The Effects of EEG Neurofeedback and Neuro-Cognitive Processing in the Educational Environment of an Arts-Based Private Elementary/Middle School

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Statement of the Problem

The purpose of this study was to ascertain measurable differences in academic outcomes among two groups of learners within a creative arts curriculum that employed a self-directed, stress-reduced, and individualized curriculum. One group was provided with EEG neurofeedback and neuro-cognitive coaching for stress reduction, while the other was not. This study measured the rate of improvement in academic progress that a learner can achieve when formalized learning takes place in a stress-reduced arts-based learning environment with EEG neurofeedback and neurocognitive coaching. Neurofeedback was used as a tool to improve the ability of the student to reduce stress, to focus attention, and to improve concentration, thus improving performance. The physiological effects of stress on a learner have been examined and found to decline as a result of applying a course of EEG neurofeedback and neuro-cognitive therapy. Stress is a psychophysiological response that occurs in the brain, the results of which can range from intensifying the damage due to stroke, to causing seizures, to reducing the capacity to remember or to learn. Turkington (1996) described the role of the limbic system in stress as being stimulated by environmental or physical stressors such that an imbalance in the brain is produced that results in tension between limbic and cortical impulses. It is commonly believed that stress has a negative impact on people's performance and functioning in the areas of work, home and education. Life, as most of us now know it, can be characterized by a sense of urgency to operate at high levels of speed, productivity and performance. For this reason, this writer believes that the ultra-high-speed era of technology has cultivated a group of learners resistant to the slow pace of conventional educational methods. It is imperative for contemporary educational methodologists to develop teaching systems that can keep pace with the speed of technology and that can reduce stress in the learning context.

It was through the design and development of this study that this writer was able to identify means of reducing stress in learning environments. The means identified included: the use of specialized academic environments, creative curriculums, psychophysiological profiles, and neurophysiological tools such as EEG neurofeedback and the binaural listening techniques developed at the Monroe Institute. In the United States, achieving academic excellence has been of paramount concern. On standardized tests designed to measure such achievement, students scores have declined at the same time that emphasis on improving performance has increased (Healy, 1997). It is critical for educators to find casual factors for this decline and then design learning environments and apply techniques that promote learning for all students. Clearly, there are problems in our educational system. With an illiteracy rate in the United States of about 20 percent, roughly two out of ten people in any given classroom are likely to have significant difficulties in the areas of reading, writing, listening and or speaking. (C. Florence, Personal Communication, September 1997).

A student's ability to learn depends upon that student's interpretations of, and reactions to, challenges and environmental qualities (Ekman-Lundy, 1998). If a learning environment is perceived by a student as threatening, whether due to the actions of classmates, the teacher or to the overall classroom experience, that student is likely to respond with elevated levels of stress. For example, when couples used sarcasm, interruptions, and criticism during discussions they showed decreased immune responses and larger, more persistent increases in blood pressure (Kiecolt-Glaser et al., 1993). In the classroom, the use of sarcasm, interruption and criticism in teacher-student and student-student interactions creates stress in some students. When exposure to stressful, negative behavior was prolonged, persistent high levels of cortisol were found that suppressed immune function. Excessive amounts of cortisol were also found to be associated with stress-related diseases, including colitis, cardiovascular disorders, and adult onset diabetes. It was also found to be a major contributor to emotional instability and cognitive deficits (Murphy, 1991).

It has been reported that individuals experiencing persistent physiological stress experience corresponding impairments in cognitive functioning, particularly in fast-paced, competitive, performance and product driven learning environments (Healy, 1997). An exacerbation in the level of stress often produced symptoms such as hyperactivity, short attention span, irritability, short temper, and aggressive behavior. A poor tolerance for additional levels of stress was also found (Comings, 1997). These scenarios suggest that individuals living under the condition of ongoing stress are likely to experience a persistent fight-flight response.

According to the Ohio Handbook for the Identification, Evaluation, and Placement of Children with Language Problems, language is an organized system of symbols shared among a group of people, which represent objects, actions, feeling, processes, and relationships. "Every language has a set of rules that govern the content, form, and use of that language." Therefore, problems within any of the areas of reading, writing, listening or speaking are indicative of a language disorder. In this study, two of these four areas--reading and listening--were targeted for investigation.

The typical learner with a language disorder may show impairments or developmental delays in the areas of pragmatics, semantics, phonology, morphology and/or syntax. In the area of pragmatics, a student may be unable to accurately understand the content of language, and misinterpret the information as a result. A pragmatically impaired listener may take offense at a speaker when s/he misconstrues tonal inflections in such a way that the speaker's intended meaning is not comprehended. This kind of listener might also hear a speaker's statement of opinion, and then construe it as a statement of fact. These types of misunderstandings frequently occur in those diagnosed Attention Deficit Hyperactivity Disorder (ADHD) and Oppositional Defiance Disorder (ODD). In the area of semantics, the meaning of the word being used figuratively might be taken literally, as in the figurative phrase, "she just fell apart." Developmental delays are often seen in the areas of phonology, morphology and syntax. When individuals with delays in these areas form the physical make-up of words and sentence structures, they tend to mispronounce words, leave off word endings or use words in the wrong context. A student with difficulties in this area may not understand the basic rules of language, and may have difficulty sounding out words. Difficulties in phonology, morphology and syntax are usually seen with individuals displaying central auditory processing disorders.

Students with both a language disorder and ADHD have been found, through positron emission topography (PET) scans, to have less cerebral blood flow in their frontal lobe and more activity in the limbic system of the brain (Carter, 1998). While mental activity is occurring, typically the brain region with the greatest density of glucose and oxygen is in the frontal cortex. Those with ADHD, however, have been shown to experience less than typical levels of activity in the frontal cortex during periods of mental activity (Amen 1997). PET scans have also demonstrated that in the ADHD learner, the majority of neuronal firing occurs primarily in the amygdala, which lies within the limbic system (Amen, 1997).

In the field of Neurofeedback it is generally recognized that when children with ADHD experience stress, they are more likely to react negatively than they are to interact and proceed towards a positive outcome. One reason given for ADHD negative interpersonal reactivity has to do with unusual levels of activity in the amygdala when under stress. The amygdala is the emotional control center in the brain. When fear is the active emotion in this center, neuronal activity has been shown to slow down to the alpha/theta wave frequencies (Brown, 1991).

The Alpha/theta State is a pleasant, comforting, relaxation response for normal individuals when the eyes are closed and the body is still. However, when ADHD individuals experience a stress induced alpha/theta state with their eyes open combined with efforts to be focused, often there is an accompanying reduction in the level of cortisol, and with that, a helpless, forced state of fear that is associated with symptoms such as sweaty palms, elevated heart rate and dilated pupils. This complex response may lead individuals with ADHD to react or act out rather than think through and attempt to mitigate the condition that is producing stress for them. By contrast, normal individuals can experience an alert beta state as a response to stress. When stressed, brainwave activity in those with language disorders originates as a slow alpha/theta frequency (Amen, 1997) and underscores the tendency among these individuals towards reactive, fear responses.

In summary, the beta state--a state characterized by mental alertness--is the typical brainwave frequency for children without language disorders when their eyes are wide open and they are attempting to concentrate attention on completing a task (Evans & Abarbanel, 1999). When these same children close their eyes and begin to relax, their brainwave frequencies typically slow to the point that they enter an alpha/theta state. By contrast, among children with language disorders, the opposite reaction tends to occur. That is, alpha/theta waves--characteristic of relaxation--prevail when their eyes are open and they are trying to concentrate, and beta waves prevail when their eyes are closed and they are trying to relax or fall asleep (Lubar 1995), Lazzaro, et. al. (1999).

It may be due to the tendency towards alpha/theta vs. beta brainwave reversal in children with language disorders and ADHD that these children experience difficulties with resting and sleeping. It is uncertain as to whether these difficulties are due to the condition of alertness as indicated by the presence of a beta brainwave state when the children's eyes are closed, or whether ADHD itself is secondary to a sleeping disorder. It may also be that low frustration tolerance and a tendency towards impulsivity and inappropriate behavior are additional untoward consequences of alpha/theta vs. beta brainwave reversal. Changes in elevations of these neuro-hormonal levels are thought not only to contribute to, but also to increase, both the frequency and the intensity of low frustration tolerance, impulsive, and inappropriate behaviors (Brown, 1991).

The preceding discussion details a number of problems specific to individuals, and to children in particular, with language disorders and ADHD--problems that appear to be a function of contextually atypical brainwave patterns. These problems include, but are not necessarily limited to, impairments in the ability to focus mental concentration to tolerate frustration and stress, to rest and sleep; and to behave in thoughtful, context appropriate ways. Insofar as the means exist to measure typical and atypical brainwave patterns (the Electroencephalogram (EEG)), and the techniques exist that can teach individuals to modify such patterns, i.e., EEG neurofeedback and neuro-cognitive coaching, then it may be possible to document whether or not these techniques can be efficacious towards improving the neuro-cognitive functioning of persons with language impairments and ADHD. Bringing together a body of findings to document the impact of these techniques is the essential purpose of this study. As an ancillary index, this documentation will also include findings from quantitative measures of skills and skill development in the areas of verbal and auditory processing.

The fundamental premise of this study is this: if individuals were taught to improve focus and concentration, that improvement would alleviate their concentration difficulties, would modify their brain neurochemical levels, increase their scores on quantitative measures of verbal and auditory processing skills, and positively contribute to their level of academic performance.

This study will examine the impact of neuro-cognitive coaching combined with EEG neurofeedback in a private school that employs a creative arts curriculum in conjunction with music/sound therapy that, when taken together, is intended to create a low-stress learning environment. EEG neurofeedback will be utilized to teach students to focus and concentrate by becoming able to voluntarily modify their own brainwave patterns. The study focused on fulfilling the needs of study participants both with and without language disorders or ADHD and documents the effects of EEG neurofeedback and neuro-cognitive coaching. It was the intent of the research to statistically analyze the results from the participants' exposure to neuro-cognitive coaching and EEG neurofeedback.

Definition of Terms

Academic Terms

At the time of this writing, the following academic terms were generally being used in the creative arts curriculum. A *learner* is a student learning in the creative arts classroom. A *facilitator* is a teacher teaching in the creative arts classroom. References to *traditional* classrooms mean that classroom environments are teacher directed and/or teacher-lecture driven. In the creative arts curricula, however, classroom activities tend to be more *learner-directed.* Learner-directed education in a creative arts curriculum constitutes a process of learning that tends to be primarily initiated by the learner, wherein activities and projects proposed by the learner are discussed with, guided and approved by, the facilitator.

Biofeedback Terms

Terms frequently used in the field of biofeedback are defined as follows: An *Electroencephalogram,* commonly known as an EEG, is a recorded tracing of wave patterns of electrical brain activity obtained by placing electrodes on the skull. *EEG neurofeedback* is an electroencephalogram that uses auditory and visual feedback that is displayed on a computer monitor allowing participants to observe their own brainwave activity. *Neuro-cognitive processing* is a combination of *EEG neurofeedback* and *language process coaching.* Language Process Coaching involves determining the effectiveness of learners' expressive and receptive skills and then using that information to strengthen their auditory and visual modes of learning.

EMG biofeedback is defined in this study as *electromyography.* Electromyography is a method of measuring muscle activity by means of a device that produces auditory and visual feedback. Peripheral work can be used to make self-regulated adjustments in blood pressure, body temperature, heart rate, and muscle tension. The *International 10/20 system* for EEG placement specifies where electrodes are placed on the scalp during EEG neurofeedback training (See Appendix A). The *bremer band* defines the brain activity in terms of hertz (Hz) levels starting with delta at 0.5-4 Hz, theta 4-7.5 Hz, alpha 7.5-12.5 Hz, and lastly, beta 12+ Hz. *Amplitude* is defined as the voltage in microvolts measured from the peak to the trough of the brainwave. *Frequency* refers to the rate at which a waveform repeats its cycle within one second (also known as hertz or Hz).

Music Terms

Circadian rhythmicity is an intrinsic, innate rhythm synchronized to twenty-four hour time frames as a function of recurring periods of light and dark that, in humans, affects body temperature, sleep and wake cycles, hormone levels, urine production and levels of cognitive and motor production (Turkington, 1996). An individual's circadian rhythm can be influenced through the use of specially designed music that causes that individual's own rhythms to become *entrained* to the rhythms of the music. *Entrainment* refers to the alteration of internal psychophysiological rhythms as a function of being exposed to music with specific configurations of dominant beats (Wigram, 1999). "Brainwaves, heart rhythms, respiration, emotional tone, timing, pacing and other organic rhythms can change subtly according to the music we listen to" as a function of the process of entrainment. (Campbell, 1997).

Persistent rhythmic auditory stimuli *(binaural beating)* manifests, neurologically, as a cortical frequency-following response (FFR) in the electrical activity of the brain (Smith et al., 1975; Marsh et al., 1970; Hink et al., 1980). *Binaural beats* are auditory brainstem responses that originate in the superior olivary nucleus of each hemisphere and result from the interaction of two different auditory impulses originating in opposite ears. In *binaural beating*, a sound signal is played to each ear that is heard independently by each ear as a single tone. When both signals are played simultaneously, the resulting vibrato perceived is called *binaural beating* (Monroe, 1982). Monroe experimented with the application a variety of frequency signals that later became a process that he patented, known as *Hemi-Sync.* Through his experimentation, Monroe developed sets of auditory frequencies that were able to produce distinct, specific hemispherically synchronized states. *Hemispheric-synchronization* (Hemi-Sync), as applied in *audio-guidance* and music, can produce a variety of states, ranging from heightened focus and concentration to deep relaxation, depending on which Hemi-Sync signals are being combined and played. For example, a state of profound relaxation can be produced when Hemi-Sync signals are utilized that cause the brainwave frequency to move into the alpha/theta, 4-12 Hz range (Monroe, 1982). In the *audio-guidance process,* different sounds or tones are isolated for each ear by means of a stereo headset. The brain hemispheres then 'hear' a third signal, which is the difference between the two original tones. This third signal is not actually a sound, but an electrical signal that can only be perceived within the brain by both brain hemispheres working in synchrony.

Neuroimaging Terms

Currently, several neuroimaging techniques are being used in neuroscience to acquire information about the physiology of the brain. One of these techniques is magnetic resonance imaging (MRI). The MRI is also referred to as nuclear magnetic resonance imaging. This technique provides high quality cross-sections of the brain without using radiation or x-rays (Turkington, 1996). The MRI is most commonly used as a diagnostic tool for a variety of head and spinal cord injuries. Because the MRI can scan on several different planes it is usually preferred over the Computerized Axial Tomography scan (see below). Recently, science has been able to integrate findings from two, disparate media that depict brain physiology: biophysically based (MRI) images, and electrogenically-based EEG brainwave pattern recordings. Correspondences between membrane and molecular biological measures on the one hand, and psychophysical, electrogenic measures on the other, have now been established (Thatcher, 1999). The correlation of findings from the field of anatomy, via the MRI, and the field of psychophysiology, via the EEG, has created a new dimension for the field of neuro-cognitive processing. It is now possible to see an image of what is happening at the psychological level by examining the micro-world of our cells with the MRI and the EEG. These instruments can show an internal picture of the psychophysical "feelings" of an individual. Moment-to-moment psychological changes are reflected at the internal, physical level. These internally reflected psychological changes are now measurable.

Functional Neuroimaging is a new technique that measures four-dimensional biophysical brain processes related to normal and pathological brain function, including perception and cognition (Thatcher *et al.*, 1994, 1996; Frackowiak *et al.*, 1997). The *Computerized axial tomography (CAT) scan* is a procedure that can provide quick and accurate diagnoses and can produce clear cross-sectional images that illustrate a remarkable differentiation between varying soft tissues. *Positron emission tomography* (PET) is an imaging technique used for recording real time chemical activity occurring in the brain. With regard to acquiring information about the physiology of the brain, the MRI has two significant advantages. First, the MRI generates high quality, cross-sectional images of the brain without the radiation, used in x-ray images. Second, MRI images provide better differentiation between white and gray matter in the brain than CAT scans.

