Effect of Neuroscience-based Cognitive Skill Training on Growth of Cognitive Deficits Associated with Learning Disabilities in Children Grades 2-4

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Working memory, executive functions, and cognitive processes associated with specific academic areas, are empirically identified as being the core underlying cognitive deficits in students with specific learning disabilities. Using Hebb's theory of neuroplasticity and the principle of automaticity as theoretical bases, this experimental study examined the effectiveness of a specific 12-week neuroscience-based, cognitive-skills computer-training program on the cognitive processing of 40 elementary students in grades 2-4 with specific learning disabilities. The study results indicated the experimental group had significantly increased performance over the control group in every skill area examined. Implications include understanding the impact of cognitive skill training on underlying cognitive deficits of students diagnosed with specific learning disabilities. Such training can result in increased academic performance.

Executive functions have been shown to be related to academic achievement and the ability to learn, as well as a range of a neurodevelopmental disorders including specific learning disabilities including attention-deficit hyperactivity disorder (ADHD; Biederman, et al., 2004). The failure of many traditional educational interventions for students with specific learning disabilities may be attributed to large deficits in executive functions, including working memory and inhibition (Hanson, Sharman, & Esparza-Brown, 2008). Understanding the role of executive function, and then determining which educational strategies best address it, may offer new learning opportunities for children facing educational barriers due to specific learning disabilities.

The study examined how computer-based training might aid students with specific learning disabilities in enhancing their executive functions and specific cognitive deficits associated with academic areas of reading and math.

Problem Statement

Although there is evidence that children with specific learning disabilities have specific information processing deficits (Individuals with Disabilities Education Act [IDEA] 2004, Public Law 108-446), current practices in special education focus primarily on the deficit academic areas as opposed to the weak underlying neurological processes. As a result, students diagnosed with specific learning disabilities do not improve their cognitive deficits and do not necessary respond well to special education or Response-to-Instruction (RTI: Fletcher, Morris, & Lyon, 2003; Gerber, 2005; Hallahan, 2006). Recent research in cognitive neuroscience has indicated that children with specific learning disabilities have cognitive deficits in executive functions (Swanson, 2009; Geary 2004) and working memory (Swanson & Jerman, 2006). Although there is a high level of heterogeneity in specific learning disabilities, a meta-analysis of the literature indicated that the main cognitive differences between children with specific learning disabilities and typically developing children include visual working memory, verbal working memory, executive function, processing speed and short term memory (Johnson, Humphrey, Mellard, Woods, Swanson, 2010). Executive functions have been shown to be related to academic achievement and learning ability (Biederman et al., 2004) and a range of a neurodevelopmental disorders including specific learning disabilities and Attention Deficit/Hyperactivity Disorder (Meltzer, 2007). Swanson (2009) and Geary (2004) attribute the lack of effectiveness of the traditional intervention methods on specific learning disabilities students to be due to the presence of large deficits in executive functions, including working memory and inhibition.

These findings support the need for intervention methods aimed at strengthening these weak neurological processes for children with specific learning disabilities. Though computer-based cognitive skill training has demonstrated success for general education students (Helms & Sawtelle, 2007), the degree to which such interventions might benefit specific learning disabilities students in unknown. There is a need to examine the effectiveness of cognitive skill training program among students diagnosed with specific learning disabilities. Understanding the potential of cognitive-based skills training may directly benefit specific learning disabilities students while helping districts keep students in special education for shorter period of time. To date, there is an insufficient body of literature to determine the potential of this cognitive skill intervention for specific learning disabilities students.

Purpose of the Study

The purpose of the experimental study was to examine the effectiveness of a specific neuroscience-based cognitive-skills computer training program on the cognitive processing and predicted academic achievement of students in Grades 2-4 with specific learning disabilities. Through an intensive 3-month computer-based cognitive skill training, aimed at strengthening different cognitive processes such as executive function, visual and verbal working memory, processing speed, and short-term memory, an examination was made regarding the improvements on the specific cognitive processing deficits associated with specific learning disabilities in young children and their predicted academic achievement. The independent variable was the computer-based cognitive skill training program. The dependent variables were: (a) overall cognitive growth, (b) executive functions, (c) visual working memory, (d) verbal working memory, (e) processing speed, (f) short term memory and (g) predicted achievement score. This study provided insight into the possibility of cognitive-skills computer training programs for the support of students with specific learning disabilities.

