained the following variables: random ID numbers, client age in years and months, grade, city, state, zip code, ethnicity, sex, diagnosis, pre-intervention standard scores, and post-intervention standard scores. Before and after LiftOff training, each client was assessed using the WJ III Cognitive Abilities and Tests of Achievement. This test is a nationally standardized norm-referenced test that is often used by educators and psychologists to measure cognitive skills and academic abilities (Abu-Harmou et al., 2012).

Data Analysis Procedures

The current causal-comparative study set out to understand how the LiftOff program affects students by age, as well as sex. Addressing the various and already known developmental differences between ages and sexes without the program, I made a comparison regarding the effectiveness of the program on cognitive skills. Comparisons between the groups demonstrate whether it aids one sex or age more effectively than the others. For example, the program may show promise in 5-year-old boys and 6-year-old girls. Similarly, cognition may improve in 7-year-old boys only. The data indicates who the program helps and how it helps.

Research question 1 assessed the effectiveness of the LiftOff program on cognitive skills for children ages 5 to 7-years old. For this question, the casual-comparative study compared pre-intervention WJ III Scores with the post-intervention WJ III scores using a paired-samples t-test for the pretest to post-test change in standard scores for everyone. A Bonferroni-corrected p-value of $p < .01$ was used for significance testing, and the effect size was assessed using Cohen's d.

For research question 2, a factorial MANOVA was used to examine differences by age, differences by sex, and the interaction of sex and age. This analysis shows if there is an association between cognitive training and improvement in cognition and if that is impacted by age, sex, or both. These analyses compared the gain scores, post minus pre-Standard Score, for children age 5, 6, and 7 to each other. The Tukey post-hoc test was also performed to answer research question 2 to control for multiple comparisons and see the exact differences (Armstrong, 2014). If statistically significant effects are obtained with more than two groups, a post-hoc test needs to be performed to determine which groups differ. The use of effect sizes is important because it allows for comparing the magnitude of experimental treatments from one experiment to another. The effect size was assessed using partial eta squared (Napierala, 2012). Additionally, a *p*-value of 0.05 was used in the analysis.

The results were then plotted appropriately, addressing the differences in the groups if there were any to be found. The data indicated whether the program is effective, and for which group it works best. The data analysis addressed where the program would be used most effectively. The results of these analyses determined if this program was effective for this group of children and which children benefited the most from the intervention.

Ethical Considerations

Approval from both Concordia University and Gibson Research Institute's IRB process were sought out and obtained. The sample for this study involved archived data gathered from a database of clients from LearningRx and not collected directly me. Archived data should conform to ethical and legal guidelines with the safeguarding of anonymity when this has been requested by participants or guaranteed to them (Corti & Thompson, 2012). All participants, as part of the orientation process of LearningRx, signed a study statement containing the following:

> Student test scores are used in scientific research studies to evaluate our cognitive training programs. To ensure confidentiality, only the principal researchers will have access to data associated with student identities. When publishing research results, no personally identifying information will ever be disclosed as well as provided in a Privacy Policy Statement. (See Appendix B)

I have owned and operated my center since May 2017. Since my center does not use the WJ III Cognitive Abilities and Tests of Achievement as an assessment tool, it eliminated the possibility that any of the participants received training or were assessed at my location. This casual-comparative study used pre-existing archival data from an instrument that I did not have a role in the creation, validation, or distribution of.

The data for this current casual-comparative study was obtained from a centralized database of client records for a national network of cognitive training centers that administered both the WJ III and LiftOff training between 2011 and 2020. The data were queried by a member of the research department at the organization. The data was stripped of all identifying information and emailed to me containing the following variables: random ID numbers, client age in years and months, grade, city, state, zip code, ethnicity, sex, diagnosis, pretest intervention measures, and post-tests intervention measures. At the time of starting this research, I had not personally trained a client using the LiftOff program and was unfamiliar with the protocols and training methods associated with it.

Limitations

The lack of a control group is the most obvious limitation and one that prevents a causal connection between the intervention and the outcome measures. By using control groups, researchers can confirm that study results are due to the manipulation of independent variables rather than extraneous variables (Allen, 2017). This means that control groups are made up of participants who are not exposed to the manipulated independent variable but are measured on the study's dependent variables. Including a control group, it can strengthen if a researcher can conclude the study.

Another limitation of the casual-comparative study is that the data were taken from archived records and not collected directly by the researcher. Data may be considered archived as any sort of information, previously collected by others, amenable to systematic study (Jones, 2010). In the social sciences, there is a well-established tradition of reanalyzing quantitative data (Corti & Thompson, 2012). The use of existing data sets presents the opportunity to provide some methodological benefits. To reduce or overcome issues to internal validity such as experiment bias an effective technique is to use multiple existing data sets. By using of multiple data sets, or purely external data sets can strengthen arguments for being able to take a broad view of the results of a study (Shultz et al., 2005)

In some cases, the use of a pretest-posttest model could be a limitation in that the pretest may sensitize participants to the focus of the experiment which may potentially influence the results such as participants would be able to study the test (Rogers & Revesz, 2020). However, considering the age of the participants, 5 to 7-years old and the length of time between pre- and post-intervention measures (average 60 hours), it is unlikely that would be a factor. It is impossible to know if reporting errors were made in the original records. However, the large sample size mitigates the impact a few errors might have on the overall results (Anderson et al., 2017).

Summary

This causal-comparative study used secondary archival data analysis of intervention measures standard scores collected from students between the ages of 5 and 7-years old who completed the LiftOff cognitive training program between 2011 and 2020 at one of 70 LearningRx centers in the United States. The use of a causal-comparative design enables the researcher to decide if the independent variable is associated with a change in the outcomes, or the dependent variable, through a comparison of two or more groups of individuals. When using a paired sample t-test, the pretest functions as a default control group since no participants have yet to be subjected to the program; therefore, the post-test is the caused result of the program on the same group (Xu et al., 2017).

The effect size in this study was assessed using Cohen's d to answer research question 1. The use of Cohen's *d* is appropriate use for effect size when comparing any two assessment results to see how substantially different they are (Nissan et al., 2018). Effect sizes are reported in Cohen's *d* values defined by .20 as a small effect, .50 as a medium effect, and .80 as a large effect (Cohen, 1988).