An x-ray called *functional magnetic resonance imaging* (fMRI), is able to record areas in the brain where the greatest concentrations of glucose and oxygen exist at any given time. Glucose-oxygen brain activity imaging is being increasingly utilized by brain mappers because of the increased evidence of site specific behavioral and cognitive dysfunction relative to glucose and oxygen concentrations in specific brain areas. S*ingle positron emission computerized tomography* (SPECT) scan is a type of radionuclide scanning requiring the individual to ingest a radioactive substance that tracks blood flow and enables the SPECT scan to measure brain activity.

Stress

Two distinct components, the brain and spinal cord, make up the *central nervous system* (CNS). Associated with the CNS is the *autonomic nervous system* (ANS). The ANS is an involuntary system of nerves that control and stimulates the output of cortisol from the adrenal cortex and adrenaline from the adrenal medulla. Adrenaline increases heart rate and blood pressure and it can quickly mobilize energy reserves. Conversely, cortisol reduces heart rate and blood pressure, and it conserves and replenishes energy supplies. The autonomic nervous system consists of two parts: the *sympathetic nervous system* and the *parasympathetic nervous system.* In emergency situations that cause stress or require a *fight or take flight response*, the sympathetic nervous system is dominant. The *fight-or-flight response* is an instantaneous reaction to a perceived threat that creates a chain reaction of psychophysiological responses. In non-emergency situations where conservation and renewal of energy is needed, the parasympathetic nervous system is dominant. In these situations, blood pressure and heart rate decrease and the digestive process is active.

Stress is a psychological and physical response of the body that occurs whenever we must adapt to changing conditions, be those conditions real or perceived. Stress is commonly viewed as a frustrated "fight or flight" response. It arises when individuals perceive that they cannot adequately cope either with the demands being made on them or with threats to their well being (Lazarus, 1966). In an educational context, for example, if a learner perceives a situation to be threatening and believes the situation is beyond their ability to cope, then that learner is experiencing stress. The learner might feel helpless, frustrated and then automatically "downshift" into the limbic system, the most primitive part of the brain (Caine & Caine, 1997).

Chapter II

Survey of Related Literature

The discussion of neuro-cognitive processing was taken from literature in the fields of neuropsychology, neurocognitive sciences, neuroanatomy, neuropharmacology and neurophysiology. Related literature was derived, not only from these areas, but also from the areas of music therapy, educational psychology, biofeedback and neurofeedback. The literature discussed was selected based on its pertinence to the research conducted in this project demonstrating excellence (PDE), particularly as it related to neuro-cognitive processing.

Biofeedback and Neurofeedback

The fields of biofeedback and neurofeedback were born as a result of classic experimentation conducted by a group of prominent researchers that included: Barry Sterman, Elmer and Alyce Green, Tom Budzynski, Joel Lubar, Valdeane Brown and Eugene Peniston. Sterman (1969) was the first to recognize that cats operantly trained to augment the amplitude of *sensory motor rhythm* (SMR) levels were able to preclude chemically induced seizures, and cats without such training were not able to preclude them. This finding played a significant role in the application of nonmedicinal methods and procedures by psychotherapists in the treatment of seizure disorders in humans. In addition, the finding suggested that if the autonomic nervous system could be relaxed to such a degree that seizures were precluded, then this degree of ANS relaxation might also be useful in the treatment of stress related and neurogenetic disorders such as ADHD, stuttering, Tourette syndrome and Raynauds disease.

Green and Green (1974) introduced the relationship between alpha/theta training and accessing altered states of consciousness. That is, if an individual could comfortably remain in the alpha/theta brainwave frequency, then a number of physiological advantages were possible. As an example, a yogi from India was locked in an airtight three by three-foot box, in the lotus position, for a period of eight hours. The yogi did not suffocate because his breathing rate slowed to less than four breaths per minute, he vasoconstricted from his extremities and, during this time, he produced alpha brainwaves almost continuously. In another report that may demonstrate the psychotherapeutic utility of alpha/theta training, when a theta mode of 4.5-7.5 hertz was maintained, subjects were able to enter an altered state that could promote the emergence and therapeutic release of negative, repressed childhood memories, or the appearance of archetypal images that would offer subjects useful, life-changing advice (Budzynski, 1999).

Budzynski (1973) is remembered for his ‘twilight learning’ experiments, and for his study of cognitive abilities associated with the theta state. He discovered that as individuals grew drowsier, their brain waves gradually shifted from high-amplitude alpha to low-amplitude theta--the ‘twilight state’ (4.5-7.5 hertz). Budzynski reported that subjects learned more quickly when the material was presented to them while they were in the ‘twilight state’. Later, Budzynski (1978), created the Twilight Learning System. In this system, prerecorded information was presented that got louder as subjects reached the theta state, in order to prevent them from falling asleep (Robbins, 2000). Subjects remained relaxed during the learning process and demonstrated higher retention levels as a result.

Lubar (1972) pioneered studies in modifying *sensory motor rhythm* (SMR) levels to preclude seizures, and he demonstrated that there are differing theta/beta ratios among attention deficit disorder and non-attention deficit disorder populations. In the mid-70's, he pioneered the application of neurofeedback training in the treatment of learning and attention problems. Later, he suggested that benefits obtained through neurofeedback might be long-term for many and, in some cases, permanent (Lubar, et al., 1995).

Peniston (1989), a researcher in alpha/theta training, found that depression and poorly synchronized brainwaves were associated with alcoholism and post traumatic stress disorder (PTSD). According to Peniston, using neurofeedback for prolonged periods of time resulted in relief from depression, established synchronization of brainwaves, and decreased the relapse rate. Regular, daily relaxation training was shown to be more effective than traditional treatment methods (Robbins, 2000).

Researchers Boyd and Campbell (2000) reported on the efficacy of neurofeedback as a treatment of ADHD students in a public school setting. In this study, an immediate, audio-visual display of EEG biofeedback of the intensity and amplitude of brainwave frequencies were presented to subjects in the form of Hz levels. Subjects were able to see and hear their cortical activity as it was being measured. This immediate feedback strengthened the abilities of these ADHD subjects not only to maintain, but also to reproduce particular and more productive brainwave frequencies. It has been demonstrated that students with ADHD, who have acquired the ability to alter their brainwave activities, can maintain frequencies that allow them to focus and pay attention in class (Brown, 1997).

The neurophysiological response to stress includes a variety of distinct features. Brown (1997) introduced an EEG neurofeedback protocol that he used to teach subjects to respond to stress-provoking stimuli in a manner that was relaxed, instead of the typical, *autonomic nervous system* fight-flight response. Features characteristic of stress-related disorders, such as sleep problems, migraine headaches or attention difficulties can negatively effect the ability of an individual to learn. In a neurofeedback treatment study, within six to ten sessions of neurofeedback for the treatment of sleep disorders, each of those treated demonstrated improved sleeping habits. Improved sleeping habits can contribute to improved concentration. (Hughes, 1999).

Using beta brainwave training, Siegfried Othmer found average increases in IQ of up to 23 points for subjects with IQ's greater than 100, and up to 33 points for subjects with IQ's less than 100. Clearly, the Othmer, Lubar, and Greens studies have demonstrated the potential improvements in cognition and areas of retention with the use of neurofeedback (Kennerly, 1996).

Neurophysiological Disorders

It has been found that in those diagnosed with ADHD, information designated for the declarative memory system in the brain apparently does not follow the same neural pathway as it does for those without ADHD (Carter, 1998). For normal individuals, signals are first assimilated into the thalamus, then the amygdala, the hippocampus, and finally to the frontal lobes of the brain, where nontraumatic data or memories are stored in story format. Those with ADHD tend to store nontraumatic data or memories in an iconic format and by a different route. That is, signals are first assimilated into the thalamus, and then to the amygdala, where certain stimuli are given significance by means of varying degrees of intensity of emotion associated with that signal. Upon reaching the hippocampus, however, the signals appear to be sent to the parietal and occipital lobes, instead of the frontal lobe, and stored in an iconic format (Van der Kolk, 1993). It may be that when ADHD learners demonstrate low frequency, desynchronized activity in the frontal lobes, they may actually be accessing the iconic memory area. Accordingly, those with ADHD or other language disorders may have greater difficulties remembering information, as compared to those without such disorders, when they are being taught in a traditional, story-book format.

Using SPECT scans, Amen (1997) consistently found that 65% of those in the ADHD study group demonstrated decreased perfusion in the prefrontal cortex when subjected to intellectual stress, while only 5% of those in the control group experienced a decrease. Lubar and Amen (1997), using both quantitative EEG and SPECT scans showed that hypoactivation of the prefrontal lobes and medial central cortex tends to regularly occur, particularly during intellectual or academic stress tasks. They also found that as those with ADHD attempt to increase their level of concentration or performance, their cortical metabolism tended to decline. Comings (1997) using a form of stress management, appears to have created physiological changes within the brain that produced concomitant improvements in learning. The learning improvements, he believes, is a function of "having some control over stress prevents it from having an untoward effect on the brain dopamine receptors."

Evidence from electroencephalogram research suggests that those studied who had slowing in the right prefrontal lobes showed difficulties with impulse control and inappropriate actions in social situations, but good organizational skills. Conversely, those studied who had slow frequencies in the left prefrontal lobe showed poor organizational skills, but behaved more appropriately in social settings. The research also noted that children with right posterior parietal slowing were lethargic, hypoactive and often complained of being bored (Lubar 1999). In another study, individuals diagnosed with ADHD were found to have excessively slow brainwave activity (Lazzaro et al 1999). That is, alpha /theta waves predominated while their eyes were open, and while they were attempting to be academically productive (Lubar, 1999). While their eyes were open, they were also found to have excessively high midrange beta activity, a condition thought to be indicative of hyperactivity or obsessive thinking (Brown, 1997). These abnormalities in brainwave activity can inhibit productive learning, focused concentration and behavioral self-control. An examination of more than 800 children documented that the right side of the brain in boys with ADHD was 8% smaller than that of boys without ADHD (Giedd, 1994). Also, those with ADHD, male and female, have been shown to predominantly use the right hemisphere for learning (Stefanatos, 2001). The right hemisphere, although superior for higher functioning thought processes, is not ideal for rote memorization, the usual form of teaching in most educational systems (Goldberg & Costa, 1991). To best benefit from the activities of the prefrontal lobe, where most cognitive learning takes place, it is imperative that both hemispheres are stimulated simultaneously. Using audio-visual stimulation to accomplish this, Carter (1995) found a significant improvement in both cognitive and behavioral functioning among the subjects he examined.

Music as Therapy

In 1665, while working on the design of the pendulum clock, a Dutch scientist, Christian Huygens found that when he placed two such clocks on a wall in close proximity, and then started the swing of each of their pendulums at different rates, they would eventually end up swinging at the same rate. In physics, this phenomenon is known as vibratory resonance or resonant entrainment. Entrainment is the tendency for two oscillating bodies to lock into phase in such a way that they vibrate in harmony or, for two or more rhythmic cycles to eventually move into a state of harmonic synchrony. The resonant entrainment of oscillating systems is a well-understood principle within the physical sciences. For example, if a tuning fork designed to produce a frequency of 440 Hz is struck (causing it to oscillate) and then brought into the vicinity of a second 440 Hz tuning fork, which is still and has not been struck, the second tuning fork will begin to oscillate. The first tuning fork is said to have entrained the second or caused it to resonate. Everything in physical reality vibrates. Light, color, sound, even molecules! Entrainment as a phenomenon, manifests in all manner of physical events: from biology to chemistry, and from astronomy to interpersonal relations. For example, among normal and healthy couples during sleep, it is not uncommon for their hearts to pulse in synchrony or for them to breathe in unison for intermittent intervals. Nor is it rare for such couples to experience simultaneous orgasms during their most intimate moments. Similarly, in situations involving groups of women living in the same household, these women, if they are attentive, frequently discover that their menstrual cycles eventually begin to coincide (Larry Gindhart, Personal Communication, March 31, 2002).

Music, having everything to do with vibration and as a component of physical reality mediated by the amygdala, can have compelling effects on the limbic system, the most primitive portion of the human brain (Hoffman, 1997). Researchers from within the discipline of music therapy have experimented with such things as increasing the speed of the beat in pieces of music played to a group of factory workers that had the result of increasing production. These effects also examined by researchers in the Muzak experiments. These researchers have posited that particular psychoemotional experiences can be created as a function of particular musical forms particularly having to do with rhythmic tempo, tone and timbre, i.e., musical forms that cause patients to relax while waiting for an appointment in a physician's office, or one that causes a group of strangers in an elevator to feel calm (Charnetski 1998). Brainwave frequencies typically entrain, or become vibrationally resonant. This is to say that they will slow down and come into pace with slow-pulsed music when presented, accelerate and come into pace as a result of experiencing a quicker beat, or even to become irregular, just as the heart becomes, when presented with something like ghetto-style, rap music. Interestingly, there appear to be other cognitive functions that can be influenced by musical attunement. One is the "The Mozart Effect." This effect has been reported to enhance the capacity for spatial reasoning when music was generated at a 60 beat per minute interval (i.e., Mozart's *Sonata for Two Pianos in D Major)* (Campbell, 1997).

It has been said, "As our world gets faster and more crowded, our music must get slower and more spacious in order to make peace with the biological clock" (Lanza, 1994).

Neuroscience

Experimentation in the field of neuroscience has been conducted to discern not only the relationship between learning and memory, but also ways in which interactions between these processes might generate learning and memory problems, and then to discover remedies that might ameliorate these difficulties. Filley, Cranberg, Alexander and Hart (1987) found frontal lobe injury was associated with two separate deficit patterns. The first pattern involved a state of over arousal that was characterized by inattentiveness, irritability, hyperactivity, implusivity, inappropriate behavior and aggressiveness. The second pattern involved a state of under arousal that was characterized by apathy, lethargy, poor motivation, and social withdrawal. The prefrontal lobe of the cerebral cortex is predominantly responsible for deliberate, intentional planning (Miller, 1999). Neuro-cognitive specialists agree that it is imperative to access the prefrontal cortex in order for productive thought to occur. Researchers have reported that either alternately activating the prefrontal cortex of each hemisphere, or simultaneously activating the prefrontal cortex of both hemispheres, will result in an increase in cognitive abilities (Springer & Deutsch, 1993).

Neural Plasticity

Dendritic arborization is the term for the process of the branching of dendrites from the soma (or, the neuron body) and its connections, to other neurons. It is the interconnectivity of the branching that defines its pattern of activation or its function. *Neural plasticity* is the capacity for dendritic arborization to reoccur, to alter, to regrow or to otherwise produce a new arborization after a localized event such as a stroke that may have destroyed a local area of neurons or severed a local dendritic arborization due to trauma. Dendrites are part of the neuron but they are not contained within cells. Instead, they exist between cells and are the links and terminals through which neurons intercommunicate (Levine, personal communication, 2002). Neuroscientists have reported that they can discern changes in the brain's physical shape and size relative to the extent of dendritic arborization in an individual (Jensen, 1999). Neuro-cognitive specialists concur that by presenting a variety of stimuli in a learning context, such diversity can enrich the production of dendritic arborization (Jensen, 1999). Kandel and Hawkins (1992) presented a review of evidence that short-term synaptic changes associated with simple forms of learning were accompanied by molecular modification of neuroproteins.