Nature of the Study

A quantitative experimental research design was used in this study. The sample consisted of 40 grades 2-4 students who were diagnosed with specific learning disabilities. Study participants were randomly assigned to the control and intervention group, with an equal number of 20 students in each group. The intervention group completed a 12-week computer-based cognitive skill training program. The intervention was a software program aimed at developing 41 cognitive skills in six main areas: (a) attention, (b) visual processing, (c) auditory processing, (d) memory, (e) logic and reasoning, and (f) sensory integration. The program consisted of 20 exercises, each with multiple levels that become progressively more difficult. All participants were pretested using the Woodcock-Johnson III NU Tests of Cognitive Abilities and Brief Reading and Brief Math batteries. Participants were randomly assigned to experimental and control group. A control group was assembled to ensure that extraneous variables pertaining to time were controlled.

The intervention group completed the computer-based cognitive skill training program for approximately 30 minutes per day, 5 days per week, for 12 weeks. The students in the control group followed their usual special education intervention routine. A post-test, same as the , was applied to both groups at the end of the 12 week period to test the effect of the cognitive skill training program on the cognitive deficits associated with specific learning disabilities including overall cognition, executive function, verbal and working memory, processing speed, and short-term memory, and on their predicted academic achievement.

Theoretical Framework

Two theories provided a framework for the problem, purpose, and hypotheses of the study: (a) Hebb's theory of neuroplasticity (1949), and (b) the principle of automaticity. Hebb's theory on neuroplasticity pertains to the possibility of neural modification through high frequency stimulation (Sharma, 2010). The principle of automaticity states that with repetition and conducive learning environment, a skill can become automatic (Poldrack et al., 2005).

Hebb's theory of neuroplasticity is grounded on the assumption that existing neurons are modified through stimuli (Sharma, 2010). If the pre-synapses are stimulated, corresponding excitatory postsynaptic potentials (EPSPs) in the cells occur. This process called *long-term potentiation* (LTP) and has a significant effect on the creation of memories (Lomo, 2003).

Hebb's theory of neuroplasticity has been used in various studies as a framework to explain neural activities and processes (e.g., Boakye, 2009; Munte, Altenmuller, & Janke, 2002). In the educational setting, the theory of neuroplasticity and LTP are often implicated because of the significance of memory in education (e.g., Bruel-Jungerman, Davis, & Laroche, 2007). In special education settings, LTP is used to improve learning and cognitive functioning among students with special needs (Bruer, 2006). Neuroplasticity is related to the study because of the hypothesis that the modification of neural activity in the brain can lead to improved memory, which is one of the core deficits of students with specific learning disabilities (Sharma, 2010).

Based on the principle of automaticity, a skill becomes automatic when little or no conscious effort is needed to perform the skill (Poldrack et al., 2005). In order to learn and acquire new skills, repetition and practice are needed so that automaticity can be achieved (Hung, Randolph-Seng, Monsicha, & Crooks, 2008; Poldrack et al., 2005). Further, the acquisition of new skills is only possible in a meaningful learning context (Gee, 1998).

The principle of automatism was relevant in the study because the study involved the use of a computer-based program that requires mastery, repletion, and rehearsal. The underlying principle behind the selected computer-program in improving the learning deficits is that with ample time for training, cognitive skills can be improved. Two of the necessary conditions to achieve automaticity, repetition and an engaging learning context, were present in the selected computer-based cognitive training program (Gee, 1998; Poldrack et al., 2005). Based on the principle of automaticity, the hypothesis was that the computer-based cognitive training program could improve the cognitive deficits of students diagnosed with specific learning disabilities.

The diagnosis of specific learning disabilities can be based in any of three models: (a) ability-achievement consistency model, (b) consistency-discrepancy model, and (c) concordance-discordance model (Hanson et al., 2008). The concordance-discordance model is the most widely used model in the diagnosis of specific learning disabilities because of the emphasis on using multiple sources of assessment data in generating diagnosis. The cognitive, academic, and behavioral performance of a child is considered and evaluated during the diagnosis process.

To explain specific learning disabilities from a neuropsychological perspective, two prevailing perspective exist: (a) (a) the Goldstein-Strauss-Werner visual perceptual approach to specific learning disabilities and (b) the Orton-Hinshelwood developmental written language approach to specific learning disabilities (Kaufman, 2008). The Goldstein-Strauss-Werner approach conceptualized specific learning disabilities as visual perceptual problem that can be addressed by solving the underlying processing problem, whereas the Orton-Hinshelwood approach views specific learning disabilities as deficits related to the specific learning problem, not just a visual perceptual problem. The federal conceptualization of specific learning disabilities combines aspects of the two approaches, specificity of learning deficit and processing problem.

In an education setting, specific learning disabilities often involves problems in processing speed, working memory, and auditory processing of information (Macintyre & Deponio, 2003). Math learning disorder and reading disorder were the focus of this study. Deficiencies in math and reading have serious academic repercussions because both math and reading are integral components of many aspects of classroom instruction.