Partial eta squared was used to answer research question 2. The Tukey post-hoc test was also performed for to control for multiple comparisons and see the exact differences (Armstrong, 2014). Eta-squared is a measure of effect size used in t-tests and MANOVA and showed the associated strength with the interaction effect (Bakeman, 2005). The effect size for eta squared are .01 for small effect size; .06 for medium effect size; .14 or higher for large effect size. A *p*-value of 0.05 was used. Because the standard deviation includes how many clients participated, using the effect size allowed me to compare the effectiveness of training more objectively (Napierala, 2012).

Chapter 4: Data Analysis and Results

The purpose of this causal-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. LiftOff is a proprietary 12-week cognitive training program for young children offered by LearningRx, a national network of brain training centers. It is an early start learning program that targets major cognitive skills including working memory, long-term memory, visual processing, reasoning, processing speed, and multiple auditory processing skills including blending, segmenting, rhyming, and deletion of sounds.

Introduction

This casual-comparative study examined the research on cognitive skills related to learning, including those shown to impact reading skills and academic success. There is still controversy in the research on whether or not cognitive training works (Jaeggi et al., 2017). Cognitive ability or skills in early childhood are a key factor determining a child’s future academic success such as working memory linked to algebra performance (U.S. National Science Foundation, 2018).

In early childhood, to learn academic skills, children use cognitive skills therefore most academic tasks involve the use of those cognitive abilities (Evans & Stanovich, 2013; Peng et al., 2018). Being able to identify underlying causes of reading and academic difficulties can guide decisions on intervention or instructional methods to assist children at risk for future academic difficulties. Many of the efforts that have been made have focused on instructional strategies and reading skills building. Unfortunately, these have not met their goal of improving national student performance and narrowing academic achievement gaps (Wigfield et al., 2016).

Sample Population

The sample population for this study involved archived data gathered from a database of clients from LearningRx. This sample was a nonprobability sample (*n* =1,067) based on Creswell and Creswell's (2017) description of when the researcher selects the individuals due to their availability, convenience, and having specific characteristics that the researcher is studying. LearningRx is a national network of clinics that offer a comprehensive clinician-delivered cognitive training curriculum for children and adults involving intensive reading and math interventions for children and adolescents. The primary clientele of LearningRx centers are children with learning disabilities or academic struggles, including dyslexia, attention deficit hyperactivity disorder, and speech and language delays (Moore et al., 2019).

The 1,067 children were between the ages of 5 and 7-years old who completed the LiftOff cognitive training program at one of 70 learning centers in the United States between 2011 and 2020. The composition of the sample involved 678 (63%) males and 398 (37%) females with a mean age of 5.9 years (months = 70.8, *SD* = 8.2). Table 1 indicates the ethnic composition of the sample population.

Table 1

Sample Size Ethnic Composition

Race/Ethnicity	*N*	%
Caucasian	596	55%
Black	71	7%
Asian	42	4%
Hispanic	53	5%
Mixed Race	39	4%
Native American	1	<1%
Not Reported	293	27%

Within this sample population Table 2 shows the number of participants in the sample data who reported a disability and a description of the disability.

Table 2

Reported Disabilities

Disability	*N*	%
Speech and Language disorder	199	18.3%
ADHD	196	18%
Reading Disability	82	7.7%
Autism Spectrum Disorder (ASD)	74	7%

Data were analyzed using IBM SPSS Version 26. Threats to internal validity can often include maturation, history, selection, testing, instrumentation, design contamination, experimental mortality, design contamination, and the John Henry Effect, which occurs when the control group knows its role in an experiment (Saretsky, 1972).

Due to the fact that I reviewed archived data over previous years and all participants, as part of the orientation process of LearningRx, signed a study statement reading, "Student test scores are used in scientific research studies to evaluate our cognitive training programs" (see Appendix B), there was no threat of design contamination, instrumentation, or the John Henry Effect. The use of archived data from a second party, reduced the threat of internal validity since there were no new events that impacted participants' progress. There was also no threat to experimental mortality because there was no potential for participants to drop out of the study since I used archived data. The secondary archived data for each participant came from an average of 3 to 4 months' time span between pre- and post-assessment, so there was no threat of maturation.

To answer Research Question 1, paired-samples *t*-tests were conducted to determine if there was a statistically significant difference between pretest and post-test standard scores on each variable of interest. The paired *t*-test was used because data were matched pairs, and I wanted to show that the difference of each pair was normally distributed as suggested by Xu et al. (2017). A Bonferroni correction was applied to account for multiple comparisons using a new alpha of $p < .01$ for the significance threshold. The Bonferroni correction was used to be sure that was not a single false positive in the set of tests since that would be an issue. Bonferroni correction is effective if there is a small number of multiple comparisons and what is being evaluated is that one or two might be significant (Armstrong, 2014). Effect sizes are reported in Cohen's *d* values defined by .20 as a small effect, .50 as a medium effect, and .80 as a large effect (Cohen, 1988).

To answer Research Question 2, a factorial multivariate analysis of variance (MANOVA) was conducted. A MANOVA was used since there was a correlation between the dependent variables. This allowed for more statistical power as the MANOVA identified effects that are smaller more so than what an ANOVA can find. A MANOVA also allowed for multiple dependent variables to be examined for patterns (Smith et al., 2020).

The Tukey post-hoc test was also performed for research question 2 to control for multiple comparisons and see the exact differences (Armstrong, 2014). A post hoc test was used after a statistically significant result was found and wanted to determine where those differences came from (Allen, 2017). The effect size was assessed using eta squared. Eta-squared is a measure of effect size used in *t*-tests and MANOVA and showed the associated strength with the interaction effect (Bakeman, 2005). The effect size for eta squared are .01 for small effect size; .06 for medium effect size; .14 or higher for large effect size

Results

R1: Is There a Statistically Significant Difference in Cognitive Skills in Children Ages 5 to 7-years old Who Completed LiftOff, a One-On-One Cognitive Training Program?