Dominant vs. Holographic Hemispheric Functioning

The differential function of each of the hemispheres of the brain has been extensively researched and discussed. These discussions have given rise to two notions: 1) that each hemisphere has distinct characteristics that make one more suitable for some functions and not for others, and; 2) that one hemisphere will predominate over the other in service of optimally performing specific tasks. Springer and Deutsch, (1997) indicated that the phenomenon of cerebral dominance exists because each hemisphere has its own cognitive style. The cerebral dominance model of hemispheric functioning suggests that although one hemisphere might be dominant at a particular moment in time, there is a profoundly complex intercommunication-taking place between each of the hemispheres such that each "knows" what is going on within the other. It is the corpus callosum, a broad band of nerves interconnecting the two hemispheres, that provides this pathway of hemispheric intercommunication to such an extent that "carbon copies" of the activities of each hemisphere is transmitted to it's counterpart in a timely manner. The callosal fibers are also utilized for one hemisphere to become dominant over the other, while at the same time, keeping the nondominant hemisphere appraised of its activities (Talbot, 1992).

Cook (1984) recognized that a "mirror-image negative relationship" could exist between the two hemispheres. In other words, "callosal homotopic inhibition allows the 'two brains' to momentarily hold different perspectives on the same information." In the early 1970's, "Bribram found evidence that the visual system worked as a kind of frequency analyzer, and since frequency is a measure of the number of oscillations a wave undergoes per second, this strongly suggests that the brain might be functioning as a hologram does" (Talbot, 1992). The holographic model of the brain suggests that the hemispheres may operate simultaneously and in concert, instead of oppositionally, as the cerebral dominance model postulates. If the whole brain can engage both hemispheres simultaneously, given functional hemispheric specialization, then holistic, multidimensional thought can occur.

Stress, Brainwaves and the Learning Environment

Suppressed, asymmetrical brainwave activity, as shown through EEG neurofeedback, is often detected in individuals who experience chronic stress (McIntyre, Trullas & Skolnick, 1988). Suppressed brainwave asymmetry is indicative of a disruption in cerebral homeostasis, characterized by an asymmetry involving higher amplitude of cortical activity predominant to one hemisphere. Such asymmetry is often associated with immune deficiencies. Individuals with such deficiencies tend to be prone to migraine headaches, Raynauds disease, hypertension and sleeping disorders (Brown, 1998). Biofeedback and neurofeedback therapists have found that through neurofeedback training, individuals with asymmetric, homeostatic disruption--fundamentally, a stressed and imbalanced central nervous system--can learn to balance the amplitudes of cortical activity in both hemispheres with the result of decreasing stress and boosting the immune system.

Slow cortical activity (3-5 Hz) is generally indicative of emotional reactivity (Brown, 1997). Symmetrical rhythmic surging, or bursts of uncontrolled cortical activity sometimes accompanies low-frequency cortical activity. Such reactivity often manifests as temper fits or emotional outbursts in individuals diagnosed with Oppositional Defiance Disorder or Bipolar Disorder. Brainwave frequencies in the theta (4-8 Hz) range can have similar untoward accompaniments. EEG studies have found that the same kind of rhythmic surging noted above can also occur in the theta range. It is believed that when frequency surges of significant amplitude are dominant in the hippocampus prevalent emotions of fear, anger, lust and jealousy are present. The hippocampus provides these emotions and it is found beneath the temporal lobe, (Turkington, 1996). Behavioral outcomes from these surges include patterns of aggression, low frustration tolerance and exaggerated sexual drives. The hippocampus is the also the area of the brain that as consistent controlled cortical activity occurs produces meditative states, tender emotions, and creativity. In order for an individual to attain this controlled cortical activity it is typically coupled with fast frequency gamma waves (38-42 Hz) present in the frontal lobes, that stimulate attention, and conscious perception (Desmedt & Tomberg, 1994). When the frontal lobe is suppressed, the primitive limbic system can become predominately active. As stress increases, access to the pre-frontal cortex decreases and is replaced by access to the limbic system. Taken together, these conditions result in a marked lack of cognitive control (Caine & Caine, 1997). In summary, chronic stress can inhibit the prefrontal cortex from becoming active (Mizoguchi et al., 2000). The frontal lobe and the hippocampus control the autonomic nervous system (Restak, 1989). Slowed brainwave activity, combined with reduced frontal lobe activity, inhibits the capacity to learn and it produces a "fight or flight" response due to a perceived inability to cope. The less activity there is in the pre-frontal cortex, the greater the feeling there is of being out of cognitive control.

The heart pumps blood through the body at pulse rates and with corresponding pressures that vary relative to prevailing circumstances. These phenomena parallel activities in the brain, except that, instead of variations in pulse and pressure, the brain exhibits variations in oscillations of waveforms and frequencies. Writings in the science of EEG neurofeedback have attributed particular states of consciousness to particular ranges of cortical activity. The following is a summary of brainwave patterns, ranging from the slowest to the most rapid, and the states of consciousness attributed to these patterns as described in these writings (Robbins, 2001). Delta: 0.5-3.5 Hz. associated with both deep and comatose sleep. Theta: 4.5-8.5 Hz. associated with cognitive over-reactivity and archetypal imagery. Alpha: 8.0-11.5 Hz. associated with *rapid eye movement* (REM) sleep, relaxation and engaged thought. Slow Beta: 12-18 Hz. associated with a sensory motor response (SMR) indicative of accelerated learning, of resting, and of alert awareness (Robbins, 2001). Beta: 15-38 Hz. associated not only with anxiety and hyperactivity, but also with "drudging and mulling" (Brown, 1997). Shear Beta: 38-42 Hz. associated with high levels of invigoration, stimulation and the creation of new levels of conscious awareness (Vanderwolf, 2000).

Stressors can be considered equally as beneficial or detrimental depending on perception. Stressors perceived as a challenge, or an urge toward positive development, can have a stimulating, productive influence. Conversely, stressors perceived as so threatening that they are beyond one's ability to cope, create a state of helplessness and that causes a "downshift" into the brain stem, wherein resides the limbic portion of the brain (Caine & Caine, 1997). The brain stem, which contains the primitive limbic system, is the oldest and smallest region in the human brain. Medical science refers to this 200 million year-old area of the brain in mammals as the *mammalian brain,* owing to the mechanisms that make these entities, mammals and not reptiles. Evolutionary science, however, refers to this area in humans as the *reptilian brain*, because it is so resembles the entire brain of present-day reptiles. The cells in the brain stem determine the brain's general level of alertness and regulate the vegetative processes of the body such as breathing and heartbeat. This area of the brain, although without the capacity for language, nonetheless controls life functions such as the autonomic nervous system, breathing, heart rate and the fight or flight mechanism. Lacking language, its impulses are instinctual and ritualistic. The brain stem is fundamentally concerned with survival, physical maintenance, hoarding, dominance, preening and mating. It is also concerned with emotions, as it is the emotional part of the brain. It houses the *amygdala*, *hippocampus* and the *cingulate gyrus,* all of which allow relatively direct and minimally filtered access to memories and emotions (Turkington, 1996). For example, olfactory sensory stimuli provide excellent examples of direct, minimally filtered access to memories and emotions. The aroma from a particular recipe of freshly baked cookies, the smell of new mown grass, the fragrance of a certain variety of flower can transport one into vivid memories, replete with age-specific emotions contained within the memory---from Grandma's kitchen, to cutting the lawn for the first time, to pinning on flowers for the senior prom. Although the preceding examples are positive, for most people, the process works in the same way for accessing negative memories and emotional experiences. The mechanism is the same for both, but the content varies in accordance with idiosyncratic associations.

Insofar as most educators do not have access to EEG neurofeedback data about their students, they do not have access to the information described in the foregoing discussion that could be of aid to students who are struggling with their schoolwork. Stress in the learning environment can range from being unable to recall information when called upon to recite, to being unable to adequately form one's pre-verbal thoughts into language. The classroom environment and the response of classmates to one's difficulties often sets the scene, not only for the student's behavior and self-perception, but also for which area of the brain, for better or for worse, is activated (Jensen, 1999).

Neuro-Cognitive Processing

The application of EEG neurofeedback, supported with language processing and academic coaching, created an environment conducive to new learning as well as to improvements in the retention and retrieval of learned information. These improvements were documented by measures of neuropsychological, cognitive and neurophysiological changes that included improved sleeping habits as early as the fifth session, and improved retention capabilities, inner focusing abilities and gradual improvements in grades by the 20th session. According to most professionals in the field of EEG neurofeedback, twenty-to-thirty sessions are generally required in order to establish effective reconditioning (Brown, 1997).

The use of neuro-cognitive coaching in combination with EEG neurofeedback--a guided form of brain training--is predicated on the notion that this combination can assist students to achieve holistic, multidimensional patterns of thinking. For most people, music predominantly stimulates the right hemisphere. However, if a piece of music is accompanied by appropriate sound frequencies, preplanned rhythmic and dynamic variations, the left hemisphere can be equally engaged with the result of a more wholly integrated brain response. One example of this is Monroe's Hemi-Sync process. Monroe experimented with a variety of frequency signals that he subsequently codified and then developed into sets of auditory frequencies that have been able to consistently produce distinct, specific hemispherically synchronized states within those who listened to these Hemi-Sync sound tracks. These tracks are comprised of music, and specifically designed audio frequencies in combination with binaural beating (Atwater, 2001).

Once the configuration of an individual's optimal brainwave learning frequencies has been accurately identified, by means of electroencephalogram neurofeedback and neuro-cognitive processing measurements, rhythms, audio frequencies and dynamics can be intentionally employed to modulate that individual's brainwave activity towards its most efficient range.

Chapter III

Methods, Procedures and the Meridian Academy of the Arts

Pedagogy is the art of educating. The pedagogical foundations upon which the Meridian Academy of the Arts Elementary and Middle School was built came from methodologies established by three innovative pioneers in the field of education.

The Meridian Academy of the Arts (MAA) was founded in 1988, by Lise' DeLong (the author of this document). She crafted a curriculum derived from Maria Montessori's approach of learning through hands-on experiences, to Rudolf Steiner's approach of a student-directed creation of individualized curricula, to that of Shinichi Suzuki's approach of "learning through love." To these three methodologies, DeLong contributed a fourth. DeLong's approach was to create individualized learner curricula in a stress-reduced, arts-based educational environment. Such an environment would provide the latitude for learners to progress at their own individual rates and use styles of learning characteristic to, and optimal for, their own, unique natures.

The educational environment at Meridian Academy has not been focused on grades, tests, textbooks or competition. Instead, it was designed to instill sufficient levels of self-confidence in learners that allow them to become intrinsically directed and motivated. The reduction of stress in this learning environment has resulted in an educational program that is rich in academic successes. Beyond this, the work of the learners is self-directed and intrinsically motivated. Such internally driven accomplishments have given rise to remarkable levels of personal pride and high levels of maturity among MAA learners.

Neuro-cognitive coaching coupled with EEG neurofeedback training in the controlled learning environment, of Meridian Academy of the Arts were presented to learners both with and without language disorders. It was proposed that a regimen of neuro-cognitive coaching and EEG neurofeedback would be able to achieve the desired “shift” from limbic system access to frontal lobe access, thereby stimulating the amygdala and hippocampal regions of the brain and providing a fertile foundation for academic growth.

The purpose of this study was to ascertain any measurable differences in academic outcomes for two groups of learners enrolled in a creative arts educational setting that utilized a self-directed, stress-reduced, and individualized curriculum. One group would receive EEG neurofeedback and neuro-cognitive coaching while the other group would not. Twenty-four learners were randomly selected from the body of enrollees at MAA, and then randomly assigned to one or the other of the study groups.

The Meridian Academy has established a learning environment that is noncompetitive, and a curriculum that is non-tested and non-graded. Such a curriculum is defined by Caine (1997) as stress-reduced. All learners in this study participated in MAA's stress-reduced, arts-based learning environment that included music, dance, drama, literature, and the visual arts. Half of the learners received EEG neurofeedback and neuro-cognitive coaching in an individualized, one-on-one therapy program.

In this study, the methods used for neuro-cognitive coaching included playing auditory processing, visual processing, language comprehension (both verbal and receptive), and eye-hand coordination games. Visual and auditory processing have been consistently documented as areas that neurofeedback can enhance. Similarly, levels of improvement can also be expected in memory, concentration, focus and listening skills.

The Neuro-Cognitive Coach:

A neuro-cognitive coach utilizes a specific protocol and adjusts its content within each session according to the cognitive needs of the learner. This approach can be thought of as an ongoing process of interactive, therapeutic analysis.

Experimental Group	**Control Group**
MAA with Additional Cognitive Games, Neuro-Cognitive Coaching & Neurofeedback	*MAA without Neuro-Cognitive Coaching & Neurofeedback*

Comparison of Groups

Common to Both Groups	
Brain Gym Activities	Association Games
Auditory Sequential Memory	

Exclusive to the Neurofeedback Group	
Auditory Reception Games	Semantics Games
Pragmatic Games	Specific Reading Activities
Sign Language	Visual Memory Games
Specific Phonological Games	Stress Reduction Techniques
Music Therapy Activities	Hemi-Sync, Binaural Beats CD

Research Design

Population:

The population of the study was a random sample of twenty-four learners with and without Language Disorders, from the private school, Meridian Academy of the Arts.

All twenty-four study participants attended classes with the following characteristics: 8-10 students per multi-age and multi-academic level classroom, a self-directed curriculum with facilitator supervision, an individualized academic program, and non-graded and non-tested learning activities derived from individual interests and adapted to each learner's developmental skill level.

Data were collected on the performance of all of the learners in each of the groups as they participated in MAA's stress-reduced, creative arts curriculum. Data collected from the performance of participants in the EEG neurofeedback and neuro-cognitive coaching group was compared to data collected from the performance of participants who did not experience EEG neurofeedback or neuro-cognitive coaching. The following conditions were taken into account in the process of evaluating the data. A random sample of twenty-four study participants was selected from the total of thirty learners who were enrolled at The Meridian Academy of the Arts in Greenwood, Indiana.

Standardized tests were administered in order to measure changes in specific areas of language development including auditory and reading skills, and to evaluate global improvements in academic achievement. The findings from these tests were evaluated for the purpose of discerning whether or not any significant differences in rates and levels of language development or academic achievement occurred between the two groups during the course of this study.

Hypothesis

The following hypothesis was formulated to guide the analysis and to direct the treatment of the problem.

Learning in two designated language areas (reading and listening) as well as overall improvement in academic achievement will be significantly higher for learners in a creative arts curriculum who are exposed to neuro-cognitive coaching and EEG neurofeedback than it will be for other learners, in the same curriculum, who are not exposed to neuro-cognitive coaching and EEG neurofeedback.

Basic Assumptions

1. Participants in the EEG neurofeedback and neuro-cognitive coaching group can learn to shift their brainwave frequencies from an undesired alpha/theta state to a desired beta state in a manner that is consistent and under their own voluntary control.
2. Performance in the classroom learning environment will reflect greater improvements for the neuro-cognitive coaching and EEG neurofeedback group, when compared to performance of the control group. This difference will be attributed to their improved ability to focus and to concentrate as a result of being exposed to neuro-cognitive coaching and EEG neurofeedback. Performance differences between the two groups can be measured by standardized tests.
3. Neuro-cognitive coaches can utilize specific activities during their sessions with study group participants that are known to produce desired beta brainwave states and, by these means, facilitate the likelihood that these participants will achieve their educational objectives.

Limitations

The statistical significance of the findings from this study was difficult to determine due to the small sample size (N=24). It was determined that a larger study group would have provided a more comprehensive body of data that would have resulted in a greater degree of statistical significance, (see p. 57). During the course of this study, Meridian Academy of the Arts Elementary / Middle school had an uncharacteristically low enrollment in the upper grades. Enrollment was higher than usual in kindergarten and first grade. Accordingly, there was an increase in younger study participants than initially expected, particularly during the second semester of the research, in the neurofeedback study group.