Computer-based cognitive skill training has been found by previous researchers in improving the cognitive abilities of students diagnosed with specific learning disabilities (Aleven & Koedinger, 2002; Hung et al., 2008; Mezzacappa & Buckner, 2010; Olesen, Westerberg,& Klingberg, 2003; Thorell, Lindqvist, Bergman, Bohlin, & Klinberg, 2008; Westerberg et al., 2007). Cognitive abilities such as domain knowledge, crystallized intelligence, memory, and psychomotor speed predict success in computer-based cognitive training programs (Ownby, Czaja, Loewenstein, & Rubert, 2008). Previous studies showed that computer-based training can be effective in improving executive functions and working memory (e.g., Aleven & Koedinger, 2002; Floyd, Bergeron, Hamilton, & Parra, 2010; Mezzacappa & Buckner, 2010).

Executive functions pertain to cognitive processes such as control, regulation, and maintaining balance of various processes such as cognition, memory, and behaviors (Floyd et al., 2010). In the education setting, executive functions are important because the processes involved in executive functions such as inhibition is relevant in children's academic achievement (Kloo & Perner, 2008).

Previous studies on training executive functions using computer-based programs have two main implications (e.g., Cipriani, Bianchetti, & Traubchib, 2006; Kloo & Perner, 2008). First, executive functions are trainable (Kloo & Perner, 2008). Second, the effect of computer-based cognitive programs on different cognitive disorders is not similar (Cipriani et al., 2006). For example, when Cipriani, et al. examined the effects of computer-based cognitive training programs on groups with Alzheimer's disease, mild cognitive impairments, and multiple system atrophy, the researchers found that executive functions only improved among the individuals with Alzheimer's disease. No improvements in executive functions were observed from the group with mild cognitive impairments and with the group with multiple system atrophy.

Computer-based cognitive training programs have been found by previous researchers to be effective in improving the working memory of adults and students (Aleven & Koedinger, 2002; Olesen et al., 2003; Westerberg et al., 2007). In Westerberg et al.'s study, the researchers found that computer-based cognitive raining program improved the working memory of adult patients who had stroke within the past year. Olesen et al. found similar results regarding the effectiveness of computer-based cognitive raining programs in healthy adults. Using students as the sample, Aleven and Koedinger (2002) and Thorell et al. (2008) found similar effectiveness of computer-based cognitive training programs in improving working memory.

The gap in the literature is the lack of previous studies examining the effectiveness of computer-based training program in improving the cognitive abilities of students diagnosed with specific learning disabilities and their academic achievement. As contended by Cipriani et al. (2006), the effects of a particular computer-based cognitive training program cannot be generalized to all disorders. The current study adopted the methodology that Helms and Sawtelle (2007) used. The main difference is that the study examined the effectiveness of computer-based cognitive training program using a sample of students diagnosed with specific learning disabilities. The study of Helms and Sawtelle consisted of participants who had academic problems but not diagnosed with specific learning disabilities.

Research Design

This true experimental quantitative, pretest post-test study examined the relationship of cognitive skill training to that of the executive function, visual and verbal working memory, processing speed, and short term memory of participants. The study compared the sustainability of the levels of these variables made by the children with learning disabilities in grades 2-4 who were provided with computer-based cognitive skill training versus those who were not receiving the intervention. Students were randomly assigned to either the control or experimental group. The control group did not receive the intervention while the experimental group received 12 weeks of cognitive skill training. A visual representation of the research design is presented in Figure 1.