Pretest and post-test scores on each of the five variables were collected from archived student records. The mean standard scores and standard deviations are presented in Table 3 along with the results of the paired-samples *t*-tests, which revealed a statistically significant difference between pretest and post-test on all variables measured ($p < .001$) with medium to very large effect sizes represented by Cohen's *d* in the final column.

Table 3

Paired Samples T-Tests Results

Variable	Pretest Score (*SD*)	Post-test Score (*SD*)	Mean change (*SD*)	95% *CI*	*t*	*df*	*p*	*d*
Visual processing	102.2 (14.0)	108.5 (10.9)	6.3 (11.0)	5.6-7.0	18.7	1067	.000	.57
Logic and reasoning	98.2 (14.9)	107.8 (15.0)	9.6 (12.6)	8.9 - 10.4	25.0	1067	.000	.44
Working memory	92.5 (15.7)	100.6 (14.4)	8.1 (14.1)	7.2-8.9	18.7	1067	.000	.57
Processing speed	100.5 (9.3)	105.9 (9.9)	5.4 (7.8)	4.8-5.8	22.3	1067	.000	.69
Auditory processing	98.6 (19.3)	112.6 (18.5)	14.0 (6.4)	13.5 - 14.2	71.2	1066	.000	2.2

Note. *SD*, standard deviation; *CI*, confidence interval; *t*, *t*-score; *df*, degrees of freedom; *p*, probability; *d*, Cohen's *d*.

First, consider *t*-tests and confidence intervals for the mean change in the five sub-scale scores. The mean change in score indicated a statistically significant improvement on each sub-scale ($p < .0001$). The confidence interval for the mean improvement for each is also reported. The visual processing score improved by 6.3 points on average (95% *CI*: 5.6, 7.0), logic and reasoning score improved by 9.6 points on average (95% *CI*: 8.9, 10.4), working memory score improved by 8.1 points on average (95% *CI*: 7.2, 8.9), processing speed score improved 5.4 points on average (95% *CI*: 4.8, 5.8) and auditory processing score improved 14.0 points on average (95% *CI*: 13.5, 14.2). The largest effects were seen in auditory processing and processing speed. The smallest effect was seen in logic and reasoning.

Mean changes in standard scores ranged from 5.4 points (SD = 7.8) to 14.0 points (SD = 6.4) with the greatest changes found in auditory processing and working memory. The smallest change was found in processing speed. Because all comparisons indicated a statistically significant difference between pretest and post-test scores, the null hypothesis was rejected in favor of the research hypothesis and thus there is a significant difference between pre-test and post-test scores for children who completed the LiftOff cognitive training program.

R2: Does the Effect of the LiftOff Cognitive Training Program Differ by Age and Sex?

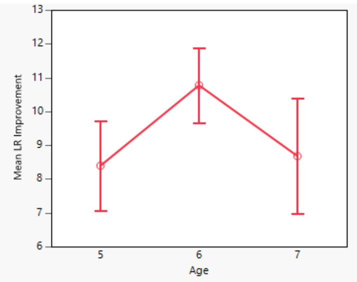
Using age and sex as the independent variables and change scores for each test as the dependent variable, MANOVA with Tukey post-hoc tests were conducted to see the impact of age and sex alone as well as the interaction of age and sex. The overall MANOVA was significant for the effect of age ($\Lambda = .98$, $F = 1.84$, $p = .049$, partial $\eta^2 = .009$) but not significant for the effect of sex ($\Lambda = .99$, F(5,1057 = 1.09, $p = .364$, partial $\eta^2 = .005$) or the interaction of age and sex ($\Lambda = .99$, $F = .97$, $p = .46$, partial $\eta^2 = .005$). Results further indicated the overall effect of age was only significant for logic and reasoning ($F = 4.23$, $p = .015$, partial $\eta^2 = .008$) and processing speed ($F = 3.42$, $p = .033$, partial $\eta^2 = .006$) with very small effects.

Post-Hoc Analysis of Age

To determine the specific effect of age on change in logic and reasoning and processing speed scores, a Tukey post-hoc test was performed. The post-hoc analysis indicated a significant difference between 5 and 6-year-olds on change in logic and reasoning scores (*M* = 2.39, *SD* = .88, *p* = .018) but no significant difference between five and seven-year-olds (*M* =-2.39, *SD* =.879, *p* =.18) or between six and seven-year-olds (*M* = -204, *SD* = 1.018, *p* =.112). Figure 4 shows the age effect on logic and reasoning.

Figure 4

Age Effect on Plotted Logic and Reasoning



As shown in Figures 5 and 6, neither sex nor age is significantly related to the mean VP, WM, PS, or AP improvement. Therefore, the null hypothesis cannot be rejected. A confidence interval for the difference in the improvement does not appear that large; however, with a mean difference of 2.38 points (95% *CI*: .32, 4.44). The post-hoc analysis also revealed that the effect of age on change in processing speed scores did not survive the correction for multiple comparisons (*p* > .05).

