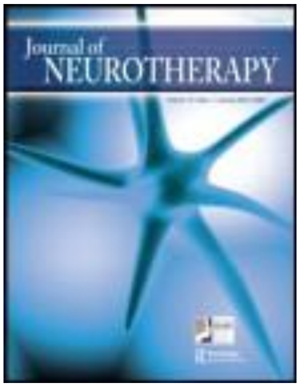

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Use of Auditory and Visual Stimulation to Improve Cognitive Abilities in Learning-Disabled Children

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ABSTRACT. *Introduction*. Learning disabilities (LD) comprise cognitive deficits in executive functioning which include working memory, encoding, visual-motor coordination, planning, and information processing. This study examined the effects of auditory and visual stimulation (AVS) on four specific cognitive abilities in children diagnosed with LD who demonstrated low and below average scores on the Wechsler Intelligence Scale for Children, Third Edition (WISC-III) Symbol Search, Coding, Arithmetic, and Digit Span (SCAD) profile to determine if such a treatment intervention could improve these specific cognitive weaknesses.

Methods. The WISC-III SCAD profile was administered pre- and post-12, biweekly 35-minute AVS sessions. Two index scores from the SCAD profile were also assessed: Freedom from Distractibility and Processing Speed. The study design was quasi-experimental, with repeated measures pre- and post-treatment.

Results. Findings demonstrated that AVS produced significant changes in all of the specific cognitive abilities as measured by the WISC-III SCAD profile, suggesting that AVS may benefit children with LD.

Discussion. AVS technology has the potential to greatly enhance cognitive abilities and quality of life for the learning-disabled individual who may be at risk for social, psychological, and a multitude of personal disappointments and life-long failures without such intervention.

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INTRODUCTION

Learning disabilities (LD) fall under many complex definitions and have a wide variety of manifestations and theoretical causes. The current definition of learning disabilities (Hammill, 1993) suggests that their etiology involves deficits in basic cognitive functions that are developmentally related to central nervous system dysfunction. Substantial evidence supports this theory (Chase, 1996; Flowers, 1993; Galaburda, 1991; Hynde & Semrude-Clikeman, 1989) and it is commonly agreed that such deficits specifically stem from weaknesses in executive functions, including working memory, encoding, visual-motor coordination, attention and response inhibition, planning, and processing (Barkley, 1997; Denkla, 1996; Douglas, 1972; Pennington & Ozonoff; 1996; Prifitera & Dersh, 1993; Welsh & Pennington, 1988).

Various areas of the brain must communicate with each other to establish the basis of the assimilation of sensory information, sensorimotor coordination, and other brain functions that are necessary for learning, memory, information processing, behavior, and perception (Mitner, Braun, Arnold, Witte, & Taub 1999). Hebb (1949) theorized that such communication occurs through the formation and connection of cells whose synaptic linkages are strengthened as a result of the synchronous firing of activated cells. It has been only since the development of technologies such as EEG to demonstrate its existence that Hebb's concept has validity. Studies have demonstrated that faster EEG activity in the gamma range (20-70 Hz) heightens during, and may be associated with, the formation of ideas and memory, linguistic processing and other abilities and behavioral functions (Singer, 1990; Singer & Grey, 1995). Mitner et al. (1999) demonstrated that increased gamma band activity was not only linked to associative learning, but they found that gamma band coherence also increases between regions of the brain that are receptive. According to Mitner et al. (1999) increased gamma activity is also connected to associated learning, and their research found that gamma band coherence expands between brain regions that takes in the two types of stimuli needed in an associative learning procedure. Hebb (1949) suggested that brain communication occurs when cells are activated and fire synchronously, strengthening synaptic linkages. Mitner et al. (1999) proposed that such a heightened coherence between the brain's regions may meet the requirements necessary for the formation of hebbian cell assemblies, linking and strengthening areas of the brain that are required to communicate together in order for associative learning to occur. They further suggest that coherence may be an indicator of associated and other types of learning.

Many of the previous studies using auditory and visual stimulation (AVS) targeted slower brain frequencies and numerous sessions (Carter & Russell, 1993, 1994; Joyce & Siever, 2000; Patrick, 1994). This research study targeted faster brain frequencies in the high beta and gamma range (20-40 Hz) when applying auditory and visual stimulation based on studies finding that faster frequencies were associated with learning (Mitner et al., 1999; Singer, 1990; Singer & Grey, 1995). These studies suggest that brainwave coherence in the gamma range may increase and strengthen synaptic linkages through the synchronistic firing of activated neural cells.