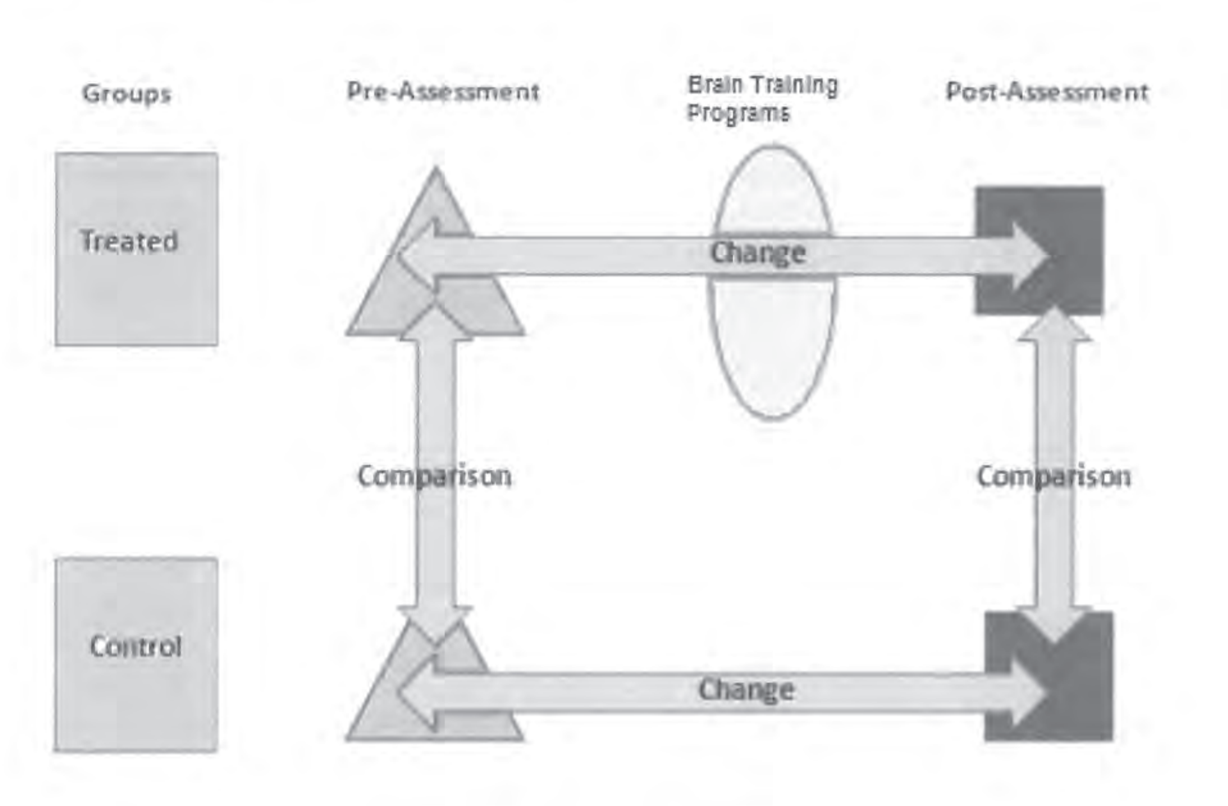
Data Analysis

Data analysis was used to address the research questions stated previously using the data collected for the experimentation.

An independent sample t test was performed to determine the pretest equivalence of the control group compared to the experimental group. A MANCOVA model was used for this study because it allows one to compare the difference in means among multiple groups (like an ANOVA), but also allows covariates to be included as control variables. This is necessary to determine since equivalency on the cannot be

Figure 1

Visual representation of the research design



assumed and that the groups are alike in terms of properties like race, gender, socioeconomic status, quality of the school, quality of the teacher, and so on. An independent sample t test of equivalence of pretest scores was used to equate the control and experimental groups. The Levene's test (Levene, 1960) for equality of variance was used to establish any statistical difference in variance. Additionally, an ANCOVA of the z-scores adjusted pretest and post-test W scores was added to address the non-equivalence in the control and experimental group math and reading scores. In addition, descriptive statistics were reported for the study.

The executive functions, visual working memory, verbal working memory, processing speed, short term memory scores were gathered for the students' cognitive skills levels. The researcher used MANCOVA to measure mean differences in the aforementioned scores to look for a significant difference between the cognitive scores of the two populations of participants. The two populations consisted of those students that received the cognitive skill intervention program (intervention group) and those students that did not receive the intervention and simply followed their usual special intervention activities (control group).

The researcher used the Woodcock Johnson III test of cognitive abilities (WJIII NU COG) as the testing instrument for the pretest and the post-test. The test results are represented as W Scores, which indicates an individual's level of ability on the skill area or task presented. The W Score was translated into a W-diff Score, which is the difference in W Scores and the reference W (the median score of the individual's age or grade peers). The W-diff Scores were converted into the Relative Proficiency Index (RPI), which represent the probability of answering correctly when peers achieve 90% success, the RPI scores were then converted into age equivalence figures (AE).

The researcher was able to gather 40 respondents, half of which are in the control group and the other half in the experimental group. The majority of participants are female students; only 2 males in the control group and 6 males in the experimental group. The average age for the control group is lower than the experimental group by 0.82 years or 9.84 months. The average grade level for both groups are somewhere between grades 3 and 4. Same data is shown in Table 1.

Table 1

Participant Demographic Data: Age and Grade

	Control			Experimental		
Values	Female (*n*)	Male (*n*)	Total (*N*)	Female (*n*)	Male (*n*)	Total (*N*)
Count of test	18	2	20	14	6	20
Average age (months)	105.22	116.00	106.30	117.57	112.67	116.10
Average age (years)	8.77	9.67	8.86	9.80	9.39	9.68
Average grade level	3.32	3.70	3.36	3.97	3.37	3.79

An independent samples t test was performed to determine the pretest equivalence of the control group compared to the experimental group.