Figure 5

Post-Hoc Analysis By Age

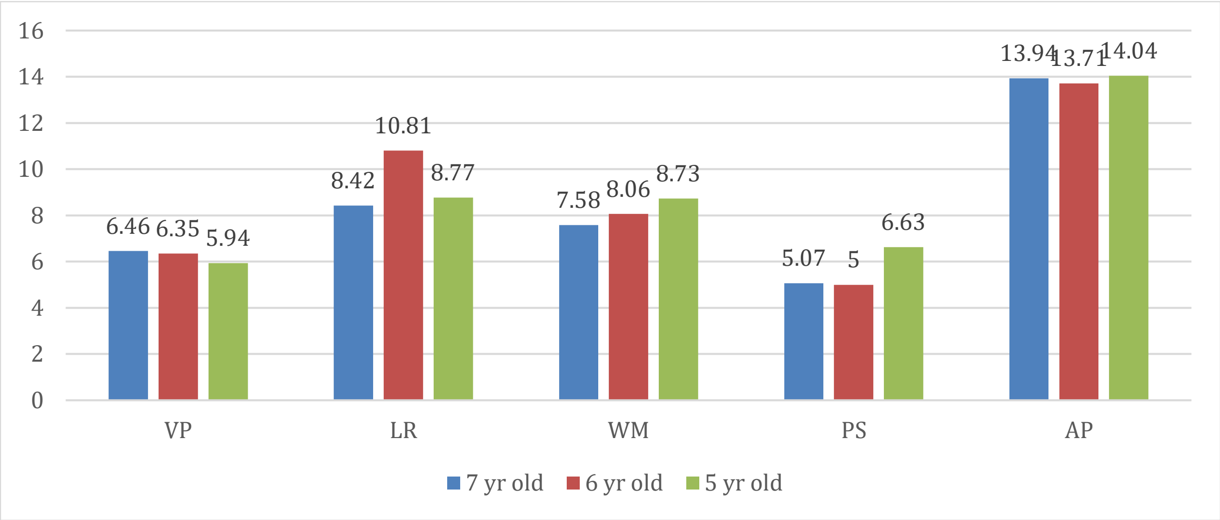
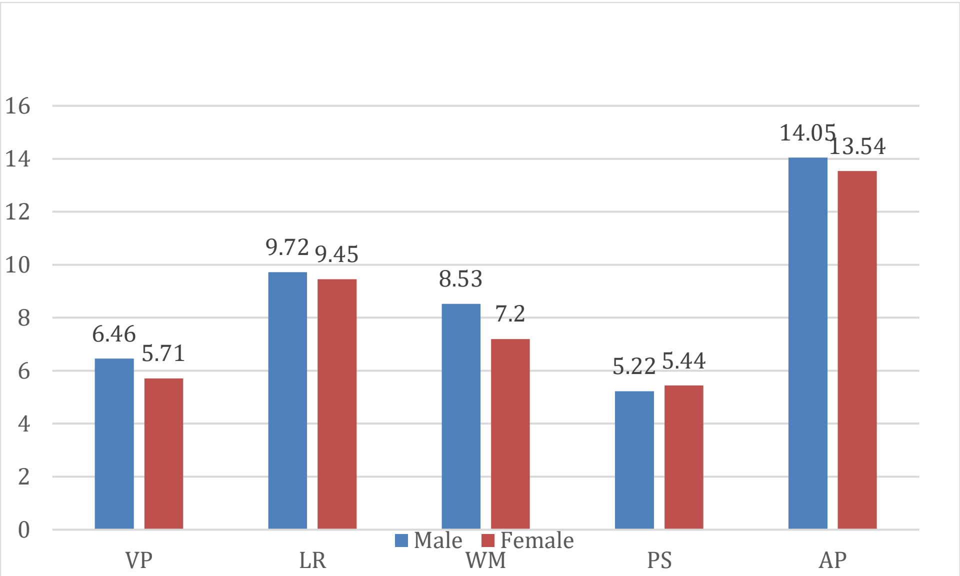


Figure 6

Post-Hoc Analysis By Sex



Figures 7 through 11 show the estimated marginal means for each cognitive skill by age and sex.

