

The effect of hemisphere specific remediation strategies on the academic performance outcome of children with ADD/ADHD

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Abstract: The development and normal function of the cerebrum is largely dependent on sub-cortical structures, such as the cerebellum and basal ganglia. Dysfunction in these areas can affect both the nonspecific arousal system and information transfer in the brain. Dysfunction of this sort often results in motor and sensory symptoms commonly seen in children with ADD/ADHD. These brain regions have been reported to be underactive, with that underactivity restricted to the right or left side of the sub-cortical and cortical regions. An imbalance of activity or arousal of one side of the cortex can result in a functional disconnection similar to that seen in split-brain patients. Since ADD/ADHD children exhibit deficient performance on tests thought to measure perceptual laterality, evidence of weak laterality or failure to develop laterality has been found across various modalities (auditory, visual, tactile) resulting in abnormal cerebral organization and associated dysfunctional specialization needed for lateralized processing of language and non-language function. This study examines groups of ADD/ADHD elementary school children from first through sixth grade. All participants were administered all the subtests of the Wechsler Individual Achievement Tests, the Brown Parent Questionnaire, and given objective performance measures on tests of motor and sensory coordinative abilities (interactive metronome). Results measured after a 12-week remediation program aimed at increasing the activity of the hypothesized underactive right hemisphere function, yielded significant improvement of greater than two years in grade level in all domains except in mathematical reasoning. Results are discussed in the context of the concept of functional disconnectivity in ADD/ADHD children.

Keywords: Attention deficit hyperactivity disorder, hemispheric function, rehabilitation, synchronized metronome

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Submitted: December 20, 2009. **Revised:** January 15, 2010. **Accepted:** January 20, 2010.

INTRODUCTION

Attention-deficit/hyperactivity disorder (ADHD) is the most common neuro-behavioral disorder of childhood. ADHD is also among the most prevalent chronic

health conditions affecting school-aged children. The core symptoms of ADHD include inattention, hyperactivity, and impulsivity (1,2). Children with ADHD may experience significant functional

problems, such as school difficulties, academic underachievement (1), troublesome interpersonal relationships with family members (3) and peers, and low self-esteem. Individuals with ADHD present in childhood and may continue to show symptoms as they enter adolescence (4,5) and adult life (6-9).

Most of the development and normal function of the cerebrum is dependent on subcortical structures, especially the cerebellum and basal ganglia. A failure to develop or a dysfunction in these areas or both can affect the nonspecific arousal system as well as specific transfer of information in the brain. Dysfunction in these areas will usually result in specific motor and sensory symptoms that are commonly seen in children with cognitive or behavioral disorders, especially ADD (Attention Deficit Disorder) and ADHD. We have demonstrated elsewhere that these brain regions are often seen to be underactive in these children, based on electrophysiological coherence studies (2,10,11). These cortical loci have been shown to be connected with the prefrontal cortex, which have also often been noted to be underactive in children with neurobehavioral developmental disorders (1). The underactivity and or atrophy is usually restricted either to the right or to the left side of the sub-cortex and cortex (1).

An imbalance of activity or arousal of one side of the cortex or the other can result in a functional disconnection syndrome, similar to what is seen in split-brain patients and early reported by Leisman (12-14) and Sroka and colleagues (15). This could be an underlying source of many if not all of the symptoms that we see with children with behavioral and cognitive disorders. For example, post-mortem examinations have indicated structural differences between the brains of good and impaired readers. High concentrations of micro-dysgenesis have

been noted in the left temporoparietal regions of dyslexic brains. The concentration is most evidenced in the planum temporale region (16-18). These micro-dysgeneses seriously impair the normal pattern of architecture of dyslexics and remove the asymmetry normally observed between the enlarged language areas of the left temporoparietal region and the smaller homologous areas of the right hemisphere (13,16). Our studies alluded to earlier show such effects in ADD/ADHD individuals.

The capacity for language is generally correlated with a significant development in the magnitude of the left temporoparietal region and an attrition of neurons in the right hemisphere. These neuronal casualties may produce the observed asymmetry between corresponding areas in the left and right hemispheres (13,14,19). The relative symmetry in the dyslexics' brains might reflect their impaired linguistic development, and the asymmetry in ADD/ADHD may likewise underlie those disorders.