For both semesters, the ages for all study participants ranged from 6 to 15. The mean age for all semester 1 participants and for all semester 2 participants was 9. The mean age for the neurofeedback group was 10.12 for semester 1 and 8.7 for semester 2. The range for this group was: 7 to 15 for semester 1 and 7 to 10 for semester 2. The mean age for the control group was 7.8 for semester 1 and 8.2 for semester 2. The range for this group was: 6 to 13 during both semesters.

MAA is located in a growing rural area, just south of Indianapolis, Indiana. Although there was little socioeconomic diversity among those enrolled (because MAA is the most expensive private school in the area), there was moderate ethnic diversity.

Purpose of Study

The purpose of this pilot research was to document changes in academic outcomes related to changes in brainwave frequencies among participants in an EEG neurofeedback and neuro-cognitive coaching group who would learn to consistently shift their brainwave frequencies from an undesired alpha/theta state to a desired beta state in a manner that was under voluntary control.

Outcome Measures

Academic and behavioral performance outcomes were measured for participants in the study group, who were exposed to neuro-cognitive coaching and EEG neurofeedback, and for participants in the control group who were not exposed. The architecture of the study was based on the rationale that employing a creative arts curriculum, augmented by EEG neurofeedback and language process coaching would supplement the educational experience of the broad range of elementary and middle school-aged learners who participated in the study group.

a) The study group received EEG neurofeedback training and neuro-cognitive coaching that included listening to Hemi-Sync, binaural beating CD's, in addition to the academic methodology of the Meridian Academy of the Arts.

b) The control group received only the academic methodology of the Meridian Academy of the Arts.

(Human Informed Consent form- Appendix B)

Medication:

Medication usage was monitored and documented. A decrease in medication use was charted as the study progressed. Only one study participant, however, was on medication.

Gender:

There were equal numbers of female and male participants.

Other Therapies:

Students were restricted from participating in any other type of therapy during the research period. This restriction applied particularly to: auditory integration therapy, vision therapy, FastForward therapy, speech and language therapy, cranio-sacral therapy and light and sound therapy.

Profile:

Table 1 Profile Matrix by Gender, Age, Semester and Special Needs

First Semester			Second Semester		
Gender	**Special Needs**	**Age**	**Gender**	**Special Needs**	**Age**
NF-Male	Yes	10	NF-Female		9
NF-Female		7	NF-Female	Yes	7
NF-Male		12	NF-Male	Yes	9
NF-Female		10	NF-Male	Yes	9
NF-Male	Yes	15	NF-Female		8
NF-Female		7	NF-Male	Yes	10
Con-Female		6	Con-Female		7
Con-Male		6	Con-Male		11
Con-Female		6	Con-Female		11
Con-Male		10	Con-Male		8
Con-Female		6	Con-Male		6
Con-Male		13	Con-Female		13

NF = neurofeedback group

CON = control group

Table 2 ***Study Concept Model***

Scheduling for Research Application

First Semester	***Second Semester***
3 girls & 3 boys with neuro & coaching	3 girls & 3 boys with neuro & coaching
3 girls & 3 boys w/o neuro & coaching	3 girls & 3 boys w/o neuro & coaching

Method of Random Selection

1.) The names of all thirty children enrolled in MAA, ages five through fifteen years were placed in two containers, one for each gender.

2.) An objective person was chosen to select the names of potential study participants from the two containers. Each of the gender specific containers held the names of fifteen children.

3.) The first six names drawn from the female gender container were assigned to the study group. The second six names were assigned to the control group. The remaining three names were held as alternates.

4.) This procedure was duplicated for the names in the male gender container.

5.) All study participants were given numeric identities. Names were not used to identify study participants.

6.) For any child who needed to withdraw from study participation, the name of another child of the same gender was selected as a replacement from the alternates in this same manner. One male participant did withdraw during the semester break due to his family relocating. Accordingly, an alternate was selected as a replacement.

Instruments: *The following instruments were utilized for data collection in this study.*

Table 3. ***The Pre/Post Rating Instruments***

BASC - Behavioral Assessment System for Children
Woodcock Auditory Discrimination - 2 subtests
ITPA - Illinois Test of Psycholinguistic Abilities - 3 subtests
Key Math - AGS
PPVT-III -Peabody, Revised III
Woodcock Reading Mastery Test- 3 subtests

<u>Descriptions of Instruments</u>

BASC- Behavioral Assessment for Children Monitor for ADHD

The BASC monitor is an assessment designed to survey the primary symptoms of ADHD in a format that supports repeated assessments. The system is primarily used with children ages 4-18 and it has several components. The component used in this study was a brief rating scale of a child's observable behaviors. This scale is designed for two applications, one for teachers to complete and the other for parents to complete. The scale takes into account four areas of behavior: Attention Problems, Hyperactivity, Internalizing Problems, and Adaptive Skills.

The BASC Monitor System is primarily used for treatment purposes. It provides psychologists with information that can be used in making decisions as to whether the pharmacological treatment for the child is working or whether it needs to be adjusted. This monitor system was designed to coordinate medical and nonmedical treatments, and to provide courses of helping strategies for treatment providers and caregivers, including teachers, physicians, clinicians and parents in their efforts to assist the child.

The scoring of measurement or assessment is as follows: T scores between 41 and 59 are considered *Average*; those from 60 to 69 are considered *At Risk*; and the T scores of 70 and above are considered *Clinically Significant.* "The scores are reversed on the Adaptive Skills scale, where a low score indicates the absence of positive behaviors. The size of a difference required for statistical significance is a function of the T-score standard error on that scale: the smaller the standard of error, the smaller the difference must be to be significant" (Kamphaus et. al., 1997).

Goldman-Fristoe-Woodcock Test of Auditory Discrimination

The Goldman-Fristoe-Woodcock Test of Auditory Discrimination was designed to provide measures of speech-sound discrimination ability. Created by Goldman, Fristoe, and Woodcock, the test was designed for use with individuals aged 4 through adulthood. The test is comprised of three parts: the training procedure, the quiet subtest, and the noise subtest. The training procedure familiarizes the subject with the test's word-picture associations. The quiet subtest provides a means of evaluating the acuity of auditory discrimination in the absence of background noise. The noise subtest evaluates the acuity of auditory discrimination in the presence of distracting, background noise.

This test simulates the speech-sound discrimination demands of real life. The subject is presented with a set of four pictures, where the names of each of the things depicted differ by only one phoneme. The subject selects one of the four pictures by saying its name. The distinctive sounds of the names of items pictured were classified according to four qualities of speech: voicing, stop, nasality and place of articulation. The quiet and noise subtests include six test words selected from the following: voiced-plosives, voiced continuants, nasals, unvoiced plosives and unvoiced continuants.

The test construction standardization sample was n=745 subjects, with an age range of 3 to 84 years. The results were documented by age, sex and type of test. Reliability factors were established using the spilt-half method and corrected using the Spearman-Brown formula for the internal-consistency. The test-retest reliability correlation was .87 for the quiet subtest and a .81 for the noise subtest.

Illinois Test of Psycholinguistic Abilities-revised edition

Kirk, McCarthy and Kirk were the authors of the ITPA; a test whose purposes are dual. On one hand, the ITPA was designed to serve as a tool for differentially diagnosing learning problems, and on the other, as a device to aid in creating remediation strategies. This test examines three distinct dimensions of cognitive abilities: channels of communication, psycholinguistic processes, and levels of organization. It also examines auditory discrimination competencies in several areas: the auditory decoding of auditory symbols, the auditory decoding of verbally presented information, and the auditory decoding of auditory-vocal associations.

The ITPA includes twelve subtests; Auditory Reception, Visual Reception, Visual Sequential Memory, Auditory Association, Auditory Sequential Memory, Visual Association, Visual Closure, Verbal Expression, Grammatic Closure, Manuel Expression, Auditory Closure and Sound Blending. The test uses auditory association, reception and memory to determine whether or not auditory processing improvements have taken place. The auditory association component provides an index of general knowledge associations by means of such items as: "A daddy is big; a baby is ______," or "Years have seasons; dollars have_____." The auditory reception component indicates the extent to which aural information is correctly perceived by means of posing questions like: "Do bricks float?" Or, "Do mute musicians vocalize?" As with many tests, the level of difficulty increases as the test subject progresses through the tasks. Another of this test's indices, of importance to this study, is auditory sequential memory. This index asks the question, "how many digits of information can the test subject hear, retain, and then verbally recall?" Digits are read aloud without purposeful voice inflection. Auditory sequential memory served an important role in providing an understanding of study participants' abilities in short-term memory, perception of auditory detail and organization of information recall.

***Key Math* revised (nu)**

Developed by Connolly, the Key Math test has three major components; basic concepts, operations and applications. Each of the components has several subtests. The basic concepts component is comprised of numeration, rational numbers and geometry. The operations component is made up of addition, subtraction, multiplication, division and mental computation. The applications component is comprised of measurement, time and money, estimation, interpreting data and problem solving. The total test score is determined by tallying results from all of the subtests and comparing this score to test scores of others at the same age and grade level as the test subject. The total test score was formulated through "standard scores (mean of 100, standard deviation of 15), grade and age equivalency scores, percentile ranks, stanines, and normal curve equivalents NCEs" (KeyMath, 1998).

> Key Math used a split-half internal consistency reliability estimate by correlating odd and even items. These estimates were then corrected using the Spearman-Brown correlation formula for the full-length test forms. For the areas of the total test, internal consistency reliability were computed using Guilford's (1954, p.393) formula for determining the reliability of a composite.

The Key Math test was normed on students ranging from kindergarten through grade 12 for a total of n=3,184. Gender was evenly split between girls and boys. Socioeconomic status was determined by parental education and compared to U.S. averages. Race and ethnicity factors were derived from census data collected by the U.S. Census Bureau and classified according to a stratified sample of African-American, Hispanic, White, and others. The sample was designed to approximate the distribution of socioeconomic status within each racial or ethnic group in the U.S. population.

Peabody Picture Vocabulary Test, Third Ed. (PPVT-III)

Dunn, and Dunn developed the Peabody Picture Vocabulary Test. The PPVT-III was used to measure proficiencies in nonverbal comprehension. This test is especially useful because the results it shows are not diminished if the test subject happens to have a language disorder. For this study, it was imperative to have access to an achievement test that would offer a means of evaluating study participants without the biases resulting from language disorders. The PPVT-III measures vocabulary in response to sets of four, distinct pictures. The test measures auditory reception, association, memory, attention and discrimination. Test validity was established for two functions; as a test of achievement test and as a test for screening intellectual functioning. Correlation was used in the validity study for the PPVT-III during the process of standardization. Standard deviation scores were corrected for validity using Guilford's formula (1954, p.382). Correlations were derived from counterbalancing the PPVT-III against the Wechsler Intelligence Scale for Children, the Kaufman Adolescent and Adult Intelligence Test, the Kaufman Brief Intelligence Test, and the Oral and Written Language Scales.

The Woodcock Reading Mastery Test- Revised

Woodcock, developed this test in 1987, with a variety of subtests and opportunities to score at four basic levels; analysis of errors, level of development, quality of performance, and standing in a group.

In this study, measures were derived from levels of development indicated by raw scores, Rasch ability scores (test W scores, subtest part scores, and cluster W scores), and grade and age equivalencies.

Internal consistency of reliability coefficients indicates the degree of item homogeneity within a test instrument. Reliability statistics were calculated using the split-half procedure and were corrected for length with the Spearman-Brown formula. Raw scores on the odd and even items were used in the split-half coefficient calculations. The content of the test was chosen so each item was an open-ended, free-response in order parallel reading in real-life situations. This method of response also eliminated "guessing" as a confounding factor in test validity.

Protocol:

The protocol used in this study was taken in part from Brown's Five Phase Model of Functional Central Nervous System Transformation (1997). In the study, the protocol began with a pre-test of the summation of neuronal activity; fifteen seconds eyes open, and fifteen seconds eyes closed. Assessments were conducted using the Stens, Multi-trace EEG neurofeedback system and Biograph ProComp tools. In accordance with the International 10-20 system of electrode placement, a bipolar technique was utilized with the active electrodes on C3 and C4, with both reference at Fp1 and the ground on the ear lobes. The electrode site was attached with Ten20 conductive paste for adhesive purposes while using brass standard cup electrodes.

The protocol was individualized to each participant's cognitive, behavioral or physical needs. This particular protocol gave the technician the latitude to make changes in the EEG neurofeedback experience during sessions, based on behaviors reported by parents, by teachers or by the researcher. Therefore, if sleeping problems were reported, then a fractionation of SMR and beta work would be repeated. If lethargy or a lack of focus was reported, then shear beta was warranted. Thus, a specific program was developed for each session depending on the participant's experiences and reported outcomes resulting from neurofeedback. Cognitive games and language-based activities were also modified for each session as participants learned new concepts and overcame difficulties.

Brown's protocol was arranged in the following manner and it served as a sample from which individualized programs were designed:

Table 4 ***Matrix Menu of Three Separate Periods Used in EEG Neurofeedback Therapy***

Protocol Matrix		
Period One	*5 minutes SMR training*	*5 minutes beta training*
Period Two	*20 min. Alpha w/ eyes closed Hemi-Sync Music*	*20 min. eyes open beta cognitive processing activities*
Period Three	*10 minutes Aura eyes open cognitive processing activities*	*10 minutes Sheer Beta cognitive processing activities*

Period One: Symptom resolution through re-establishing circadian rhythms:

Pre/post-sample

Five minutes of SMR

Five minutes of beta (alternate between SMR and beta for a total of three cycles)

Period Two: Self-integration through profound relaxation:

Pre/post-sample

Twenty minutes alpha, eyes-closed training (Monroe Institute, Hemi-Sync Music)

Twenty minutes beta, eyes-open training (language processing activities)

The learners with difficulty sustaining eyes in a closed position for twenty to thirty minutes due to age, attention, or maturity continued Period 1 work rather than enduring prolonged frustration of eyes closed relaxation techniques.

Period Three:

Pre/post-sample

Ten minutes aura screen, eyes open,

Ten minutes shear beta, eyes-opened, (language processing activities)

Collection of Data

The following intake forms were given to the families for our files.

Table 5

Intake Forms
Behavior Assessment System for Children
Confidentiality Form
Consent to Treatment Form
Developmental Questionnaire
Home Situations Questionnaire
Informed Human Consent Form
Permission for Research

A three-hour testing and evaluation session that involved academic and behavioral assessments, using the instruments discussed above, was conducted prior to commencing EEG neurofeedback training. The protocol, individualized and adapted on a session-by-session basis, was utilized in twenty-five sessions of therapy. All measurements were taken in a private testing room at the school. The instruments employed were designed to measure progress, or lack thereof, in the areas of auditory processing, implusivity, concentration, focus, and global academic development.

Treatment of Data

A secured computer database was used to store baseline and other pertinent information. The utmost care was taken to record information with regard to both privacy and accuracy. The data and scores were then compared for the semester 1 and 2, study and control groups. Comparisons were derived solely from the data collected, and scored with the required statistical support and documentation. The matrix of statistical analysis includes data entry units from twenty-four study participants and, for each participant, the results from each the five test instruments and associated subtests.

Parents were given an opportunity to view their child's progress from pre- to post-test. The complete findings from this research, however, will not be shown to either the participants or their parents until it has taken final form, and is published.