Summary of Analyses

Below is the summary of growth in age equivalence (AE), grade equivalence (GE), and proficiency (RPI) between pretest and post-test mean W and W-diff scores of both the control group and the experimental group. The experimental group showed higher growth for all the measurements in all the skill areas studied. A summary of results are shown in Table 2

The data show that the overall cognitive performance (GIA) of the experimental group has a higher improvement than the control group. The current study also measured the underlying neurological processes that result in cognitive deficits. The study focused on five underlying cognitive skill areas, namely executive functions (EF), visual working memory (GV), verbal working memory (WM), processing speed (GS), and short term memory (Gsm). These five cognitive skill areas showed higher improvements in the experimental group as compared with the control group which supports the higher growth in cognitive performance (GIA). The academic skills areas of reading and math were also measured and analyzed, because disabilities are specific weaknesses in the acquisition of academic skills such as reading, writing, and arithmetic (Kohli, Kaur, Mohanty, & Malhotra, 2006). There have also

Table 2

Summary of Growth between Pre-test and Post-test Scores in Age Equivalence (AE), Grade Equivalence (GE), and Proficiency (RPI) Scores

Growth	Control			Experimental		
	AE	GE	RPI	AE	GE	RPI
GIA - Cognitive Performance	2	0.1	1	34	2.8	25
EF - Executive Functions	3	0.2	1	30	2.4	19
GV - Visual Working Memory	2	0.2	2	79	6.4	11
WM - Verbal Working Memory	3	0.3	9	40	3.3	39
GS - Processing Speed	2	0.2	1	17	1.3	9
Gsm - Short Term Memory	3	0.3	3	52	4.2	32
Reading	1	0.1	1	10	0.8	31
Math	2	0.2	4	12	1.0	28
Ga - Auditory Processing	5	0.4	0	66	5.3	10
Att - Broad Attention	2	0.2	3	41	3.3	27

*AE in months, GE in grade levels, RPI in % proficiency

been documented relationships between specific cognitive abilities/processes and specific academic skills (Hale et al, 2010; Fiorello, Hale, & Snyder, 2007). The results show that reading and math have higher improvement in the experimental group than the control group. Additional cognitive skill areas measured were for auditory processing and broad attention, which also showed higher improvements in the experimental group than the control group.

To put these improvements into context, the proficiency scores (RPI) must be addressed. The RPI score represents the probability of answering a question or performing a task correctly when peers achieve 90% success. The proficiency score (RPI) table shows that overall cognitive performance (GIA) during pretest was 63% proficiency for the control group and 64% proficiency for the experimental group. During post-test, the RPI score increased to 64% proficiency in the control group while the experimental group increased to 89% proficiency. This means that after 3 months of normal special education intervention/routine, the control group is still behind their peers in cognitive proficiency by 26% (90 minus 64). Meanwhile the experimental group, after 3 months of normal special education intervention/routine with 3 months (30 minutes per day, 5 days a week, 12 weeks) of computer-based cognitive-skills training, has nearly caught up with their peers in cognitive proficiency at 89%. The experimental group is only behind their peers in cognitive proficiency by 1% (90 minus 89).

Proficiency scores in post-test for the control group on the five underlying cognitive skill areas did not reach 90% proficiency. The experimental group managed to exceed their peers in 3 of the three cognitive skill areas studied, namely for visual working memory (GV) with 94%, verbal working memory (WM) at 93%, and short term memory (Gsm) at 93%. Auditory processing (Ga) and broad attention (Att) also exceeded 90% proficiency for the experimental group during post-test, at 95% and at 93%, respectively. The control group scored 88% for auditory processing (Ga) and 69% for broad attention (Att) during post-test.

Reading and math post-test RPI scores for the control group (reading at 30% and math at 46%) were lower than the experimental group (reading at 68% and math at 77%). However, reading and math RPI scores at post-test for both the control group and the experimental group were still below 90%. Although the growth in academic performance was significant for the experimental group, it was not enough to bring them to 90% proficiency or reach peer levels. Higher improvement in academic performance should be expected for around 3 to 6 months after the conclusion of the intervention, since this gives the students enough time to actually make use of their strengthened cognitive skills to learn in class.

Below is the summary of the results of the analysis of covariance (ANCOVA) performed on the collected data. All the ANCOVA results show significant relationships between participant group (control or experimental) and the scores in the assessed skill area, except for processing speed (GS) when using W-diff scores. The analyses also show that the experimental groups have higher means than the control groups in all the assessed skills areas, either for W scores or for W-diff scores. All the null hypotheses were rejected since the difference between the control and the experimental group W Score/W-Diff Scores for all skill areas were found to be significant, as can be seen in Table 3.