As Orton (20) indicated, it is generally assumed that persons with ADD and ADHD have abnormal cerebral organization including atypical or weak patterns of hemisphere specialization (21,22). The developmental lag hypothesis proposed by Lenneberg (23) suggested that such children are slower to develop basic language skills and demonstrate weak hemispheric specialization for language tasks, including reading. In a reformulation of the progressive lateralization hypothesis (24), it may be that subcortical and antero-posterior progressions have a differential developmental course with ADD/ADHD children and adults compared with control subjects or those with acquired syndromes.

Because ADD/ADHD children exhibit deficient performance on a variety of tests thought to be a measure of perceptual laterality, evidence of weak laterality or

failure to develop laterality has been found across various modalities (audio, visual, tactile) (25). These children are thought to have abnormal cerebral organization, as suggested by Corballis (22). The basic assumption is that dysfunction in the central nervous system, either prenatally or during early postnatal development, results in abnormal cerebral organization and the associated dysfunctional specialization needed for lateralized processing of language function and non-language skills. It is thought that cortical and subcortical dysfunction resulting from aberrant patterns of activation or arousal (25), inter- and intra-hemispheric transmission deficits, inadequate resource allocation (26), or any combination of these may compromise hemispheric specialization in those with cognitive and behavioral deficits (22).

Rabiner and Malone (27) has indicated that children with learning problems associated with ADD/ADHD can acquire at least grade-level reading skills if such children receive early intensive intervention to correct their deficiencies (28,29). The comorbidity of ADD/ADHD and reading difficulties described earlier justifies the examination and evaluation of remedial strategies for cognitive tasks in ADHD children that are hemisphere specific. To examine this notion further, we conducted a pilot study evaluating ADD/ADHD elementary school children from first through sixth grade. All participants were administered tests of academic performance evaluating relevant cognitive abilities, motor and coordinative, and rudimentary literacy skills. ADD/ADHD children were tested both before and after participation in a hemisphere specific remediation program.

METHODS

The pool of participants for this study consisted of 122 children between 6-12.11 years of age diagnosed with Attention

Deficit Disorder (ADD) or Attention Deficit Hyperactivity Disorder (ADHD). The participants presented with inattention, hyperactivity, impulsivity, academic underachievement, and/or behavior problems, and each met the criteria of the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition, and clearly demonstrated the absence of coexisting conditions as evaluated by non-participating licensed Psychologists or Psychiatrists. The participating children came from clinics associated with one of the authors located in school districts in middle- to upper-middle-class school districts in Nassau and Suffolk Counties, New York. Of the total participants, 94 (77%) were male and 28 (23%) female. All were in the average range of intellectual ability as measured by standardized tests of intelligence (data not herein reported). Parental informed consent was obtained. The exclusionary criteria included (a) severe vision or hearing problems, (b) frequent ear infections, (c) severe emotional problems, (d) limited intellectual ability, (f) English as a second language, and (g) diagnosed Pervasive Developmental Disorder. All children in the study were taking stimulant medication before, during, and at the conclusion of the study. No changes in pharmacological management occurred during the course of the trial for any of the participants. Formal testing employing the BADD (30), see below) was 100 percent concordant with the diagnosis of ADD/ADHD that each participant had received elsewhere before entry into the study.

Procedure

Initial pre-treatment evaluations included the functional assessments of sensory and motor function and on a separate day, academic testing as described below. The combined testing allowed the clinicians to formulate a treatment program that was

designed to selectively stimulate the skills that were significantly below age- or functional level for a given participant, and were aimed nominally at exercises thought to principally stimulate the less efficiently performing hemisphere. Each participant participated in this multi-modal program three times per week for one hour each time over a twelve-week period.

Each participant underwent specific supervised activities during that time that included: sensory stimulation, motor training, aerobic strength and conditioning, and academic training. Compliance with the regimen was achieved with most but not all participants. Also employed in the regimen were primitive reflex inhibition exercises, as well as academic home training exercises. After 36 sessions over a 12-week period, participants were again tested on the same battery of tests of sensory, motor, and academic performance, including the completion of the parent behavioral checklist. The academic testing was performed by the same individual during both the pre- and post-treatment sessions. The treatment attempted to achieve a temporal coherence between large cortical networks on the left and right hemispheres and to increase all functions in that hemisphere that were functionally deficient. The idea was to achieve an evenness of skills that would be at or above the child's actual age and or grade level.