Figure 7

Estimated Marginal Means of Visual Processing

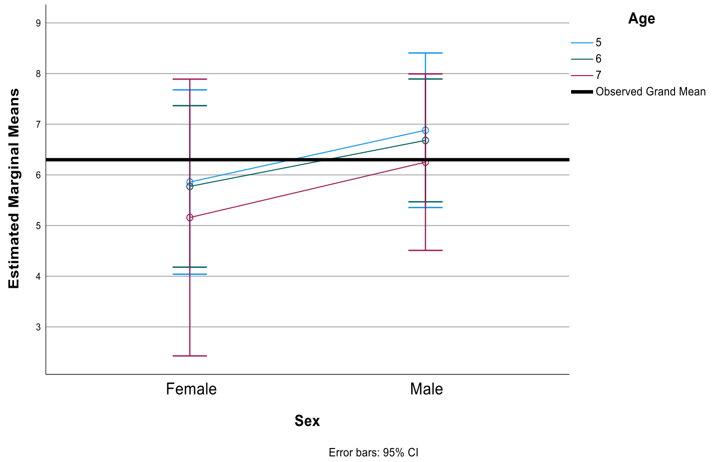


Figure 8

Estimated Marginal Means of Logic and Reasoning

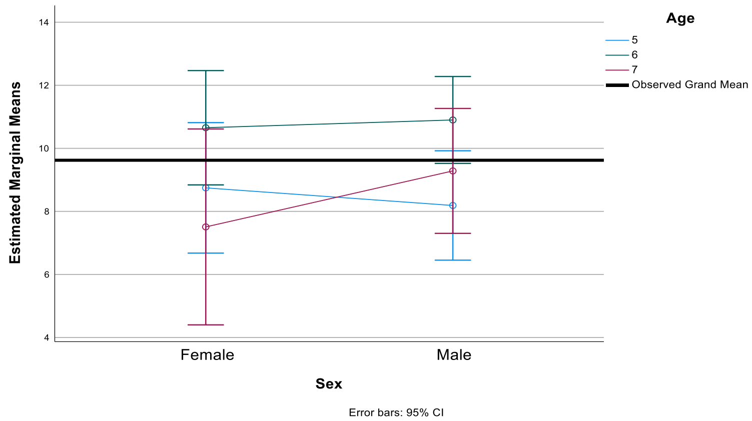


Figure 9

Estimated Marginal Means of Working Memory

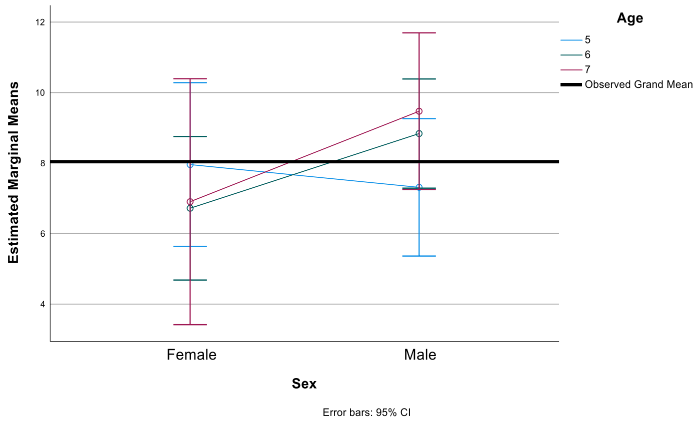


Figure 10

Estimated Marginal Means of Auditory Processing

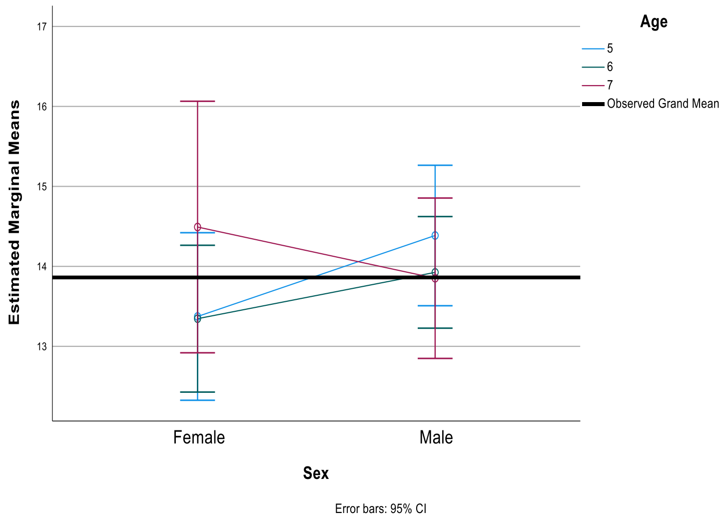
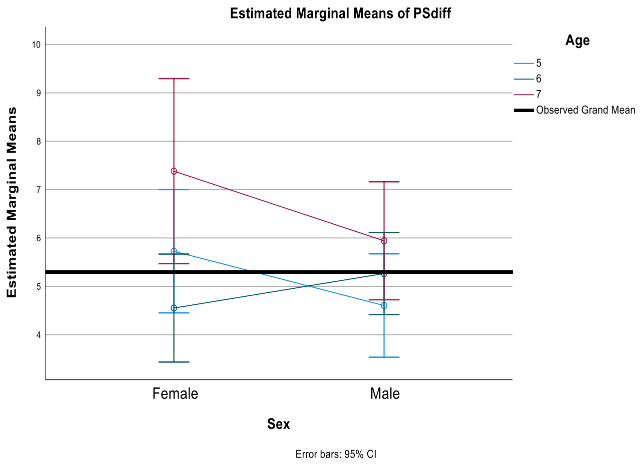


Figure 11

Estimated Marginal Means of Processing Speed



Summary

The data was collected from archived data from LearningRx of pre-test and post-test scores on the WJ III Tests of Cognitive Abilities and Tests of Achievement regarding a sample population of 1,067 children ages 5 to 7-years old who completed the LiftOff cognitive training program. The results indicated significant improvement in all cognitive skills measured. Statistical analyses revealed significant changes from pre-test to post-test on all five measures: visual processing, auditory processing, processing speed, working memory, and logic and reasoning. The largest effects were seen in auditory processing and processing speed. The smallest effect was seen in logic and reasoning.

Additional analysis showed that sex is not significantly related to any of the measures. Age is significantly related to only logic and reasoning, whereas the post-hoc analysis indicated a significant difference between 5 and 6-year-olds on change in logic and reasoning scores. These results show that the LiftOff cognitive training program is significantly associated with improvements in cognitive skills for this sample of children ages 5 to 7-years old.

Chapter 5: Discussion and Conclusions

The purpose of this causal-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. A causal-comparative design makes the connection between the dependent and independent variables following action or intervention (Creswell & Creswell, 2017). The objective is decided if the independent variable changed the outcome, or the dependent variable, through a comparison of two or more groups of individuals.

Introduction

Being shown as effective, the results of this study could provide a viable alternative response to intervention for young children struggling to read and learn. The ability to identify underlying causes of reading academic difficulties can guide decisions on intervention or instructional methods to assist children at risk for future academic difficulties.

If there is an underlying cognitive issue for a child with learning difficulties, it may be even more challenging (Barnes et al., 2020). Identifying these challenges and how they manifest themselves in a child's learning ability can be a critical piece to addressing their needs. There may be a reason for many students' challenges in school that is linked to one or more underlying cognitive deficits. Research has shown that when children are identified early with a deficit in learning and cognitive skills would make it easier to develop mediation strategies that would aid in overcoming the difficulties and realizing their learning potential (Tzuriel, 2020).

The goal of this study was to determine the answers to the following research questions any hypotheses:

R1: Is there a statistically significant difference in pretest and post-test measures of cognitive skills for children ages 5 to 7-years old following completion of the LiftOff cognitive training program?

H_1: LiftOff training program shows significant improvements in cognitive skills in children ages 5 to 7-years old.

H_0: LiftOff training program does not show significant improvements in cognitive skills in children ages 5 to 7-years old.

R2: Does the effect of the LiftOff cognitive training program differ by age and sex?

H_1: There are significant differences in early reading and cognitive test score changes following Liftoff cognitive training based on age and sex.

H_0: There are no significant differences in early reading and cognitive test score changes following Liftoff cognitive training based on age and sex.

Discussion and Interpretation

Cognitive theory was found to be the best theoretical perspective to conduct this research. Cognitive theory examines how the brain thinks using different processes and the impact of internal and external factors (Schwarzer & Luszczynska, 2005). Cognitive theory uses developmental psychology and cognitive science (Xu, 2019). Having research that has a strong basis in cognitive theory, made it easier to review the literature and determine how they fit within the purpose of this study.

Specifically, considering the efficacy of cognitive training on cognitive skills that support learning, Feuerstein's theory of structural cognitive modifiability was the best framework (Tzuriel, 2020). Feuerstein's theory asserts that cognition is not static but malleable as a result of mediated experiences with the world (Haywood, 2020). Feuerstein focused more on the prerequisites of thinking and ways to help people learn how to learn. Tan (2003) argued that each learner has different capabilities to benefit from a mediated experience. Each person displays differences concerning their cognitive structure, their knowledge base, and their operational functioning.