Interpretation of the Findings

It was found that the experimental group showed significantly higher improvement in every skill area studied, namely cognitive performance (GIA), executive function (EF), visual working memory (GV), verbal working memory (WM), processing speed (Gs), short term memory (Gsm), reading, math, auditory processing (Ga), and broad attention (Att). The age equivalence scores, grade equivalence scores, and proficiency scores for both the control group and the experimental group showed an increase between each group's pretest and post-test scores on all the skill areas (refer to the summary of analyses section above). This means that majority of respondents showed improvement between pretest and post-test, regardless of whether they were part of the control or the experimental group.

Table 3

Summary of ANCOVA and estimated marginal means

Research Question	Skill Area	Measure	Sig.	Estimated Marginal Means Control	Experimental	EXP (-) CTL	%diff
RQ1	GIA	W Score	0.000	482.705	498.595	15.890	3.29%
		W-diff Score	0.000	-14.812	-1.288	13.524	
RQ2-A	EF	W Score	0.000	486.674	498.026	11.352	2.33%
		W-diff Score	0.000	-10.615	-1.085	9.530	
RQ2-B	GV	W Score	0.000	491.395	505.355	13.960	2.84%
		W-diff Score	0.000	-5.400	5.150	10.550	
RQ2-C	WM	W Score	0.000	481.056	501.797	20.741	4.31%
		W-diff Score	0.000	-17.334	3.134	20.468	
RQ2-D	GS	W Score	0.000	488.365	496.835	8.470	1.73%
		W-diff Score	0.058	-6.267	-2.233	4.034	
RQ2-E	Gsm	W Score	0.000	482.746	506.304	23.558	4.88%
		W-diff Score	0.000	-14.636	4.286	18.922	
RQ3-A	Reading	W Score	0.000	468.074	480.876	12.802	2.74%
		W-diff Score	0.000	-25.997	-14.703	11.294	
RQ3-B	Math	W Score	0.000	472.736	487.564	14.828	3.14%
		W-diff Score	0.000	-20.589	-9.911	10.678	
Additional	Ga	W Score	0.000	496.966	507.634	10.668	2.15%
		W-diff Score	0.000	-2.310	7.460	9.770	
Additional	Att	W Score	0.000	483.648	501.602	17.954	3.71%
		W-diff Score	0.000	-12.986	3.336	16.322	

1. Independent variable used is the participant group (control or experimental)
2. Dependent variables were the post-test scores
3. Covariates were the pretest scores

The objective of this study is to identify if there is a statistically significant difference between the improvement of the control group and the improvement of the experimental group. It was found that the experimental group had higher growth or improvements than the control group in all skill areas assessed, in terms of mean W Scores, mean W-diff Scores, age equivalence scores, grade equivalence scores, and proficiency scores. Furthermore, when pretest scores are used as covariates the estimated marginal means show that the experimental group had a statistically significant improvement than that of the control group.

Overall cognitive performance went up by 15.890 points or 3.29% compared to the control group. The improvement in cognitive performance (GIA) for the experimental group was higher than the control group by 2.7 years in AE score, 2.7 years in GE score, and 24% in RPI score. However, the size of the improvements vary among the different underlying cognitive skill areas (refer to Table 3). Short term memory (Gsm), verbal working memory (WM), and broad attention (Att) showed the most difference between the control group and the experimental group for both W Scores and W-diff Scores.

The estimated marginal mean scores for Gsm of the experimental group was higher than the control group by 23.558 points or 4.31% in W Scores and by 18.922 points in W-diff Scores. The improvement in the age equivalency score for Gsm of the experimental group was 4.1 years more than the control group. The improvement in the RPI score for Gsm of the experimental group was 29 points more than the control group. The estimated marginal mean scores for WM of the experimental group was higher than the control group by 20.741 points or 4.88%23 in W Scores and by 20.468 points in W-diff Scores. The improvement in the age equivalency score for WM of the experimental group was 3.1 years more than the control group. The improvement in the RPI score for WM of the experimental group was 30 points more than the control group. The estimated marginal mean scores for Att of the experimental group was higher than the control group by 17.954 points or 3.71% in W Scores and by 16.322 points in W-diff Scores. The improvement in the age equivalency score for Att of the experimental group was 3.1 years more than the control group. The improvement in the RPI score for Att of the experimental group was 30 points more than the control group.

Thorell's et al. (2008) study examined whether computer-based training could improve the executive functions such as working memory and inhibitions of pre-school children. Executive functions refer to neurocognitive functions that are essential in problem-solving (Craik & Salthouse, 2000). It involves cognitive processes that enable individuals to control themselves mentally to achieve a goal (Pennington & Ozonoff, 1996). In Thorell's et al. study, children who were assigned to the computer-based training program that targeted working memory improved on trained tasks and non-trained tasks such as spatial and verbal working memory. The children who were assigned to the computer-based training program that targeted inhibition, no significant improvement occurred in working memory tasks.