Chapter IV

The Analysis

The statistical analysis of the data gathered in this study examined a number of variables. A three-way analysis of variance was performed to determine the effects of: the variables that were intrinsic to the design of the study, i.e., group (control, or study), semester (1, or 2), and special needs (yes, or no), and to determine the effects of differences between pre- and post-test findings for each of the 10 outcome variables that were fundamental to the architecture of this study. These outcome variables include: Auditory Discrimination Quiet, Auditory Discrimination Noise, ITPA Reception, ITPA Memory, ITPA Association, Peabody, Key Math, Woodcock Word ID, Woodcock Attack, and Woodcock Comprehension.

Table 6

The Statistical Matrix for the Identification of Three-Way Analysis of Variance

	Statistical Matrix					
	Group		Semester		Special Needs	
Auditory Discrimination Quiet	Control	Neuro	1st	2nd	Yes	No
Auditory Discrimination Noise	Control	Neuro	1st	2nd	Yes	No
ITPA - Reception	Control	Neuro	1st	2nd	Yes	No
ITPA - Memory	Control	Neuro	1st	2nd	Yes	No
ITPA - Association	Control	Neuro	1st	2nd	Yes	No
Peabody	Control	Neuro	1st	2nd	Yes	No
Key Math	Control	Neuro	1st	2nd	Yes	No
Woodcock Word Identification	Control	Neuro	1st	2nd	Yes	No
Woodcock Word Attack	Control	Neuro	1st	2nd	Yes	No
Woodcock Word Comprehension	Control	Neuro	1st	2nd	Yes	No

This matrix divides the data into four subgroups. "A" designates the Neurofeedback study group and "C" designates the control group. "A1" designates the semester 1 group and "A2" designates the semester 2 group. The participants are designated as number "1" through number "24."

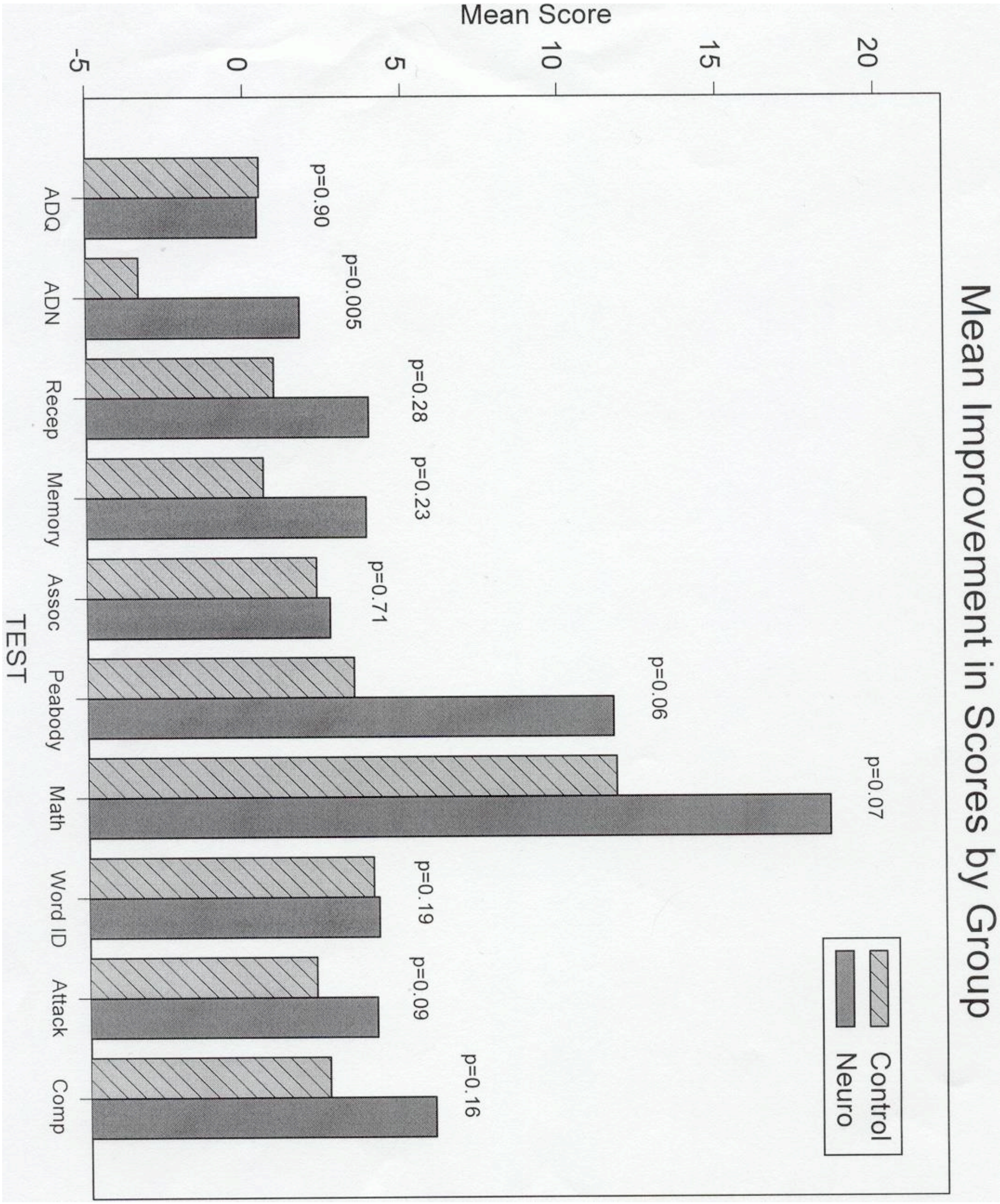
If semester and group variables were not statistically significant at the 0.05 level, then a two-sample t-test was performed to test for the effect of the group variable on the difference between the pre- and post-test scores. If the variables of either semester or special needs were significant, using the two-sample t-test, then a two-way ANOVA analysis was performed that would include only the significant predictor and the group variable.

Table 7 ***The Three-way Analysis of p-values for Group, Semester and Special Needs***

Difference	**Test**	**Special Needs p-value**	**Semester p-value**	**Group p-value**
Auditory Discrimination Quiet	t-test	C	C	0.9017
Auditory Discrimination Noise	t-test	C	C	0.0046*
ITPA Reception	t-test	C	C	0.2847
ITPA Memory	t-test	C	C	0.2349
ITPA Association	t-test	C	C	0.7060
Peabody	t-test	C	C	0.0600
Key Math	2-way ANOVA	C	0.0033*	0.0740
Woodcock Word ID	2-way ANOVA	0.0115*	C	0.1895
Woodcock Word Attack	t-test	C	C	0.0873
Woodcock Word Comprehension	t-test	C	C	0.1550

- ***= Significance with p>0.05***

- Table 8 Mean Improvement in Scores by Group



Results Achieved:

A three-way analysis of variance was performed to identify the level of statistical significance in each of the areas examined. The limited sample size (n=24), was found to be insufficient for the purpose of showing statistical significance in all areas of interest. Therefore, a two-sample t-test was employed in the analysis. Regarding the study constituent of auditory discrimination noise, this test indicated a substantial improvement in the Neurofeedback group versus the control group. Through statistical analysis of the parameters involved in the entire study, it was determined that a minimum sample size of (n=48) would have been needed in order to have documented significant statistical findings in the areas of cognition, reading and auditory processing.

The table illustrating mean improvement by group (Table 8) depicts the mean value represented for each of the ten assessment instruments used in this study. The auditory processing tests; Goldman-Fristoe-Woodcock Test of Auditory Discrimination (noise and quiet subtests in particular), and the ITPA reception, memory and association tests, showed substantial educational gains for members of the study group. These tests measure the cognitive receptive processing skills that are responsible for the comprehension of aurally presented information. Cognitive receptive processing skills are also involved in cognizance of letter order in spelling, the order of words in grammar, in executing the flow of a set of instructions or directions and in the organization of thinking. The neurofeedback group increased in these auditory skills by a factor of 2.90 over the control group. This factor indicates a 290 percent increase in listening skills for the study group, as compared to the control group.

In the area of reading skill development, this study shows that the EEG neurofeedback group increased their performance by a factor of 1.62 or 162 percent over the control group. The areas of reading that were examined included word identification, word attack and word comprehension. The Woodcock Reading Mastery Test has 6 subtests. In this study, we were concerned with the subtests that showed the greatest promise towards revealing overall reading abilities: word identification, word attack and word comprehension. Improvements in word identification scores were indicative of improvements in the ability of participants to comprehend written vocabulary. Improvements in word attack scores reflect the ability of the participant to discern, and filter out, nonsense words. Improvements in word comprehension reflect an increase of context specific knowledge of words and their meanings. The comprehension subtest did not show that the gestalt of the story was comprehended, instead, it showed that site-specific words were being comprehended. The strong gain made in this area suggests that a significant opportunity may exist for remediating illiteracy by means of the techniques utilized in this study.

The Peabody Picture Vocabulary Test (PPVT-III) measured global achievement. Results from this measure showed an overall global achievement increase in the neurofeedback group by a factor of 3.41; a rate that is equivalent to a value of $p=0.0600$. These figures represent an increase for the neurofeedback study group of 341 percent over the control group, and indicate a substantive educational improvement in a period of only ninety days. The level of results obtained when taking this test depends upon concentration levels and auditory processing skills. Therefore, it can be postulated that as auditory processing skills improved, and as mental concentration levels became more focused, participants in the study group were able to demonstrate considerable improvements in global achievement.

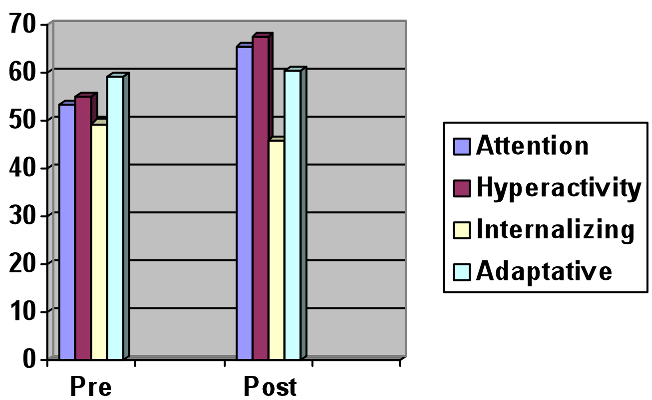
Math scores for the study group increased only by a factor of 1.57 or 157 percent, when compared to scores obtained by the control group. Improvements in math scores are often associated with improvements in global achievement. It is likely that this blend of improvements is related to developing the problem solving and reasoning skills that are demanded as a function of performing mathematical tasks.

Mathematical achievement or lack thereof is highly dependent upon the level of stress experienced by learners in the classroom. It has been demonstrated that the frontal lobe performs the “executive function” skills that are associated with solving mathematical problems. Unfortunately, stressed learners tend to “downshift” away from frontal lobe access. Such a shift is antithetical to gaining access to the part of the brain needed for solving mathematical problems. In this study, both the study and the control groups showed improvements in math scores. The margin of increase between the study and control groups was not substantive. This result suggests that, the comparable gains in math scores for both groups may be related to both having participated in a stress-reduced learning environment.

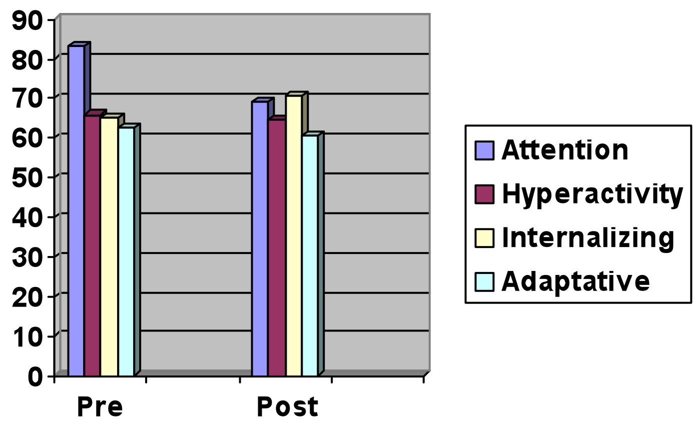
Three participants in this study had been previously diagnosed as having learning disabilities. Three additional participants, as a result of study involvement, were found to display a variety of conditions associated with special needs groups. Because of this finding, a two-way ANOVA analysis was performed on the data to determine the effect of the substantial number of special needs participants in this study. The effect was found in the Woodcock Word Identification score difference (p=0.0126). All other p-values were greater than 0.40. When comparing the groups by semester there was significance when predicting the Key Math difference in scores (p=0.0048). All other p-values were greater than 0.05. The only score affected by group was the Auditory Discrimination noise score (p=0.0046). The difference in the scores was greater for the neurofeedback group than for the control group.

The BASC monitor was completed by 19 of the 24, or 79 percent of the study's participants. The mean scores for the control group in the areas of attention, hyperactivity, internalizing and adaptive skills, were actually lower on the post-test than on the pre-test. Table 9 illustrates these results.

Table 9 **Comparison of BASC Monitor**



Control Group



Neurofeedback Group

Table 9 illustrates the mean difference among the nine participants in the control group who completed the BASC monitor documents and the 11 participants in the neurofeedback study group who completed these documents. It was expected that the elevations in the first three categories--attention, hyperactivity and internalizing--would decline to signify improvement, while the forth category--adaptive--would increase to signify improvement. Contrary to expectations, the data shows that the control group became less attentive and more hyperactive. Although they did internalize less, their adaptive skills slightly declined. The neurofeedback study group, however, showed a marked improvement in attention, a very slight improvement in hyperactivity, and a decline in internalizing while making minor progress in their adaptive skills.

Table 10 ***The statistical Means by Group for Standard Deviation and Mean***

Group	Difference	n	mean	std dev
Control	Auditory Discrimination Quiet	12	0.50	2.15
	Auditory Discrimination Noise	12	-3.33	4.08
	ITPA Reception	12	0.92	5.96
	ITPA Memory	12	0.58	6.46
	ITPA Association	12	2.25	2.05
	Peabody	12	3.42	10.52
	Key Math	12	11.75	10.74
	Woodcock Word Identification	12	4.00	4.18
	Woodcock Word Attack	12	2.17	2.72
	Woodcock Word Comprehension	12	2.58	4.40
Neurofeedback	Auditory Discrimination Quiet	12	0.42	0.79
	Auditory Discrimination Noise	12	1.75	3.82
	ITPA Reception	12	3.92	7.37
	ITPA Memory	12	3.83	6.58
	ITPA Association	12	2.67	3.17
	Peabody	12	11.67	9.86
	Key Math	12	18.50	10.48
	Woodcock Word Identification	12	4.17	9.66
	Woodcock Word Attack	12	4.08	4.08
	Woodcock Word Association	12	5.92	4.72

The results above reflect gains or declines using a traditional pre-test/post-test process and standardized test scores.