Auditory and visual stimulation (AVS) is a method of brain stimulation and brain wave "entrainment" that is applied through the ears and eyes by means of headphones and specially designed glasses inset with white light-emitting diodes (LEDs). These lights flash at predetermined frequencies, and are coupled with tones that are received through headphones. The light emitting from the glasses and rate of the flickering affect the brain through the optic nerve, and cause the brainwaves to "entrain" or match the rate of flickering to a desired frequency, depending on the preferred outcome. The external flicker of light at specific frequencies has been found to induce the brainwave activity to fall into specific frequencies by becoming entrained or synchronized (Carter & Russell, 1993; Pigeau & Frame, 1992; Timmermann, Lubar, Rasey, & Frederick, 1998).

Studies using AVS with LD/ADHD children have found increases in cognitive processes and enhanced academic performance as demonstrated on standardized testing (Carter & Russell, 1981, 1993, 1994, 1995; Micheletti, 1998; Patrick, 1994). Other studies found that AVS decreased the symptoms and improved problem behaviors in ADHD children (Joyce & Siever, 2000; Olmstead, 2000, 2001) and children diagnosed with autism (Woodbury, 1996). Though all of these studies demonstrate varying improvements in standardized tests and tests rating behavior, few of these studies addressed the changes in specific cognitive functions known to be common to LD.

Many of the previous studies using AVS targeted slower brain frequencies and numerous sessions (Carter & Russell, 1993, 1994; Joyce & Siever, 2000; Olmstead, 2000, 2001; Patrick, 1994). This research study targeted faster brain frequencies in the high beta and gamma range (20-40 Hz) when applying auditory and visual stimulation based on studies finding that faster frequencies were associated with learning (Mitner et al., 1999; Singer, 1990; Singer & Grey, 1995). These studies suggest that brain wave coherence in the gamma range may increase and strengthen synaptic linkages through the synchronistic firing of activated neural cells.

This study investigated the effect of 12, 35-minute AVS sessions on four specific cognitive abilities in children diagnosed with learning disabilities as measured by the Wechsler Intelligent Scale for Children, Third Edition (WISC-III). The null hypotheses were that AVS would not induce any change in four cognitive abilities as measured by the WISC Symbol Search, Coding, Arithmetic, and Digit Span (SCAD) profile.

METHODS

Participants

All participants were screened to eliminate those with seizures, migraine, and prior head trauma. Though the presence of a learning disability was the primary criteria for inclusion in the study, many children with some form of LD were also diagnosed with ADHD. All participants were administered the WISC-III SCAD profile. Regardless of their specific learning disability diagnoses (LD/ADHD), those participants who demonstrated low or below average scores on all of the four subtests (Symbol Search, Coding, Arithmetic, and Digit Span) were admitted into this study. Scores on the Freedom from Distractibility (FFD) and Processing Speed (PS) indexes were also obtained. No participants were undergoing individual behavioral modification therapy by a private therapist, or were involved in any school based behavioral intervention programs while in this study. Permission for possible publication of results was obtained and confidentiality of individual participants was guarded.

There were 30 children who participated in the study, with ages ranging from 6 to 16 years of age, from varying socioeconomic backgrounds. Many of the children were recommended by therapists, psychologists, and other private clinical practitioners. The children were volunteered by their parents and agreed to be in the study. There was an over-representation of boys in this study (24 boys and 6 girls), which may be accounted for as there is a general over-representation of LD/ADHD boys to girls found in much of the literature (Anderson, Williams, McGee, & Silva, 1987; Baumgartel, Wolraich, & Dietrich, 1995; Wang, Chong, Chou, & Yang, 1993).

The WISC-III SCAD Profile

The WISC-III SCAD Profile comprises the subtests Symbol Search, Coding, Arithmetic, and Digit Span. The combined Coding and Symbol Search subtest scores yield the Processing Speed (PS) index score: the speed at which an individual processes information. The combination of the Arithmetic and Digit Span subtests yield the Freedom from Distractibility (FFD) index score: the measure of an individual's ability to attend and concentrate (Groth-Marnat, 1997). The WISC-III factor indices are expressed as standard scores with a mean of 100 and a standard deviation of 15, with reliability coefficients which range from .85 to .94 and standard errors of measurement from 5.83 to 3.78 (Wechsler, 1991).

Apparatus

The AVS device called the Pro Tutor was provided on loan from Photosonix Inc. This is a small, plastic, battery-operated device consisting of headphones and white full-spectrum eyeglasses. A compact disc (CD) and cassette player with a selection of Walt Disney story soundtracks was added to the device. The Pro Tutor device was set at 50% to full intensity in both light and sound controls depending on the participant's comfort level. A microchip was programmed by this investigator to activate and control the frequency of the flickering lights and tones, which began at 14 Hz and increased every five minutes to achieve 40 Hz. The alternating program began at 40 Hz and decreased every five minutes until it reached 14 Hz. The AVS sessions were alternated with a 35-minute excitatory program (14 Hz increasing to 40 Hz) and a 35-minute inhibitory program (40 Hz decreasing to 14 Hz).