Synchronized Metronome Treatment (SMT) was employed. Participants wore a headphone and listened to a reoccurring metronomic beat. As they listened to the beat, they engaged in physical movements such as clapping hand-to-hand with a sensor on one palm as they matched their physical movement to the presentation of the beat (e.g., clap at the beat). The training attempted to reduce the mean negative synchronization error during normal tracking of the regularly occurring metro-

nome beat (clapping before or past the beat). During training, participants received feedback through an auditory guidance system as they progressed through the simple, interactive physical movements. Although feedback was also provided through visual stimuli, the auditory feedback guidance system was the primary feedback method. The auditory feedback system provided tonal stimuli that indicated whether the participant responded before, at, or past the regularly occurring auditory metronomic beat. The accuracy of participants' expectancy response to the metronome beat was provided in milliseconds (ms), with different tones indicating far from, close to, or at the metronome beat. A visual reading of millisecond latency was also presented to the participants on a computer screen.

The purpose of the training was to improve participants' timing/rhythmicity by reducing the latency between the onset of the metronome beat and the participant's expectancy response to the beat. At the completion of the treatment program, participants had engaged in approximately 25,000 motoric repetitions. The purpose of the procedure was to examine the relationship between improvements in domain-specific SMT-based intervention and domain general improvements in the areas of academics and ADD/ADHD functioning—more fully explained in (1).

All participating children were given the Wechsler Individual Achievement Tests [WIAT-II] (31), including Word Reading, Reading Comprehension, Mathematical Reasoning, Spelling, Written Expression, Listening Comprehension, and Oral subtests. All subtests were given immediately before the participants' start in the program and again at the conclusion of the 12-week hemisphere-specific intervention program. Additionally, all participants were given the Brown Attention Deficit Disorder Scales

(BADD) (30) that was appropriate for each participant's age, both before and after the 12-week intervention program.

The 122 participant children were selected from a larger group of 181 children undergoing the treatment program; 59 were excluded for reasons indicated above. A control group of untreated children was not included for comparison purposes for this pilot study. At the conclusion of the 12-week intervention program, all children were tested again using the same instruments. All the obtained percentile scores were converted to grade equivalent.

These WIAT reading tasks were chosen because they require the ability of the participant to correctly read a series of printed words, sentences, and paragraphs and to answer questions about what was read and to correctly apply phonetic decoding rules when reading a series of nonsense words.

The Mathematical Reasoning Subtest of the WIAT was chosen because it assesses the ability of the participants to add, subtract, multiply, and divide one- to three-digit numbers and to understand number, consumer math concepts, geometric measurement, basic graphs, and solve one-step word problems.

The Spelling (Written Language) subtest was chosen because it requires the participants to correctly spell verbally presented words and to generate words within a category, generate sentences to describe visual cues, combine sentences, and compose an organized paragraph. This subtest likely measures skills less related to attentional concerns and more to a direct measure of achievement.

The WIAT Oral Language subtest was chosen as the tasks require the participants to identify a picture best representing an orally presented descriptor or to generate a word that matches the picture and to generate words within a category, to

describe scenes and give directions.

Whereas IQ subtests are largely tests of thinking and reasoning skills, the WIAT-II is a test of academic achievement. We were interested in examining whether hemispheric specific training would have an effect on unmasking the actual level of achievement with reduced attentional effects and whether we could conclude that the evidence is enough to warrant a clinical trial on the notion of hemisphere-specific training.

Statistical analyses

Pre-Post treatment differences were examined by using correlated t tests.

RESULTS

The results indicate significant differences ($t = 5.25$, $df = 60$, $p < .000005$) between pre- and post-treatment responses by parents of the ADHD children. Indeed, 81% of the participants demonstrated a significant improvement on pre- as compared with post- testing (see table 1).

Pre-post sensory-motor measured performance changes were likewise significant. Rhythmic integrated eye-hand and eye-foot coordination revealed that in excess of 87 percent of those ADD/ADHD children tested demonstrated statistically significant improvement ($t = 74.71$, $df = 97$, $p < .000001$).

In the measurement of academic performance on subtests of the WIAT, the results indicate significant changes in all domains measured that required a strong attentional component to test performance. Tasks like Mathematical Reasoning, which require greater academic skill and less attentional focus, were more resistant to change. For example, on the WIAT Word Reading subtest, 84% of participants demonstrated a significant improvement, defined for this study as greater than two years improvement in grade level ($t = 2.94$,