Relevant Data Were Analyzed:

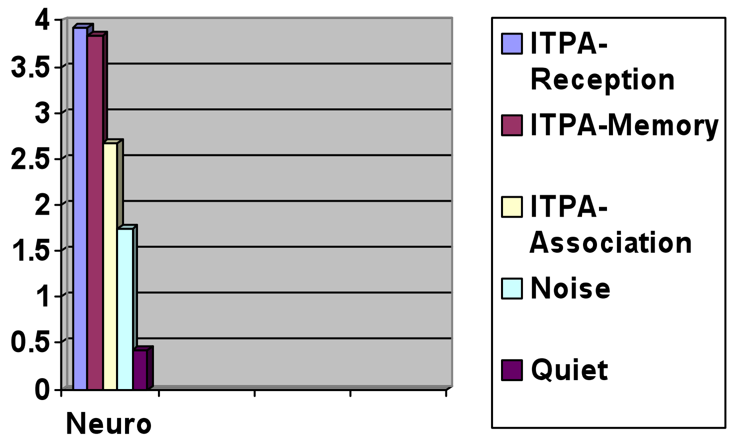
A. To determine the effects of EEG neurofeedback with neuro-cognitive processing on participants in study group of private elementary/middle school students, and;

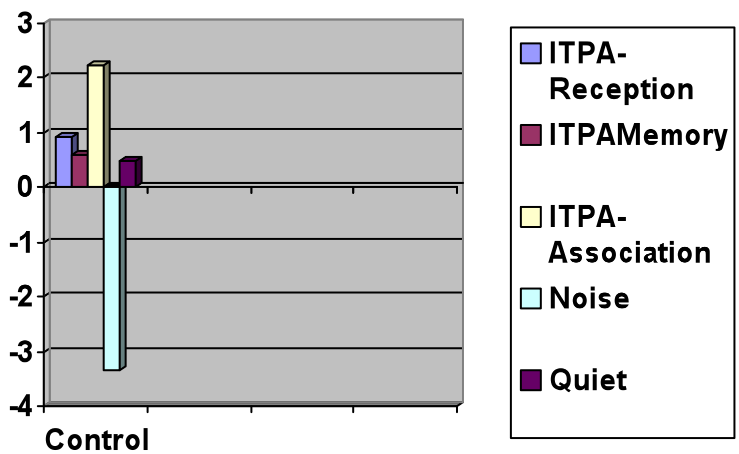
B. To compare these effects to the effects of not being exposed to EEG neurofeedback with neuro-cognitive processing on participants in a control group of private elementary/middle school students.

Table 11 ***Designated Tests Analysis***

Auditory Processing	**Reading**	**Math**	**Nonverbal Achievement**
ITPA-Reception	Woodcock Word ID	Key Math	Peabody (PPVT-III)
ITPA- Memory	Woodcock Word Attack		
ITPA-Association	Woodcock Comprehension		
Auditory Discrim Quiet			
Auditory Discrim Noise			

Table 12 ***Auditory Gain by Group***





Analysis of Auditory Processing

<u>Hypothesis:</u>

The degree of learning in two designated language areas (reading and listening), and the degree of overall improvement in academic achievement, will be greater for a group of students in a creative arts curriculum that was combined with neuro-cognitive *coaching and EEG neurofeedback, than it will be for another group of students in the same creative arts curriculum who were not exposed to neuro-cognitive coaching and EEG neurofeedback.*

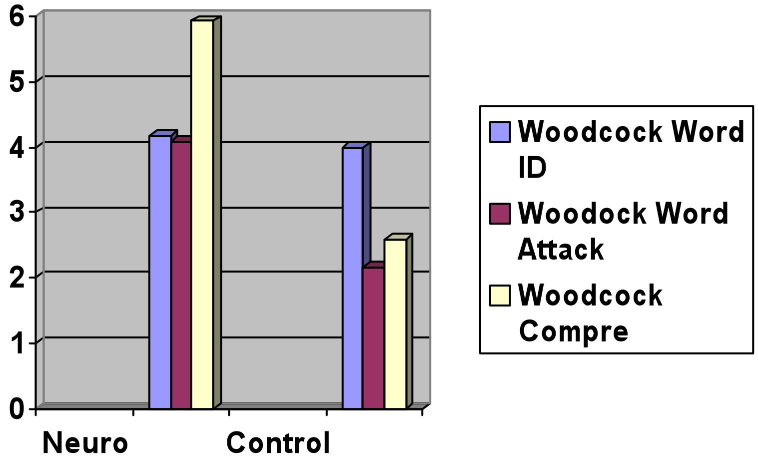
Auditory Processing Analysis:

Auditory processing tools were used to obtain information in the areas of quiet versus noise processing discrimination, auditory information reception, auditory sequential memory and auditory association skills. The results for the group receiving the neurofeedback showed a marked improvement in all raw scores compared to the results for the control group.

Results:

The auditory processing tests were not statistically significant at a 0.05 level using a three-way analysis of variance. Therefore, a two-sample t-test was performed to determine whether there was an effect of group on the pre- and post-test findings. The test found a strong significance level of 0.0046 for auditory discrimination noise.

Table 13 ***Reading by Group***



Analysis of Reading

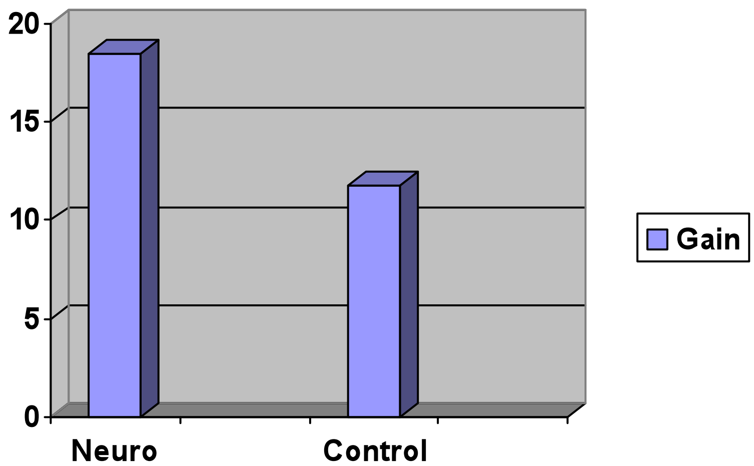
<u>Reading Analysis</u>

The Woodcock Reading Mastery instrument has three subtests that were measured in this study: word identification, passage comprehension and word attack. The raw scores for each of the three subtests were higher for the neurofeedback group when compared to the raw scores for the control group.

<u>Results:</u>

The statistically significant subtest was word identification. A two-sample t-test revealed an increase in vocabulary scores for the neurofeedback group that was significant at p=0.0126 level.

Table 14 ***Math Gain by Group***



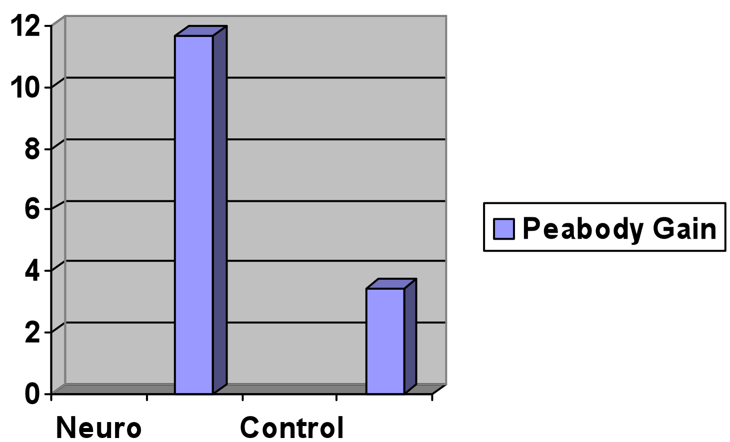
<u>Analysis of Math:</u>

The AGS Key Math is composed of three basic subtests that are made up of several, distinct components. The Basic Concepts subtest contains numeration, rational numbers, and geometry. The Operations subtest, includes addition, subtraction, multiplication, division, and mental computation. The Applications subtest contains the elements of time and money, estimation, interpretation of data and problem solving. The Key Math instrument scored each of these subtests individually and it provided a total test score. In this study, the total test score was interpreted as a global math-processing indicator.

<u>Results:</u>

The three-way analysis of variance performed on the data did not show statistical significance at the 0.05 level. As a result, a two-sample t-test was used to determine the level of difference between the study and control groups. Results from the two-sample t-test indicated that it would be necessary to perform a 2-way ANOVA. The ANOVA analysis found a significance level of 0.0033 for the total score of Key Math when comparing semesters 1 and 2 for each group.

Table 15 ***Achievement Gain by Group***



Analysis of Global Achievement

The Peabody (PPVT-III) is a nonverbal test of global achievement that was designed as a measure of receptive vocabulary. In addition, it can serve as a measure to screen verbal ability, or it can be used as one element in a comprehensive battery of tests to evaluate cognitive processing abilities.

<u>Results:</u>

The raw scores on the PPVT-III indicated a level of improvement for the neurofeedback group that was greater than the level of improvement for the control group. There was a duration of three months between the pre- and post-test. Both groups showed improvements in receptive vocabulary and academic scores. It is believed that participation in the arts-based program at MAA may have influenced this outcome. The results for the PPVT-III were not statistically significant using the three-way analysis of variance, the two-sample t-test or the 2-way ANOVA for group, for special needs, or for semester.

Total Test Effects by Group:

The Binomial Test of Distribution was used to indicate the probability of randomness between the differences in pre- and post-test scores for the control group and the neurofeedback study group. The Binomial Test of Distribution assumes the probability of getting a higher score on the post-test is the same as the probability of getting a lower score on the post-test and is, therefore, 50 percent. The probability that at least 9 out of the 10 tests would show a positive mean difference for the control group was 0.0108. The probability that all ten tests would show a positive mean improvement for the neurofeedback group was significant at the 0.0010 level. This distribution indicates that the differences found for participants in the neurofeedback study group was not randomly made, and that these differences reflected their having been exposed to EEG Neurofeedback and neuro-cognitive coaching.

The following table shows the distribution of the total number of improved scores per person within both groups. For the control group: 1 participant improved on 4 of the tests, 4 participants improved on 5 of the tests, 4 participants improved on 6 of the tests, 2 participants improved on 7 of the tests and 1 participant improved on 8 of the 10 tests.

For the neurofeedback group: 1 participant improved on of the 5 tests, 2 participants improved on 6 of the tests, 4 participants improved on 7 of the tests, 1 participant improved on 8 of the tests, 3 participants improved on 9 of the tests, and 1 participant improved on all ten of the tests.

Table 16 ***Total Distribution of Test Improvement by Individual***

Number of Tests Showing Improvement	**Control**	**Neurofeedback**
1	0	0
2	0	0
3	0	0
4	1	0
5	4	1
6	4	2
7	2	4
8	1	1
9	0	3
10	0	1

For the 10 basic tests, the control group had a pre- and post-test mean improvement of 5.83, and the neurofeedback study group had a mean improvement of 7.5. The Mann-Whitney Test showed that the mean for the neurofeedback study group was statistically significant at the p=0.0087 level. This level of significance is suggestive of the power of neurofeedback as a means of facilitating the ability to perform on these 10 tests. Any concern about random increases on these tests due to a semester effect, to an increase in maturity effect during the three-month, pre- and post-test period, or to an age distribution effect should not be of consequence because the Binomial Test of Distribution and the Mann-Whitney Test were applied to the data in order to compress the value of random improvement.

Chapter V

Discussion

The findings from this study suggest that the combination of EEG neurofeedback and neuro-cognitive coaching increased auditory discrimination skills and enhanced overall academic achievement for participants in a study group who ranged in level from first through eighth grade. Improved auditory discrimination skills may be indicative of increased attention and focus as a result of experiencing EEG neurofeedback training and neuro-cognitive coaching.

Integration of Current Findings with Prior Literature

The findings of this study are consistent with the findings of many studies in the literature that indicated attention and concentration can be improved through the use of EEG neurofeedback. As Barry Sterman discovered in 1965, there exists a state-of-mind, evidenced by a particular brainwave frequency range (12-15 Hz), that is characterized by a simultaneous condition of alertness and stillness (Evans & Abarbanel, 1999). Sterman named this frequency range Sensorimotor Rhythm (SMR) because of the sensorimotor cortex activity associated with this condition. He observed that, with the accompanying motor stillness, there is a distinctive, EEG sleep-like "spindle" that is induced while awake (Robbins, 2000).

The primary training used in the protocol for this research was built upon Sterman's SMR findings. The initial sessions of neurofeedback followed a five-minute fractionation of 12-15 Hz SMR activity, interchanged with five minutes of 15-18 Hz. beta activity. The results of the training for participants in this study were similar to that reported by Sterman; namely, the condition of a relaxed body and an alert mind.

The results of Joel Lubar's studies indicate that children diagnosed with Attention Deficit Hyperactivity Disorder can benefit from neurofeedback training because it improves concentration skills and increases focusing abilities while completing tasks (Evans & Abarbanel, 1999). Lubar was the first researcher to report that EEG neurofeedback not only decreased impulsivity and distractibility in students but also that it raised their IQ scores by as many as ten to fifteen points (Robbins, 2000).

The findings from this study concurred with those reported by Lubar. Academic performance levels for each of the study group participants increased by several years. Their ability to focus attention in the classroom also increased. A possible explanation for the increase in the ability to focus attention can be attributed to a significant improvement in auditory discrimination skills due to neurofeedback training and cognitive coaching. Further, the findings suggest that the increase in academic performance could be attributed to the newly-developed ability to maintain a focus of attention for extended periods, thereby allowing the study group participants to perform better on the post-test.

The combination of neuro-cognitive therapy activities with academic enhancement games may also have contributed to the overall improvement in academic achievement of children in the study group. These procedures, in combination, have also been found to enhance focusing abilities, even in active, noisy environments.

Enhancements in the ability to focus can contribute to improvements in global learning and achievement.

The learning environment at MAA for both the study and the control groups was stress-reduced, according to the definition by Caine and Caine (1999). The high, overall problem solving and critical thinking skills shown in the Key Math scores may be attributable to the reduced levels of stress in this environment that are due to the absence of tests, grades, timed-activities and competition. In addition, this environment provided increased opportunities for learner-centered, self-initiated projects and activities. These kinds of projects and activities have been know to increase motivation, according to Jensen, (2000). It was also noted that daily school attendance was slightly higher for participants in the neurofeedback group than it was for participants in control group. Sapolsky, (1998) suspects that reducing stress such as with neurofeedback would led to less stress-related ailments such as stomachaches, headaches, and intestinal problems.

It is also notable that the children attending the Meridian Academy of the Arts showed gains in all areas of academics over the course of the two semesters during which this study was conducted. As a group, they demonstrated over-all improvements in mathematics, in three areas of reading (word identification, passage comprehension and word attack) and in global achievement. All of the children enrolled in MAA showed more than three months academic growth during each semester.

The questions that arise from this research are:

1. Is it possible that the successful outcomes from employing a reduced-stress learning environment in combination with EEG neurofeedback

training and neuro-cognitive coaching, provided in this private school, could be replicated in a public school setting?

2. To what degree did the arts-based curriculum contribute to improvements in academic performance independent of the contributions of EEG neurofeedback training and neuro-cognitive coaching? If EEG neurofeedback training and neuro-cognitive coaching were provided to a group who were not exposed to such a curriculum, would there be similar results when compared to a group who were exposed to both?

3. Are students exposed to the combination of an arts-based curriculum, with EEG neurofeedback training and neuro-cognitive coaching more likely to improve academically than their counterparts in a traditional setting?

4. Are the improvements demonstrated in this study a result of the combination of EEG neurofeedback training and neuro-cognitive coaching, or could similar results be obtained by presenting only one of these procedures?

5. Can the methods examined by this research be instituted in a traditional curriculum and would the results obtained be lower, equal to, or higher than the results obtained in this study?

Discussion of Study Outcomes

Results from the auditory noise subtest of the Woodcock Auditory Discrimination test were found to be significantly greater for the neurofeedback study group when compared to results for the control group. This finding indicated that a learned system of filtering noise is needed by students who have difficulties processing information in loud, busy atmospheres. In schools where classroom size has increased, or an open-concept classroom structure is utilized, corresponding levels of noise and activity levels are also increased. These factors may also contribute to auditory processing difficulties.

Higher mean scores were reported on the Woodcock word attack subtest for participants in the EEG neurofeedback group possibly because improved abilities to discriminate sounds contributed to increased phonemic awareness (sounding-out letters and words).

A noteworthy correlation was found between the results for the Woodcock word comprehension subtest scores and the Key Math scores: namely, the higher the level of problem solving skills, the more developed the level of comprehension skills. During a period of three months, Key Math scores showed an over mean gain of 11.75 for the control group and 18.50 for the neurofeedback group. These gains, although not statistically significant, were realized nonetheless and reflected overall academic improvements for both groups.