The LiftOff cognitive training program aligns with the theories that cognition is malleable, and cognitive training is a means to target and strengthen major cognitive skills including working memory, long-term memory, visual processing, reasoning, processing speed, and multiple auditory processing skills including blending, segmenting rhyming, and deletion of sounds. The results produced in this causal-comparative study, align with previous research conducted with similar cognitive training programs in showing improvement in measures of cognitive skills.

Carpenter et al. (2016) conducted a study using a randomized control trial that examined the effects of a one-on-one cognitive training program (ThinkRx), which targeted memory, visual processing, auditory processing, processing speed, logic and reasoning, attention, and General Intellectual Ability (GIA) score for students age 8 to 14-years old. Results showed statistically significant differences between the experimental group and the control group on all outcome measures except for attention.

The largest difference in results between Carpenter et al.'s (2016) study and this study was in logic and reasoning (M = 21.1; M = 9.6). The difference in results for logic and reasoning could be explained by the ages of the participants and where their maturation falls in cognitive development theory. The Carpenter et al. (2016) study included participants in two distinct stages of cognitive development. Children ages 7 to 11-years old are in the concrete operational stage where they begin to think more logically about concrete events as well as having their thoughts become more organized. The formal operational stage for adolescence is where they begin to think more abstractly, develop additional deductive logic, and increase the use theoretical and abstract reasoning skills (Piaget, 1983). Table 4 shows the comparison of the results from the two studies on the measures of visual processing, auditory processing, processing speed, working memory, and logic and reasoning.

Table 4

Comparison of Measurement Results of ThinkRx and LiftOff Treatment Groups

Variable	ThinkRx Results		LiftOff Results	
	Mean	*SD*	Mean	*SD*
Visual processing	10.9	9.8	6.3	11.0
Auditory processing	13.3	12.3	14.0	6.4
Logic and reasoning	21.1	18.5	9.6	12.6
Processing speed	13.0	9.5	5.4	7.8
Working memory	13.0	15.1	8.1	14.1

The results suggest that the LearningRx LiftOff cognitive training produced significant improvement in cognitive skills, particularly auditory processing, in a relatively brief time for this sample of children. Statistical analyses indicates that there are statistically significant differences between pre-test and post-test on working memory, processing speed, visual processing, auditory processing, and logic and reasoning with a medium to very large effect size, and that age is only a significant factor in scores for logic and reasoning.

The mean standard scores and standard deviations along with the results of the paired-samples *t*-tests reveal a statistically significant difference between pre-test and post-test on all variables measured ($p < .001$) with medium to very large effect sizes represented by Cohen's *d*. The post-hoc analysis indicates a significant difference between 5 and 6-year-olds on change in logic and reasoning scores but no significant difference between 5 and 7-year-olds or between 6 and 7-year-olds.

These findings of significant pre-test to post-test change on all measures are consistent with prior research on the one-on-one cognitive training programs delivered at the learning centers. However, this study not only adds to the body of evidence for these programs but also the cognitive training literature as a whole because it is the first analysis of the LiftOff program for children ages 5 to 7-years old.

There are several strengths to this casual-comparative study worth noting. The first is the use of a larger sample size. Research sample size influences two statistical properties: the precision of the estimates, and the power of the study to make conclusions (Marshall et al., 2013). The size of the sample is vital for getting statistically significant, accurate results, and conducting a successful study. A small sample could contain a disproportionate number of individuals that are outliers and/or anomalies. These can distort the results and not provide an objective view of the population as a whole. Small sample size can also challenge the internal and external validity of the study. Jenkins and Quintana-Ascencio (2020) found that low sample size is a contributing factor to challenges related to being able to reproduce or duplicate the results, including false positives and false negatives.

Too large of sample size and the study becomes laborious, expensive, and complicated to conduct. The results are likely more accurate with a large sample size; however, too large of a sample and the costs can outweigh the benefits. Exceptionally large samples can also convert minor differences into statistically significant differences when they are clinically insignificant (Faber & Fonsecca, 2014). Since it is impossible to know if reporting errors were made in the original records, a large sample size mitigates the impact a few errors might have on the overall results (Anderson et al., 2017).

Another strength is collecting data using a norm-referenced assessment instrument. The WJ III Tests of Cognitive Abilities and Tests of Achievement) is a nationally standardized norm-referenced test that is often used by educators and psychologists to measure cognitive skills and academic abilities (Abu-Harmou et al., 2012). The use of a norm-referenced test is important so that the exact value of data is told when it correlates the scores of the study's participants and/or the entire group to applicable comparison groups (Ornstein, 1993).

The comparison of the results of this study's individual and/or group scores to a similar national sample gives a manner to evaluate the comparative strength of the study participants' scores. It is common for educational researchers to use norm-based references to evaluate the effectiveness of educational programs or interventions.

It is also important that the WJ III is revered as a reliable and valid assessment instrument. Reliability and validity are both needed for an assessment instrument so that the study results produced are credible. Providing consistent and dependable results is the core of reliability. The validity, on the other hand, refers to the accuracy of measurement. The validity of assessment instruments needs multiple sources of data to compile evidence that supports the argument that the instrument measures what it is supposed to measure (Sullivan, 2011).

Limitations

With the strengths of the results, there are also some important limitations to note that should be kept in mind when interpreting the data and planning further analyses of the program. The lack of a control group is the most obvious limitation and the one that prevented a causal connection between the intervention and the outcome measures. By using control groups, researchers could confirm that study results are due to the manipulation of independent variables rather than extraneous variables as noted by Allen (2017). This means that control groups are made up of participants who are not exposed to the manipulated independent variable but are measured on the study's dependent variables. Including a control group strengthens a researcher's conclusions regarding the results of the study.

Another limitation is that the data were taken from archived records and not collected directly by the researcher. Archived data should conform to ethical and legal guidelines with the safeguarding of anonymity when this has been requested by participants or guaranteed to them (Corti & Thompson, 2012). Data may be considered archived as any sort of information, previously collected by others and amenable to systematic study (Jones, 2010). In the social sciences, there is a well-established tradition of reanalyzing quantitative data (Corti & Thompson, 2012). The use of existing data sets presented the opportunity to provide some methodological benefits. To reduce or overcome issues to internal validity, such as experiment bias, an effective technique is to use multiple existing data sets. By use of multiple data sets, or purely external data sets, strengthens arguments for being able to take a broad view of the results of a study (Shultz et al., 2005).