Table 1. Results from pre- and post-testing

Test	Pre-Testing			Post-Testing					% [†] Change
	N	M	<i>d</i>	N	M	<i>d</i>	<i>t</i>	<i>p</i>	
Brown	60	67.11	16.87	60	53.42	16.02	5.25	.000005	.81
IM	97	194.44	1.42	97	89.84	0.96	74.71	.000001	.87
WIAT									
Word Reading	38	3.34	2.75	38	5.31	3.2	2.94	.01	.84
Math Reasoning	122	3.2	48.06	122	5.6	5.67	0.55	**	.81
Spelling	119	3.2	3.36	119	5.6	2.85	4.07	.0005	.57
Written Expression	119	2.8	3.16	119	5.8	3.3	17.64	.000001	.76
Listening Comp.	121	3.2	17.31	121	6.1	2.74	8.52	.000001	.82
Oral	117	2.7	3.02	117	6.1	4.05	10.62	.000001	.71

[†]change > 2 grade levels within the 12-week program; **Not significant

df = 38, $p < .01$) but no significant differences between pre- and post-testing were observed with WIAT Mathematical Reasoning ($t = .55$, $df = 122$, NS).

On the other hand, although 52% and 76% of participants exhibited significant change of greater than two or more years increase in performance after the 12-week treatment program in Spelling ($t = .0005$, $df = 119$, $p < .0005$) and Written Expression ($t = 17.64$, $df = 119$, $p < .000001$), respectively, a significant 82% positive change was noted in performance related to Listening Comprehension, a more heavily attentionally loaded task ($t = 8.52$, $df = 121$, $p < .000001$).

DISCUSSION

All sensory perception is based on the effectiveness of the arousal level of nonspecific, mostly subconscious, activity of the brain. No specific sensory modality perception like vision or hearing can exist without a baseline arousal level. The more stimulation or greater frequency of

stimulation, the more aroused an individual will be. Luria (32) postulated that the brain was divided into three functional units: 1) the arousal unit, 2) the sensory receptive and integrative unit, and 3) the planning and organizational unit. He subdivided the last two into three hierarchic zones. The primary zone is responsible for sorting and recording incoming sensory information. The secondary zone organizes and codes information from the primary zone. The tertiary zone is where data are merged from multiple sources of input and collated as the basis for organizing complex behavioral responses (32). Luria's dynamic progression of lateralized function is similar to Hughlings Jackson's Cartesian coordinates with respect to progressive function from brainstem to cortical regions (33).

Accordingly, the goal of clinical intervention is to attempt to develop brain-based intervention strategies for children with dysfunctions of lateralization that would seem to be threefold: first, to isolate

cognitive abilities that are especially important for learning and language development, along with deficiencies in these abilities that might distinguish between poor and normally developing learners; second, to isolate experiential and instructional variables that differentially affect achievement in school and other life programs; and third, to isolate the genetic and neurological underpinnings of the cognitive abilities underlying academic abilities in ADD/ADHD children in the interest of distinguishing between genetic and neuropathological causes of deficits in these abilities in childhood.

Brain development and the adequacy of it functioning are dependent on sensory input. Specific sensory perceptual processes like vision and hearing are dependent on non-specific sensory input. This, in turn, creates a baseline arousal and synchronization of brain activity. This is a form of constant arousal and is dependent on a constant flow of sensory input from receptors that are found in muscles of the spine and neck. These receptors receive the majority of their stimulation from gravity, creating a feedback loop that forms the basis of most if not all of brain function. Sensory input drives the brain, and motor activity drives the sensory system. Without sensory input the brain cannot perceive or process input adequately. Without motor activity provided by constant action of postural muscles a large proportion of sensory stimuli are lost to further processing. This loop is the somatosensory system (34).

Of particular interest in this study was that the Brown Attention Deficit Disorder Scale data, when completed at the outset of the intervention by the 60 participants' parents, revealed that all participants were ADD/ADHD. After the course of the 12-week hemispheric specific intervention, 81% were considered to no longer be

demonstrating ADD/ADHD behaviors, based on the Brown Scale.

We here attempted a pilot study to determine if treatment that is preferentially aimed at a hypothesized interactive right hemisphere in ADD/ADHD children would have an effect on their sensory motor performance, as well as on cognitive function related to attention focus. The results support further examination through a large-scale clinical trial of the notion of differential hemispheric training on attentional performance in childhood as a potential of non-drug therapeutics in the treatment of attentional problems of childhood. The clinical trials will have to examine the differential effects of medication and hemispheric specific treatment, as well as the effects of nutritional interventions on academic and on sensory, motor, attentional, and signal detection performance.

ACKNOWLEDGMENTS

This work was supported in part by the FR Carrick Research Institute Foundation. Authors RM, MO, and CT have financial interests in the clinics from which the outcome data were obtained.

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