Treatment Procedure

This study design was quasi-experimental with a convenience, nonrandom sample, and repeated measures, with no comparison group. Systematic AVS treatment was administered two times a week for a total of six weeks. Participants put on headsets and light goggles and completed each AVS session while reclining in a comfortable chair. Children were given the choice of listening to a story on cassette tape or compact disc during each session. Once the story was chosen and the light glasses and headphones were in place, the AVS session began. Each participant received one excitatory and one inhibitory session a week for six weeks, for a total of 12 alternating excitatory and inhibitory AVS sessions. Upon completion of the 12 AVS sessions, post testing was administered using the WISC-III SCAD profile. Scoring was based strictly on the scoring rules for each subtest. Standard scores were determined using appropriate norms. WISC-III scores were transformed to an adjusted score based on a mean of 100 and a standard deviation of 10. This allowed direct comparison of scores between pre- and post-test scores. Analysis was conducted using the Statistical Package for the Social Sciences (SPSS; 1994).

RESULTS

Paired samples *t*-tests were used to determine if there were significant changes from the mean pre-test to the mean post-test on the six WISC-III subtest scales, including FFD and PS indexes. A correlation was used to determine if there were any relationships among the six variables. Significance levels were set at .05 for all tests.

As shown in Table 1, the analysis for all 30 participants showed a statistically significant gain in the participant's speed of information processing and visual motor coordination on the Symbol Search subtest (from a pre-test mean of 6.9 to a post-test mean of 10.6, $t = 6.2$, $p < .001$). There was also a statistically significant gain in the participant's visual short-term memory and sequencing ability as measured by the Coding subtest (from a pre-test mean of 6.0 to a post-test mean of 8.2, $t = 4.2$, $p < .001$). The Arithmetic subtest also revealed significant improvements (from a pre-test mean of 6.2 to post-test mean of 8.3, $t = 5.3$, $p < .001$) demonstrating a significant gain in number ability and short-term memory. Digit Span results revealed significant changes (from a pre-test mean of 7.1 to post-test mean of 9.6, $t = 7.49$, $p < .001$). Freedom from Distractibility increased significantly (from a pre-test mean of 13.2 to a post-test mean of 17.5, $t = 6.8$, $p <.001$) as did Processing Speed (from a pre-test mean of 12.9 to a post-test mean of 18.8, $t = 6.8$, $p < .001$).

The analysis for two groups, ages 6 through 10 and ages 11 through 16 is shown in Table 2. The younger group included 18 children, with the remaining 12 children in the older group. Both groups were compared from pre-test to post-test on all of the t-tests. All children in both groups demonstrated significant gains on all measures.

TABLE 1. Summary Data for Subtest Scores Pre- and Post-Test of the WISC-III SCAD Profile (n = 30).

	Pretest		Posttest			
Variable	*M*	*SD*	*M*	*SD*	*t*	*p*
Symbol Search	6.9	2.2	10.6	2.8	6.2	< .001
Coding	6.0	2.8	8.2	2.9	4.2	< .001
Arithmetic	6.2	2.6	8.3	2.7	5.3	< .001
Digit Span	7.1	2.5	9.6	3.4	7.5	< .001
FFD	13.2	4.3	17.5	5.5	6.8	< .001
PS	12.9	3.9	18.8	4.7	6.8	< .001

Table 3 shows the correlation matrix when all variables were correlated with each other. Five correlations were found to be statistically significant: the correlation between Arithmetic and Digit Span ($r = .39$, $p < .05$), Arithmetic and Freedom from Distractibility ($r = .83$, $p < .01$), Digit Span and Freedom from Distractibility ($r = .83$, $p < .01$), Coding and PS ($r = .82$, $p < .01$), and Symbol Search and PS ($r = .70$, $p < .01$).

DISCUSSION

The analysis of WISC-III SCAD results showed significant changes from pre-test to post-test on all variables for all children and all variables when separated into younger and older children. The younger children tended to show greater improvement in scores at post treatment. There are significant changes on the Coding subtest in contrast to the results of Groth-Marnat (1997) who suggested that Coding subtest scores can be lowered by anxiety as well as depression, as the psychomotor slowing found in depressive states can produce a decrease in performance levels.