In some cases, the use of a pre-test/post-test model could be a limitation in that the pre-test may sensitize participants to the focus of the experiment, which may potentially influence the results such as participants would be able to study before the test (Rogers & Révész, 2020). However, considering the age of the participants, 5 to 7-years-olds and the length of time between pre- and post-intervention measures (average 60 hours), it was unlikely that would be a factor in this study. It is impossible to know if reporting errors were made in the original records. However, the large sample size mitigated the impact a few errors might have on the overall results.

With many components involved in LiftOff training, this casual-comparative study did not isolate which particular drill tasks or program design elements are the ones that could be attributed to the increase in scores and why some skills, like auditory processing, saw more growth than others, like logic and reasoning. Due to that, it was difficult to discern whether the program as a whole package provided the best training or if there are separate procedures or elements within the program that was most effective. For example, a unique and critical component of the training is the one-on-one delivery model of the training sessions and the immediate feedback provided by the trainer. The use of immediate feedback for both correct and incorrect responses to drills was designed to increase the client’s progress. Due to the sequential design of the cognitive procedures, having this reinforcement is important. For clients to achieve proficiency in the tasks as the procedures move from simple to more complex, providing consistent feedback and reinforcement becomes increasingly important for clients to move forward to more challenging tasks. With the intentional design element of one-on-one delivery, additional research could explore whether the same results are achieved in a small group format.

Another key question to ask is, “What role has a positive, caring, and trusting relationship between the client and trainer have in helping a client to be successful?” Beyond elements of program delivery and additional research on the individual procedures would allow a more detailed interpretation of the effectiveness of the program.

Recommendations for Future Research

The findings presented in this casual-comparative study show compelling evidence for the increased cognitive skill of children ages 5 to 7-years old who completed the LiftOff cognitive training program. Considering the fairly large sample size of children in the analysis, the use of normative measures that have been nationally standardized (WCJ III) to gather pre- and post-test data, and the solid results indicating cognitive gains following the LiftOff cognitive training, results provide strong evidence to support further research be conducted that would include additional measures to assess the transfer of skills to academic achievement in the educational system such as reading or comprehension. Teacher and/or academic data reflecting actual school performance before and after participation in the LiftOff cognitive training would add depth to this casual-comparative study.

Cognitive training does not replace subject-area content knowledge but may give children the skills to be better learners. Knowing that subject-area content knowledge is important in academic performance, some specific content knowledge instruction may be needed in conjunction with cognitive training. Considering the young ages of the children in this study, one could infer the deficits in subject-area content knowledge would be minimal so additional instructional remediation may not be needed. Since grade point average and state and national standardized tests are rarely available for this age group, finding academic measures to use to determine change before and after cognitive training may prove to be more challenging than for older children.

Post-hoc analyses of sex and age as a predictor revealed no additional insight into the explanation of variance in the scores other than age for logic and reasoning. This variance could be explained by reviewing the maturation of the participants according to cognitive development theory. Children 2 to 7-years of age would be in Piaget's preoperational stage of cognitive development. In this stage, children think in more concrete terms and struggle with logic (Piaget, 1983). No additional research was found to further explain the variances in that score.

Future research should examine additional predictors of change including socioeconomic status, race, pre-test IQ level, or the presence of pre-existing learning disabilities. This type of research would align with similar research done related to how these factors relate to academic achievement and school performance. For example, some research suggests that the socio-economic status (SES) of parents impacts how they interact with cognitive stimulation with their children at a noticeably early age. Gratz and Torche (2016) found that parental responses to early ability differences between their children are impacted by family SES, meaning that higher SES parents provide more resources, such as time, to higher-ability children, whereas, lower SES parents do not respond to ability differences. Important to note, however, is that the parental responses had an insignificant effect on the children's cognitive performance at four to five years of age.

Because LiftOff is an outside intervention that is typically privately paid for by families themselves, exploring more closely the SES of families who chose to enroll their child in the program could provide additional information as to who is most willing to invest in their child's academic performance.

Research has also been conducted examining sex and the achievement gap. In a national study, in almost every school district in the United States, female students outperformed male students on English language arts tests in Grades 3 through 8 during the 2008–2009 to 2015–2016 school years (Reardon et al., 2019). However, what was found, with math tests, the gap was much smaller in favor of male students. Some research has even explored multiple dimensions and how they impact academic achievement. Skopek and Passaretta (2018) found in the United Kingdom:

- girls outperform boys for SES
- children with higher SES families outperform children from lower SES families
- considering ethnicity, children without migration background outperform children with migration background
- children of families with home language English outperform children from homes that speak other languages
- with race, white children outperformed children from other races

Since the sample population included children with reported disabilities, additional research could examine more specifically the effects of cognitive training for specific disabilities or examine and see if there is a correlation between deficits in certain cognitive skills related to a specific diagnosis.

Moore and Ledbetter (2019) conducted a large-scale study creating cognitive profiles on over 5,000 participants, ages 4 to 40-years old, diagnosed with ADHD. What they found was that attention is not the primary cognitive deficit as many might assume. This allowed the researchers to take a closer inspection of the individual approaches. They then revealed that targeting multiple cognitive skills rather than just attention or working memory, through one-on-one cognitive training, has a significant impact not only on the trained skills, but also has transfer effects such as reduced oppositional behavior, fewer academic problems, increased confidence and self-esteem, and more cooperative behavior

Similar research could be beneficial for diagnoses such as ASD and reading disabilities like dyslexia. It could provide an avenue of getting to the root cause of the struggles rather than merely treating the symptoms or providing accommodations. Providing further research on the additional variables about cognitive training would allow a more detailed interpretation of the effectiveness of the programs for targeted populations.