Distractibility and difficulty maintaining focus of attention and concentration are characteristic qualities of those with auditory discrimination problems. Therefore, as the ability to perceive, discriminate and comprehend specific, single sounds within a noisy environment is increased, the tendency towards distractibility is reduced, and the ability to maintain focus and concentration is elevated.

The increased ability to focus attention, evidenced by the significant results found in the auditory noise subtest within a noisy environment scores, may be related to the significant increase in academic improvement found in the Key Math and Woodcock Word Identification Tests. These findings indicated increases in vocabulary and problem solving skills and in the ability to learn, reframe and reorganize information that may be due to a heightened focus of attention and concentration.

In this study, participants with language disorders in this stress-reduced, creative arts curriculum, who were exposed to EEG neurofeedback training and neuro-cognitive therapy, made notable strides in the areas of academic improvement, auditory processing and global achievement. If larger numbers of students with language disorders were exposed to this methodology, it can be inferred that larger numbers of students with language disorders would experience greater advances in the areas of academic improvement, auditory processing and global achievement.

Conclusion

In this controlled study, notable differences were found for participants in a study group who were exposed to EEG neurofeedback training and neuro-cognitive coaching in a creative arts curriculum, and participants in a control group who were exposed only to a creative arts curriculum. The mean scores obtained by this research indicated that participants in the study group made significantly greater academic gains, when compared to the gains of participants in the control group. Although the academic gains of special needs children were more modest than those of their average or gifted counterparts, they were, nevertheless, gains. That these special needs children did experience gains is a finding that is contrary to those reported by other researchers in the field of neurofeedback (Schwartz, 1995), which may suggest that the MAA curriculum and methodology were responsible for the gains.

This study demonstrated that EEG neurofeedback training and neuro-cognitive coaching, provided as an adjunct to a specialized, creative arts program characterized by a stress-reduced learning environment, small class size and individualized curricula, can result in educationally significant mean gains in the areas of auditory processing, global achievement and in several components of mathematics, including problem solving and critical thinking.

Recommendations:

Although promising, the findings from this study were not based upon a sufficiently large sample size for them to be predictively powerful. In order to be able to make probable generalizations, providing that compelling, statistical significance would be found in the resulting data, this study needs to be replicated with a sample size of n=48 or larger. The predictive power for the findings of a replication study would also be enhanced if the study sample contained large and more homogenous age groupings and more demographically diverse. For example, it would be very interesting to compare the mean academic gain for a large group of 6-year-olds vis-a-vis the academic gain for a large group of 11-year-olds, as a function of exposure to EEG neurofeedback training.

In spite of the limited study group size available to this research project, its findings relative to EEG neurofeedback training having had a positive impact with special needs students is curiosity provoking, particularly in light of past research having indicated that there is little value to be gained from applying this training to the special needs population. It would be most interesting to be able to examine academic gain data associated with EEG neurofeedback training and neuro-cognitive coaching, derived from large sample sizes of three distinct study populations: special needs, normal and academically talented. Should significant academic improvements be eventually found for special needs groups who experience competently administered EEG neurofeedback training and neuro-cognitive coaching, then remarkable improvements in the educational experience for this group could be realized.

To witness a widespread implementation of a new pedagogical methodology, derived from positive, large-scale replication studies of the impacts of EEG neurofeedback training and neuro-cognitive processing, applied not only to the experience of being educated, but also to the experience of being human, would realize the intent, the purpose and the passion underpinning this research.

References

Abarbanel, A. (1995). The gates, states, rhythms and resonance's. *Journal Neurotherapy,* Retrieved February 15, 2001. from http://www.snr-jnt.org/NFBarch/reprints/aq-nt.html.

Allen, R. J. (1990). *Developing and remediating perceptual skills for learning disabled children in the primary grades* (1st ed.). New York: Vantage Press.

Allen, T. (1997). Clinical applications of EEG [manual]. Oakland, CA: The Stens Corporation.

Amen, D. G. (1997). *Windows into the A.D.D. mind*. Fairfield, CA: Mindworks Press.

Amen, D. G. (1998). *Change your brain change your life*. New York: Random House.

Amen, D. G., & Carmichael, B. D. (1997). High-resolution brain SPECT imaging in ADHD. *Ann Clin Psychiatry*, 9: 81-86.

Anastasi, A., & Urbina, S. (1997). *Psychological testing* (7th ed.). Upper Saddle River, NJ: Prentice Hall.

Anderson, D., Winfred, H., Chitwood, S. (1997). *Negotiating the special education maze: A guide for parents and teachers*. New York: Woodbine House.

Anderson, N., & Peiper, H.(1996). *A.D.D. The natural approach* (12th ed.). East Canaan

Atwater, F. H. (2000). Binaural beats and the frequency following response. [not published]. Proceedings of the Monroe Institute Professional Division, Faber, VA. CT: Safe Goods.

Atwater, F. H. (2001). Binaural beats and the regulation of arousal levels. Proceedings INAS. 11th Forum, New York: International New Arts & Sciences.

Atwater, P. M. H. (1999). *Future memory*. Charlottesville, VA: Hampton Roads.

Bartlett, F. C. (1995). *Remembering; A study in experimental and social psychology* (3rd ed.). United Kingdom: Cambridge University Press.

Baumer, B. H. (1996). *How to teach your dyslexic child to read: A proven method for parents and teachers*. New York: A Birch Lane Press Book.

Bell, N. (1991). *Verbalizing and visualizing: For language comprehension and thinking*. Paso Robles, CA: Academy of Reading.

Bellis, T. J. (1998). *Central auditory processing disorders; In the educational setting* (3rd ed.). San Diego: Singular Publishing Group.

Bergquist, W. H., McLean, R., & Kobylinski, B.A. (1994). *Stroke survivors* (1st ed.). San Francisco: Jossey-Bass.

Boyd, W. D., & Campbell, S. E. (2000). EEG biofeedback in the schools: The use of EEG biofeedback to treat ADHD in a school setting. *Journal of Neurotherapy,* 6: 2-4.

Brierley, J. (1994). *Give me a child until he is seven: Brain studies & early childhood education* (2nd ed.). Washington, D.C.: The Falmer Press.

Brown, V. (1991). Neurofeedback and lyme's disease: A clinical application of the five phase model of CNS functional transformation and integration. *Journal of Neurotherapy,* Retrieved January 11, 2001 from: http://www.snr-jnt.org/journalNT/JNT(1-4)2.html.

Brown, V. (1997). Period three approach. Retrieved April 22, 2001. from: http://www.neurofeed.com/sueValArticleP1.asp.

Budzynski, T.H. (1978). Biofeedback in the treatment of muscle-contraction (tension) headache. *Biofeedback Self Regul*., 3: 409-34.

Budzynski, T.H. (2000). From EEG to neurofeedback. In Evans, J. & Abarbanel, A. (2000). *Introduction to quantitative EEG and neurofeedback*. (pp.66-76). San Diego. CA: Academic Press.

Budzynski, T.H., Stoyva, J.M., Adler, C.S., & Mullaney, D.J. (1973). EMG biofeedback and tension headache: a controlled outcome study. *Psychosom Med*., 35: 484-96.

Buzan, T., Buzan, B. (1993). *The mind map book*. New York: Penguin Books USA.

Caine, G., Caine, R. (1994). *Making connections*. New York: Addison-Wesley.

Caine, R., Caine, G. (1997). *Education on the edge of possibility*. Alexandria, VA: Association for Supervision and Curriculum Development.

Callas, S., Mellinger, B.J., King-Taylor, M., Boulden, K., Hiester, & K.,Walti, et al. (1998). *When teachers reflect*. Washington, D.C.: National Association for the Publication of Young Children.

Calvin, W. H. (1996). *How brains think: evolving intelligence, then and now*. New York: Basic Books.

Campbell, D. (1997). *The Mozart effect*. (1st ed.). New York: Avon Books.

Campbell, H., Boyd, K. (1996). Screening and the new genetics: A public health perspective on the ethical debate. *J Public Health Med.,* 18: 485-6.

Carroll, L. T., J. (1999). *The indigo children; The new kids have arrived*. Carlsbad, NM: Hay House.

Carter, C.S., Krener, P., Chaderjian, M., Northcutt, C., & Wolfe, V.(1995). Asymmetrical visual-spatial attentional performance in ADHD: evidence for a right-hemisphere deficit. *Biol Psychiatry*, 37:789-97.

Carter, R. (1998). *Mapping the mind* (1st ed.). London, England: University of California Press.

Cassity, M. D., & Cassity, J. E. (1998). *MultiModel psychiatric music therapy for adults, adolescents, and children* (1st ed.). Saint Louis: MMB Music.

Cera, R. M., Vulanich, N. N., & Brady, W. A. (1995). *Patients with brain injury* (2nd ed.). Austin, TX: pro.ed.

Charnetski, C.J., Brennan, F.X. Jr., & Harrison, J.F. (1998). Effect of music and auditory stimuli on secretory immunoglobulin A(IgA). *Perceptual Motor Skills*, 87: 1163-70.

Chen, A. C., & Buckley, K. C. (1988). Neural perspectives of cerebral correlates of giftedness. *International Journal of Neuroscience*, 41:115-25.

Chomsky, N. (1996). *Language and problems of knowledge*. Mendocino, CA: Audio Scholar.

Chomsky, N. (2000). *New horizons in the study of language and mind*. United Kingdom: Cambridge University Press.

Comings, D. E. (1997). *Tourette syndrome and human behavior* (4th ed.). Duarte, CA: Hope Press.

Conner, K. (1989). *Feeding the brain: How foods affect children*. New York: Plenum Press.

Cook, N. D. (1984). Callosal inhibition: The key to the brain code. *Behavioral Science,* 29: 98-110.

Cook, N. D. (1984). The transmission of information in natural systems. *Journal of Theoretical Biology,* 108:349-367.

Cooper, J. R., Bloom, F.E., & Roth, R.H. (1996). *The biochemical basis of neuropharmacology* (7th ed.). New York: Oxford University Press.

Cronin, E. M. (1997). *Helping your dyslexic child: A guide to improving your child's reading, writing, spelling, comprehension, and self-esteem* (2nd ed.). Rocklin: Prima.

Davidson, R. J., Hugdahl, K. (1998). *Brain asymmetry* (2nd ed.). Cambridge, MA: A Bradford Book.

De Backer, J., Van Camp, J., Pedersen, I.N., Jensen, B., Stige, B., & Streeter, E., et al. (1999). *Clinical Applications of Music Therapy in Psychiatry*. London, England: Jessica Kingsley.

DeBoskey, D. S., Calub, C., Cook, C., Hooker, C., Lindeman, J., & Wallace, L. (1997). *Brain Injury: A HomeBased Cognitive Rehabilitation Program* (2nd ed.). Houston: HDI

Dennison, P. E., & Dennison, G. E. (1988). *Brain gym* (1st ed.).Ventura, CA: Edu-Kinesthetics.

Desmedt, J. E. & Tomberg, C. (1994). Transient phase-locking of 40 Hz electrical oscillations in prefrontal and parietal human cortex reflects the process of conscious somatic perception. *Neuroscience Lett.,* 168:126-9.

DePorter, B., & Hernacki, M. (1992). *Quantum learning*. New York: Dell.

DesMaisons, K. (1998). *Are you sugar sensitive?: Potatoes not prozac*. New York: Fireside Press.

Dewhurst-Maddock, O. (1993). *The book of sound therapy: Heal yourself with music and voice*. New York: A Fireside Book.

Druckman, T., & Minevich, A. (1999). Applications of EEG- neurofeedback for Attention Deficit Disorder, *Biofeedback,* Retrieved March 12, 2001. from http://www.webideas.com/biofeedback/research/tdruckman.shtml.

Dunn, L. M., & Dunn, L. M. *Peabody picture vocabulary test* (3rd ed.) Circle Pines, MN: American Guidance Service.

Edelman, G. M. (1992). *Bright air, brilliant fire: On the matter of the mind* (1st ed.). New York: BasicBooks.

Edgall, G. (1997). *Learning disabilities and brain function*. New York: Springer.

Eisenreich, J. (1992). *Children with tourette syndrome* (1st ed.). Rockville, MD: Woodbine House.

Ekman-Lundy, L. (1998). *Neuroscience fundamentals for rehabilitation*. Philadelphia: W.B. Saunders.

Elkind, D. (1981). *The hurried child: Growing up too soon* (1st ed.). New York: Addison-Wesley.

Evans, J. R., Abarbanel, A. (1999). *Quantitative EEG and neurofeedback* (1st ed.). San Diego: Academic Press.

Fenger, N. T. (2000). Visual-motor integration and its relation to EEG neurofeedback brain wave patterns, reading, spelling and arithmetic achievement in attention deficit disorders and learning disabled students. *EEG Spectrum,* Retrieved April 09, 2001. from http://www.eegspectrum.com/applications/ADHD-ADD/vis-motorReadSpell-intro/

Filley, C. M., Cranberg, L.D., Alexander, M.P., & Hart, E. J. (1987). Neurobiological outcome after closed head injury in childhood and adolescence. *Archive of Neurology,* 44:194-8.

Fischbah, G. D. (1994). The biological foundations of consciousness, memory and other attributes of mind have began to emerge; An overview of this most profound of all research efforts. *Scientific American, A Special Report* [Mind and Brain], 1-11.

Fisher, B. (1998). *Attention deficit disorder misdiagnosis*. Boca Raton, FL: CRC Press.

Frackowiak, R.S., Zeki, S., Poline, J.B., & Friston, K.J. (1996). A Critique of a new analysis proposed for functional neuroimaging. *European Journal of Neuroscience*, 8:2229-31.

Gaddes, W. H., Edgell, D. (1994). *Learning disabilities and brain function; A neuropsychological approach* (3rd ed.). New York: Springer.

Gardner, H. (1993). *Frames of mind: The theory of multiple intelligences*. New York: BasicBooks.

Giedd, J. N., Castellanos, F. X., Casey, B. J., Kozuch, P., King, A. C., & Hamburger, S.D., et al. (1994). Quantitative morphology of the corpus callosum in attention deficit hyperactivity disorder. *American Journal of Psychiatry,* 151: 665-9.

Goldberg, E., & Costa, L. D.(1991). Hemispheric differences in the acquisition and use of descriptive systems. *Brain and Language*, 14:144-173.

Goldberg, S. (1997). *Clinical neuroanatomy made ridiculously simple* (25th ed.). Miami: Med Master.

Goldman, J. (1999*). Healing sounds* (5th ed.). Boston: Element Books Limited.

Goldman, R., Fristoe, M. & Woodcock, R. (1970). *Test of auditory discrimination*. Circle Pines, MN: American Guidance Service.

Goldstein, I. F., & Goldstein, M. (1978). *How we know: An exploration of the scientific process*. New York: DA CAPO Press.

Gontkovsky, S., Montgomery, D.(1999). Two case studies examining the effects of repeated eleven-hertz entrainment under eyes-open and eyes closed conditions. The *Journal of Cognitive Rehabilitation,* 17:14-19.

Gorman-Gard, K. (1992). *Figurative language*. Eau Claire, WI: Thinking Publications.

Green, E. E., Green, A.M., & Walters, E. D. (1974). Biofeedback training for anxiety and tension reduction. *Annuals of New York Academy of Science,* 233:157-61.

Greene, R. W. (1998). *The explosive child* (1st ed.). New York: HaperCollins.

Greenspan, S. I. (1993). *Playground politics: Understanding the emotional life of your school-age child.* Reading, MA: Perseus Books.

Gregory, R. L. (1998). *The oxford companion to the mind* (2nd ed.). Oxford, NY: Oxford University Press.