Thorell et al. (2008) concluded that working memory can be trained, producing significant results in executive functions tasks; however, inhibition is not easily trained. The current study findings support Thorell's assertion. The results of the current study showed that students that went through the training program showed higher scores compared to the control group in short term memory (higher by 23.558 points) verbal working memory (higher by 20.741 points) and broad attention (higher by 17.954 points). But the improvement in scores on executive function (EF) was lower, where the experimental group had a W Score that was only 11.352 points or 2.33% higher and a W-diff Score that was only 9.530 points higher. Also, the growth in EF of the experimental group was only 2.3 years higher in AE score and 18 points higher in RPI score than the control group. This also supports the findings of previous studies that have found the effects of computer-based cognitive training programs on executive functions to not be similar for all individuals and for all cognitive problems (Cipriani et al., 2006; Kloo & Perner, 2008). Cipriani et al. concluded that the effects of computer-based cognitive training programs may be dependent on the type of cognitive problem present in the individual.

Another skill area with low improvement between the experimental and the control group was for processing speed (Gs). In W Score, Gs was higher in the experimental group only by 8.470 points or 1.73%. In W-diff Scores, Gs was higher in the experimental group by 4.034 points. The growth in Gs of the experimental group was only 1.3 years higher in AE score and 8 points higher in RPI score than the control group. However, the calculations showed that the difference in W-diff scores of processing speed between control and experimental group was not significant. Processing speed refers to the capacity to use multiple cognitive functions simultaneously in performing a task at an adequate speed or the speed of mental activity (Craik & Salthouse, 2000). This also supports Cipriani's et al. (2006) statement on the success of training programs being dependent on the cognitive problems of the participants.

As for participants' performance on academic tasks, both Reading and Math showed significant improvement when comparing the control group with the experimental group. In order for reading to be fluent, a level of automaticity should be achieved (Kim & Goetz, 1994). If one of the three systems is deficient, the reader will compensate the deficient system with the non-deficient system. Depending on how math learning disorder is diagnosed, different levels of reading, visual-spatial, and working memory skills could characterize children diagnosed with math disorder (Murphy, Mazzoco, Hanich, & Early, 2007). Children diagnosed with math disorder, who are also classified as students with specific learning disabilities, can have different cognitive profiles, even though they were diagnosed under the same heading which could affect the intervention provided to students. Swanson (2009) suggested that executive functions and working memory as the two common cognitive deficits in children with reading or math disability. Improvements in short term memory (Gsm), verbal working memory (WM), and broad attention (Att) can be attributed to improved reading and math scores. Although reading and math post-test scores are still several points lower than Gsm and WM. This is most likely due to the lower improvement in executive function (EF).

It should be noted that pretest RPI scores for both the control and the experimental groups in reading and in math were all lower than 50%.

While pretest scores for both groups in overall cognitive performance (GIA), in the five underlying cognitive skill areas, in auditory processing (Ga), and in broad attention (Att) were all higher than 50% except for verbal working memory (WM). This shows that the starting RPI score from which improvements were to be measured was lower for reading and math than for overall cognitive performance and the other neurological skill areas studied. Reading and math learning difficulties cannot be entirely attributed to cognitive deficiencies.

Furthermore, higher improvement in academic performance should be expected at around 3 to 6 months after the conclusion of the intervention, since this gives the students enough time to actually make use of their strengthened cognitive skills to learn in class. The smaller increase in academic scores for the experimental group is again based on the concept of neuroplasticity and automaticity. The intervention was solely working on cognitive skills. There was no academic content or review of any conceptual knowledge that children should acquire at this age. Only after some time would the impact on reading and math become evident once the improved cognitive functioning is used by the participants to learn and understand the information they are usually exposed to in the classroom. Cognitive processes and skills are the learning tools that enable one to learn with high proficiency. The growth in academic performance of the experimental group is already significant compared to the control group. This suggests continued growth once the strengthened cognitive processes are used in the classroom.

Implications for Social Change

The study findings support the use of cognitive skill training for children with specific learning disabilities. The study results showed that the intervention had a positive impact on all the cognitive deficits associated with specific learning disabilities. Compared to the length of time that progress is seen in children with specific learning disabilities through traditional special education intervention, the study results suggests that special educators can add neuroscience-based interventions which yield significant results in a much faster way, such as in the present study which involved 3 months of exposure to a computer-based cognitive-skills training program.