Conducting longitudinal research could be beneficial in providing data on the lasting impacts of early childhood cognitive training as an intervention. Similar studies have been done specifically on Head Start programs. As study in Tulsa, Oklahoma examined the long-term impacts of a cohort of children (*n* = 424) who participated in Head Start and were now in eighth grade. What was discovered is that those who attended Head Start produce significant positive effects on achievement test scores in math and on both grade retention and chronic absenteeism for middle-school students as a whole. The researcher found positive effects for girls on grade retention and chronic absenteeism; for white students on math test scores; for Hispanic students on math test scores and chronic absenteeism; and students eligible for free lunches on math test scores, grade retention, and chronic absenteeism (Phillips et al., 2016). This type of research can be critical in establishing legitimacy to work done in the respective field and propelling it to the forefront as an effective and long-impacting intervention method.

Conclusion

In conclusion, the purpose of this casual-comparative study was to explore the effectiveness of the LiftOff one-on-one cognitive training program on children ages 5 to 7-years old. The benefit of participating in the LiftOff one-on-one cognitive training program was examined by analyzing the pre-and post-cognitive skills assessment results of 1,067 participants ages 5 to 7-years old. The focus of this casual-comparative study included the cognitive skills areas of working memory, processing speed, visual processing, auditory processing, and logic, and reasoning. All have been connected to some level of impact on reading, learning, and/or academic success.

The results of this study provide the support that LiftOff's cognitive training is effective in increasing cognitive skills for children ages 5 to 7-years old. Cognitive skills are complex and difficult to isolate in lieu of other developmental areas. Many studies have attempted to examine specific cognitive skills and how they impacted reading, learning, and academic success. Having so many cognitive skills connected to a child's ability to learn in various academic areas leads to the question of whether there is a way or ways to strengthen and improve those cognitive areas.

An additional examination has been given to the controversy surrounding the effectiveness of cognitive training or brain training. Much of the research appears to agree on the ability to improve cognitive skills at least to a specific task; however, there is much disagreement on improved ability in other tasks and if there is transfer to real-life tasks. Between defining what effectiveness and transfer present as with brain training, more research is needed.

The review of the literature and casual-comparative study results provide the starting point for further discussion and research. Overall, with the unique focus of the LiftOff cognitive training directed to children ages 5 to 7-years old, the significance of results obtained from this casual-comparative study, and the current lack of literature that exists for cognitive training specific to early childhood, publishing studies such as this is valuable in increasing the knowledge of professionals in early childhood education and psychology-related fields.

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Appendix A

LearningRx
One-on-One Brain Training Centers

Permission to Conduct Research at LearningRx

November 18, 2021

This letter grants permission for Darci Stanford to conduct her doctoral research at LearningRx contingent upon final review of her research proposal and receipt of her university IRB approval. Permission is granted for examining the effects of the LiftOff cognitive training program using de-identified student records from our national database.

In accordance with **Basic HHS Policy for Protection of Human Research Subjects**, Section 46.114 of 45 CFR 46 Code of Federal Regulations, the Gibson Institute of Cognitive Research/LearningRx Institutional Review Board may delegate review of external or collaborative research project applications to another qualified IRB to prevent duplication of efforts. For university-affiliated student research projects, it is the general policy of our IRB to rely upon the decision of the university's IRB rather than conducting a separate review. However, we do require a copy of the university's IRB decision prior to allowing students to begin research at LearningRx.

I confirm that I have the authority to grant permission for this research.

Dean Tenpas
Chief Operations Officer

5085 List Drive, Suite 200 Colorado Springs, CO 80919 (719) 264-8808
www.LearningRx.com

Appendix B

PRIVACY POLICIES

Protection of Information

LearningRx values the trust its customers place in the company. Accordingly, LearningRx adheres to the highest ethical standards in gathering, using, and safeguarding customer information that is entrusted to the company.

Use and Collection of Customer Information

LearningRx does not rent, sell, or exchange information about its customers. Access to information about LearningRx customers is restricted to the LearningRx family of business. Third parties that need access to LearningRx customer information in order to provide operational or other support services to LearningRx must agree to safeguard customer information in strict compliance with the LearningRx policy.

LearningRx gathers only the customer information that is needed to administer its business, provide superior service, and communicate offers on merchandise and services that LearningRx believes will be of interest to its customers. Personal information means identifying information about an individual relating to their physical or mental health (including medical history), the providing of care to the individual.

You have the right to determine how your personal information is used and disclosed. For most care purposes, your consent is implied as a result of your consent to treatment.

Access and Correction

LearningRx limits access to customer information to those employees who need it to carry out their business functions. LearningRx educates its employees about LearningRx policies and Centers in regard to safeguarding customer information; preventing its unauthorized access, use or disclosure; and, ensuring its proper handling.

We provide information to health care providers acting on your behalf, on the understanding that they are also bound by law and ethics to safeguard your privacy. Other organizations and agents must agree to abide by our Privacy Policy and may be asked to sign contracts to that effect. We will give them only the information necessary to perform the services for which they are engaged, and will require that they not store, use, or disclose the information for purposes other than to carry out those services.

With limited exceptions, we will give you access to the information we retain about you within a reasonable time, upon presentation of a written request and satisfactory identification. We may charge you a fee for this service and if so, we will give you notice in advance of processing your request. If you find errors of fact in your personal information, please notify us as soon as possible and we will make the appropriate corrections. We are not required to correct information relating to clinical observations or opinions made in good faith.

Accuracy and Security of Customer Information

LearningRx makes all reasonable efforts to ensure that the customer information it maintains is accurate, timely and secure. LearningRx will monitor and adopt, as appropriate, new technological developments that are designed to aid in ensuring the accuracy and security of customer information. LearningRx enforces its policies in regard to gathering, access and use of personal customer information by its employees and authorized third parties.

Opt-Out Policy

LearningRx respects the privacy of individuals and tries to make it easy for users to stop receiving communication from us. To opt-out of marketing or promotional emails from LearningRx, please click 'unsubscribe' in the body of any email communication you may receive from us. You can also contact your local center to opt-out from communications, or contact the LearningRx Home Office at 719-264-8808.

Personally Identifiable Information

LearningRx collects personally identifiable information (such as name, address, telephone number, or e-mail) only when customers voluntarily provide such information to LearningRx.