These results may be important when considering the age to begin AVS intervention in the treatment of LD. The present results suggest that

TABLE 2. Comparison of Pre-Test and Post-Test Mean Scores of Younger and Older Participants of WISC-III SCAD Profile.

Group Variable	Pretest		Posttest		*t*	*p*
	M	*SD*	*M*	*SD*		
Younger Arithmetic	6	2.7	8.5	2.9	4.1	< .001
Older Arithmetic	6.5	2.6	8.1	2.5	3.9	< .001
Younger Digit Span	6.7	2.7	9.1	3.8	6.4	< .001
Older Digit Span	7.5	2.2	10.2	2.7	4.2	< .001
Younger Coding	6	2.9	7.9	2.4	2.8	< .013
Older Coding	6	2.8	8.5	3.5	3.1	< .013
Younger Symbol Search	7.1	2.6	10.1	2.6	4.4	< .001
Older Symbol Search	6.5	1.6	11.3	3	4.5	< .001
Younger FFD	12.7	5.2	17.5	6.3	6.2	< .001
Older FFD	14	2.5	17.5	4.2	3.3	< .004
Younger PS	13.1	4.2	18	4.2	4.3	< .001
Older PS	12.5	3.4	20	5.5	5.8	< .001

Note: Younger $n = 18$, Older $n = 12$.

TABLE 3. Correlation Matrix of WISC-III SCAD Profile Subtests of Arithmetic, Digit Span, Coding, Symbol Search and Freedom from Distractibility (FFD) and Processing Speed (PS) Indexes.

Variable	Arith.	DS	Cod	SS	FFD	PS
Arithmetic	1.00	.39*	0.03	−0.1	.83**	−0.02
Digit Span		1.00	0.11	0.01	.83**	0.08
Coding			1.00	0.17	0.09	.82**
Symbol S.				1.00	−0.05	.70**
FFD					1.00	0.04
PS						1.00

Note: * $p < .05$
** $p < .01$

younger children may make more cognitive gains due to brain plasticity (the ability of synapses to change as circumstances require). It has been well documented in many studies that during early development, the brain is capable of reorganizing patterns and systems of synaptic connections in ways that an older brain cannot (Stiles, 2000). The older group of children may show less change due to either emotional difficulties or the brain's inability to respond as well as the younger group. Another factor that may account for younger children making more significant gains is the lower incidence of behavioral difficulties or self-esteem issues that have not yet developed with regard to difficulties with learning. Findings from the National Longitudinal Study of Adolescent Health (2000) found that adolescent children in grades 7 through 12 are at significantly higher risk than non-LD peers for emotional distress, suicide attempts, and violence. Other studies indicate that adolescents with LD have a higher incidence of emotional distress (Svetaz, Ireland, & Blum, 2000), significantly higher rates of depression (Goldstein & Dundon, 1986) and symptoms of anxiety (McConaughty & Ritter, 1985; McConaughty, Mattison, & Peterson, 1994). These findings suggest that earlier intervention to aid in addressing the core deficits of LD appears to be imperative to the future well being of the child diagnosed with learning disabilities.

Though this study only used four subtests of the WISC III SCAD profile to investigate the effect of AVS as opposed to utilizing other measures such as behavior rating scales and computerized tests for impulsivity, the results confirm that AVS produces significant changes in cognitive abilities known to be weak in LD participants. Though this study utilized newer technology and faster frequencies, the lower number of AVS sessions needed to improve cognitive abilities may further demonstrate its efficacy. The AVS sessions were administered two times weekly for six weeks, which may assist in better outcomes. Daily sessions may result in overstimulation of the brain. The choice of story soundtrack with regard to the application of AVS did not appear to be a detriment. This study used higher frequencies than those of other studies (14-40 Hz and 40-14 Hz) and may suggest that the most significant gains in specific cognitive improvements are produced by using the faster frequencies which may result in increased neuronal stimulation.

A weakness in this study was the population size. Though there were only 30 participants, all children did demonstrate significant improvements. Additionally, this study did not use a control group, which is partially due to time restraints and the ethical consideration of withholding medication for those who did not want to discontinue psychostimulant use. Further investigation using this technology might include the testing in other specific areas such as reading, comprehension, abstract thinking, social maturity and judgment, writing skills, listening, speaking, reasoning, and spelling. Future studies could include a larger population size with equal distribution of age and sex. A longitudinal study design that would allow for both cognitive and behavioral measures to be evaluated is also recommended as well as the use of self-reported, parent, and teacher ratings. Other future studies could include a pre-determined year follow-up to discover if academic recidivism occurs in any specific cognitive ability, and to what extent. Studies investigating AVS and brain physiology might use brain imaging technology to measure areas of activation and particular changes in neurophysiology.

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