The study can inform treatment planning for children with specific learning disabilities. Educators can use the results of this study to provide insight into effective remediation strategies that can be integrated into existing best practices in special education for students with specific learning disabilities. Neuroscience-based interventions can be used when students are diagnosed with specific learning disabilities or when they are first observed as having difficulties that would lead to academic failure. Children can make sufficient progress to meet age or grade level within the year that they are diagnosed, thereby reducing motivational and emotional consequences.

Since there was a difference in the impact of the intervention per skill area, the study further supports the need to link assessment to intervention. Depending on the patterns of strengths and weaknesses assessed, an interventionist can make educated choices about which intervention to use. The study focus was on the intervention of those psychological constructs that are implicated in the learning deficits of children with specific learning disabilities. Implied in this focus, is the understanding that if we can specify the cognitive correlates that lead to the learning deficit, we can make a stronger link between assessment and intervention by selecting an intervention that has been proven to stimulate growth in those cognitive correlates. Educators can also consider what was important about this intervention that improved the students' progress, and which processes for that particular student did it stimulate more growth. In this way, educators may have a stronger insight as to those specific deficits that were impeding in the child's academic success and can zoom in on working on that cognitive deficit(s). The study results indicate that for all children with specific learning disabilities who have deficits in a specific cognitive skill area(s), this intervention may stimulate enough growth to help the child make sufficient progress to meet age and grade peers or at least to avoid remaining in academic failure.

Considering the fact that this intervention was found to stimulate growth in general education children (Helms & Sawtelle, 2007) and in children with specific learning disabilities, it would be safe to suggest that this intervention can be beneficial to students who are identified to be at-risk for academic failure (or receiving Title I services). Including this intervention in the earlier stages may reduce the chances of these students requiring special education services.

With schools who are concerned with state test scores and with state laws requiring more inclusion of children with special needs as per No Child Left Behind (NCLB, 2001), this intervention can help school administrators stimulate growth in the cognitive processes or the learning tools necessary to do well on academic work. Schools do not choose the students they serve nor are they equipped to make sure that all their students have the adequate cognitive processes to learn, yet they are required to make sure that the majority of their students make it on all State test scores. This may give the school personal a tool that would not otherwise have.

Researchers can build on this body of knowledge for future studies on effectiveness of cognitive skill training programs on children with disability. Legislators can make informed decisions about funding such interventions under Individuals with Disabilities Education Act of 2004 (IDEA) Law. Parents can make informed decisions about the intervention strategies that can best suit children with specific learning disabilities or address the cognitive deficits of their children with specific learning disabilities. The entire educational constituency can collaborate and implement initiatives that will help children with learning disabilities attain new levels of achievement. The successful implementation of such initiatives may provide children with specific learning disabilities a strong foundation for a successful life experience and for a chance to be more effective contributors to society at large.

Conclusion

Computer-based cognitive skills training can be beneficial to students with specific learning disabilities. The current study has found significant improvement in students with specific learning disabilities that undergo this training on all the cognitive and academic skill areas assessed. However, the improvement was inconsistent among the skill areas. Some areas, such as short term memory and verbal working memory, showed higher improvement than others, like executive function and processing speed. This supports Thorell's et al assertion that some cognitive skills can be improved through stimulating and repetitive training, while other areas can be more difficult to develop even with training.

These data show that the experimental group post-test results after neuroscience cognitive skill training has caught up with their age peers on all cognitive skill areas assessed. Although academic achievement was not as great as that of cognitive achievement and its underlying skill areas, it is understood that at the time of post-test, participants have not yet had the opportunity to use their strengthened cognitive processes to learn. The assumption is that as long as other factors that inhibit academic growth, including motivation, determination, perseverance and most importantly quality of individualized instruction (Flanagan, Ortiz, & Alfonso, 2012) are not present, the students who have received the neuroscience cognitive skill training should achieve higher academic performance once they have a chance to utilize their strengthened cognitive skill processes, perhaps 3 or 6 months after the intervention.

This informs treatment planning for specific learning disabilities students by suggesting a blend of neuroscience-based cognitive skill training with evidence-based instructional strategies. Blending neuroscience training methods with special education seem to be a winning combination.

The benefit of the neuroscience cognitive skill training would be to speed up the cognitive and academic improvement as well as remediate underlying weak processes, as opposed to compensate for them or circumvent them. The special education techniques would ensure that the child receives evidence-based instruction or quality individualized instruction. The inclusion of the neuroscience cognitive-skill training in the treatment plan for children with specific learning disabilities would ultimately enable them to require less special instruction and perhaps be mainstreamed much faster into the general education classroom.

This study hopes that this method will assist in *closing the achievement gap* between general education children and special needs students, specifically children with learning disabilities.

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