Gridley, M. C. (1989). *Children who can hear but can't listen: auditory processing deficit-achievement anxiety syndrome* (1st ed., p. 8). Bloomfield Hills, MI: Minerva.

Gross, M. A. (1997). *The A.D.D. Brain*. Commack, NY: Kroshka Books.

Guilford, J.P. (1954). *Psychometric methods* (2nd ed.). New York: McGraw-Hill.

Gupta, K. (1997). *Human brain coloring workbook, An interactive approach to learning* (1st ed.). New York: Random House.

Haerle, T. (1992). *Children with tourette syndrome: A parent's guide*. New York: Woodbine House.

Haines, D.E. (1997). *Fundamental neuroscience*. New York: Church Livingstone.

Hamersky, J. (Executive Producer).(1993). *How difficult can this be? F.A.T. city* [Videotape]. New York: Public Broadcasting Service.

Harmony, T., Marosi, E., Becker, J., Rodriguez, M., Fernandez, T., & Silva, J., et al.(1995). Longitudinal quantitative EEG study of children with different performances on a reading-writing test. *Electroencephalogram Clinical Neurophysiology,* 6:426-33.

Healy, J. M. (1990). *Endangered minds; Why children don't think and what we can* do *about it* (1st ed.). New York: Touchstone.

Healy, J. M. (1994). *Your child's growing mind; A practical guide to brain development and learning from birth to adolescence* (2nd ed.). New York: Doubleday.

Hilts, P. J. (1996). *Memory's ghost* (1st ed.). New York: Touchstone.

Hink, R. F., Kodera, K., Yamada, O., Kaga, K., & Suzuki, J. (1980). Binaural interaction of a beating frequency-following response. *Audiology,* 19:36-43.

Hodgdon, L. A. (1993). *Visual strategies for improving communication* (8th ed.). Eau Claire, WI: Quirk Roberts.

Hoffman, J. (1995). *Rhythmic medicine: Music with a purpose*. Leawood, KS: Jamillan Press.

Hoffman, J. (1997). Tuning into the power of music. *Registered Nurse*, 60: 52-54.

Howard, P. J. (1997). *The owners manual for the brain.* Austin: Leonian Press.

Hughes, T. (1998). *Clinical Applications of EMG Biofeedback*. Educational presentation at the EMG Biofeedback conference, Dallas: Stens.

Humphreys, G. (1999). *Attention, space, and action: Studies in cognitive neuroscience*. New York: Oxford University Press.

Incorvaia, J. A., Mark-Goldstein, B. S., & Tessmer, D. (1999). *Understanding, diagnosing, and treating AD/HD in children and adolescents* (1st ed.). North Bergen, New Jersey: Jason Aronson.

Ingersoll, B. D. (1998). *Daredevils and daydreamers: New perspectives on attention-deficit / hyperactivity disorder*. New York: Double Day.

Jannell, E. M. (1996). *A New Tactic in The Fight Against Autism*. retrieved March 16, 2000. from http://www.flexyx.com/contents/pubs/autism.html

Jensen, E. (1998). *Teaching with the brain in mind* (1st ed.). Alexandria, VA: ASCD.

Kamphaus, R.W., Frick, P.J. (1996). *Clinical assessment of child and adolescent personality and behavior.* Needham Heights, MA: Allyn & Bacon.

Kamphaus, R.W., Huberty, C.J., DiStefano, C., & Petosky, M.D. (1997). A typology of teacher-rated child behavior for a national US sample. *Journal of Abnormal Child Psychology*, 25:453-63.

Kandel, E.R., Hawkins, R.D. (1992). The biological basis of learning and individuality. *Scientific American,* 267: 78-86.

Katherine, A. (1996). *Anatomy of a food addiction: The brain chemistry of overeating* (3rd ed.). Carlsbad, CA: Gurze Books.

Kennerly, R. C. (1996). An empirical investigation into the effect of beta frequency binaural beat audio signals on four measures of human memory. *Hemi-Sync Journal,* 14:1-4.

KeyMath . (1998). A diagnostic inventory of essential mathematics (revised).Circle Pines, MN: American Guidance Service.

Kiecolt-Glaser, J. K., Malarkey, W. B., & Chee, M., et al. (1993). Negative behavior during marital conflict associated with immunological down-regulation. *Psychometric. Medicine,* 55: 395-409.

Kirk, S., McCarthy, J., & Kirk, W. (1982). *Illinois test of psycholinguistic abilities*. Champaign, IL: University of Illinois Press.

Kisner, R., & Knowles, B. (1985). *Calisthenics for the brain, Warm-up exercises*. Eau Claire, WI: Thinking Publication.

Kohn, A. (1993). *Punished by rewards: The trouble with gold stars, incentive plans, A's, praise and other bribes*. Boston: Houghton Mifflin Company.

Kozol, J. (1986). *Illiterate america*. New York: Plume.

Kundtz, D. (1998). *Stopping* (1st ed.). Berkeley, CA: Conari Press.

Lambert, N. M., & McCombs, B.L. (1998). *How students learn: Reforming the schools through learner-centered education*. District of Columbia: APA.

Lanza, J. (1994). *Elevator Music* (1st ed.). New York: St. Martin's Press.

Lazzaro, I., Gordon, E., Li W., Lim, C. L., Plahn, M., Whitmont, S., & Clarke, S., et al. (1999). Simultaneous EEG and EDA measures in adolescent attention deficit hyperactivity disorder. *Int J Psychophysiol.,* Nov; 34:123-34.

Leedy, P. (1997). *Practical research: Planning and design*. Columbus, OH: Merrill, An Imprint of Prentice Hall.

Levine, E.S., Black, I.B. (1997). Trophic factors, synaptic plasticity, and memory. *Annuals of New York Academy of Science,* 835:12-9.

Levinson, H. N. (1992). *Turning around the upside-down kids: Helping dyslexic kids overcome their disorder* (1st ed.). New York: M. Evans and Company.

Liang, S. W., Jemerin, J.M., Tschann, J.M., Wara, D.W., & Boyce, W.T. (1997). Life events, frontal electroencephalogram laterality, and functional immune status after acute psychological stressors in adolescents. *Psychometric Medicine*, 59:178-86.

Liebman, M. (1986). *Neuroanatomy made easy and understandable* (3rd ed.). Rockville, MD: Aspen Publishers.

Love, R., & Webb, W. (1996). *Neurology for the speech and language pathologist*. MA: Butterworth-Heinemann.

Lubar, J.F., Swartwood, J.N., Swartwood, D.L. & Timmermann.(1995). Quantitative EEG and auditory event-related potentials in the evaluation of attention-deficit/hyperactivity disorder: Effects of methylphenidate and implications for neurofeedback training. *Journal of Psychoeducational Assessment* [ADHD special], 143-160.

Markova, D. (1992). *How your child is smart*. Berkeley, CA: Conari Press.

Marsh, J. T., Worden, F. G., & Smith, J. C. (1970). Auditory frequency-following responses: Neural or artifact? *Science,* 169:1222-3

McEvoy, L. K., Smith, M.E., & Gevins, A. (2000). Test-retest reliability of cognitive EEG. Clinical *Neurophysiology,* 3: 457-63.

McIntyre T.D., Trullas R., & Skolnick P. (1988). Asymmetrical activation of GABA-gated chloride channels in cerebral cortex. *Pharmacol Biochem Behav*., 30: 911-6.

McKay, M., Davis, M., & Fanning, P. (1995). *Messages: The communication skills book.* Oakland, CA: New Harbinger Publications.

McKinney, C. H., Tims, F.C., Kumar, A.M., & Kumar, M. (1997). The effect of selected classical music and spontaneous imagery on plasma beta-endorphin. *Journal of Behavioral Medicine,* 20:85-99.

McMackin, D., Jones-Gotman, M., Dubeau, F., Gotman, J., Lukban, & A., Dean., et al. (1998). Regional cerebral blood flow and language dominance: SPECT during intracarotid amobarbital testing. *Neurology*, 50:943-50.

Meckstroth, E. A., Tolan, S.S., & Webb, J.T. (1994). *Guiding the gifted child: A practical source for parents and teachers*. Scottsdale, AZ: Gifted Psychology Press.

Mike, J. (1997). *Brilliant babies powerful adults* (1st ed.). Clearwater, FL: Satori Press International.

Miles, E. (1997). *Tune your brain: Using music to manage your mind, body and mood*. New York: Berkley Books.

Miller, L. (1999). Child abuse brain injury: clinical, neuropsychological, and forensic considerations. *Journal of Cognitive Rehabilitation,* 17:10-16.

Minnich, E. K. (1990). *Transforming knowledge*. Philadelphia: Temple University Press.

Mizoguchi, K., Yuzurihara, M., Ishige, A., Sasaki, H., Chui, D.H., & Tabira, T. (2000). Chronic stress induces impairment of spatial working memory because of prefrontal dopaminergic dysfunction. *Journal of Neuroscience*, 20:1568-74.

Modayur, B., Prothero, J., Ojemann, G., Maravilla, K., & Brinkley, J.,. (1997). Visualization-based mapping of language function in the brain. *Neuroimage*, 4: 245-58.

Moir, A. (1991). *Brain sex: The real difference between men & women.* New York: Delta Press.

Monroe, B. (1992). Concentration , *Hemi Sync* [CD]. Lovingston, VA: Interstate Industries.

Montgomery, D. D., Ashley, E., Burns, W.J., & Russell, H.L. (1994). Clinical outcome of a single case of EEG entrainment for closed head injury. Proceedings of the Association for *Applied Psychophysiology and Biofeedback*, 25: 82-83.

Moustakas, C. (1997). *Relationship play therapy*. North Bergen: Jason Aronson.

Murphy, B. (1991). Steroids and depression. *J. Steroid Biochem. Mol. Biol.*, 38:537-559.

Murray, B. (2000, March). From Brain Scan to Lesson Plan. *Monitor on Psychology*, 31: 22-27.

Myss, C. (1997). *The energetics of healing* [videotape]. Boulder: Sounds True.

Neill, A. S. (1995). *Summerhill school: A new view of childhood*. New York: St. Martin?s Press.

Niehoff, D. (1999). *The biology of violence: How understanding the brain, behavior and environment can break the vicious circle of aggression* (1st ed.). New York: The Free Press.

Ornstein, R. (1997). *The right mind*. San Diego, CA: Harcourt Brace.

Ornstein, R., Thompson, R.F. (1986). *The amazing brain* (2nd ed.). Boston, MA: Houghton Mifflin.

Packer, A. J.(1997). *How rude! The teenagers guide to good manners, proper behavior, and not grossing people out*. Minneapolis, MN: Free Spirit Publishing.

Patton, M. Q. (1996). *Linking research, theory, and practice* [videotape], Cincinnati, OH: The Union Institute's Learning Council.

Peniston, E.G., Kulkosky, P.J. (1989). Alpha-theta brainwave training and beta-endorphin levels in alcoholics. *Alcohol Clin Exp Res.*, 13:271-9.

Pinker, S.(1995). *The language instinct: How the mind creates language*. New York: HarperPerennial.

Pulizzoto, R., Pelton, S., Montgomery, D., Burns, W.J., Ashley, E., & Harrison, M., et al. (1997). *The conscious universe* (1st ed.). San Francisco: HarperEdge.

Reichardt, P. (1992). *Concept building: Developing meaning through narratives and discussion*. Eau Claire, WI: Thinking Publication.

Restak, R. (1984). *The brain*. New York: Bantam Books.

Restak, R. (1989). The brain, depression, and the immune system. *Journal of Clinical Psychiatry*, 50:23-5.

Restak, R. (1995). *Brainscapes: An introduction to what neuroscience has learned about the structure, function and abilities of the brain.* New York: Hyperion.

Restak, R. (2001). *The secret life of the brain*. New York: The Dana Press.

Rice, D. M., Buchsbaum, M.S., Hardy, D., & Burgwald, L. (1991). Focal left temporal slow EEG activity is related to a verbal recent memory deficit in a non-demented elderly population. *Journal of Gerontology*, 4:144-51.

Rico, L. G., & Clagett, M.F. (1980). *Balancing the hemispheres: Brain research and the teaching of writing.* Berkley, CA: University of Berkley.

Robbins, J. (2000). *A symphony in the brain: The evolution of the new brain wave biofeedback*. New York: Atlantic Monthly Press.

Rocelia, J. A. (1990). *Developing and remediating perceptual skills for learning disabled children in the primary grades*. New York: Atlantic Monthly Press.

Rossiter, T.R., & LaVaque, T.J. (1995). A comparison of EEG biofeedback and psychostimulants in treating attention deficit hyperactivity disorders. *Journal of Neurotherapy*, 2:48-49.

Rozelle, G.R., & Budzynski, T.H. (1995). Neurotherapy for stroke rehabilitation: a single case study. *Biofeedback Self-Regulation,* 20:211-28.

Russell, H. (1996). EEG Entrainment combined with multi-modal rehabilitation of a 43-year-old severely impaired post-aneurysm patient. Proceedings of the *Association for Applied Psychophysiology and Biofeedback*, 27:108-109.

Russell, R. (1993). *Using the whole brain: Integrating the right and left brain with hemi-sync sound patterns.* Norfolk, VA: Hampton Roads.

Sanders, G. O., & Waldkoetter, R.O. (1997). A study of cognitive substance abuse treatment with and without auditory guidance. *Hemi-Sync Journal,* 15: 1-4.

Sapolsky, R. M. (1992). *Stress, the aging brain and the mechanisms of neuron death*. Cambridge, MA: A Bradford Book.

Sapolsky, R. M. (1998). *The trouble with testosterone.* New York, NY: Simon & Schuster

Sapolsky, R. M. (1998). *Why zebras don't get ulcers* (2nd ed.). New York: W. H. Freeman.

Sapolsky, R. M. (1998). *Biology and human behavior: The neurological origins of individuality* [Lecture Series]. Springfield, VA: The Teaching Company.

Savage-Rumbaugh, S., Shanker, S.G., & Taylor, T.J. (1998*). Apes, language, and the human mind*. New York: Oxford University Press.

Saxby, E., & Peniston, E.G. (1995). Alpha-theta brainwave neurofeedback training: An effective treatment for male and female alcoholics with depressive symptoms. *Journal of Clinical Psychology*, 51: 685-93.

Scherzer, B. R. (1996). *Biofeedback-assisted cognitive behavioral therapy*. Unpublished Doctoral Dissertation, The Union Institute, Cincinnati, OH.

Schiffer, F. (1998). *Of two minds: The revolutionary science of dual-brain psychology*. New York: The Free Press.

Schulberg, C. (1986). *The music therapy sourcebook: A collection of activities categorized and analyzed*. New York: Human Sciences Press.

Schwartz, M. (1995). *Biofeedback A practitioner?s guide*. New York: Guilford Press.

Scott, G. G. (1990). *Resolving conflict: With others and within yourself*. Oakland, CA: New Harbinger Publications.

Sears, W., & Thompson, L. (1998). *The A.D.D. book; New understandings, new approaches to parenting your child.* New York: Little, Brown and Company.

Shatz, C.J., Zeki, S., Damasio, A. R. and Damasio, H.,Raichle, M.E., & Gottfredson, L.S., et al. (1999).*The Scientific American Book of the Brain* (1st ed.). New York: The Lyons Press.

Smith, J. C., Marsh, J. T., & Brown, W. S. (1975). Far-field recorded frequency-following responses: evidence for the locus of brainstem sources. *Electroencephalogram in Clinical Neurophysiology* 39:465-72.

Sokhadze, T., Yi,I., Choi, S., Lee, K., & Sohn, J. (1999). Music selectively modulates post-stress recovery process. *Applied Psychophysiology and Biofeedback,* 24; 137.

Speaks, C. (1999). *Course notes and workbook for introduction to sound*. San Diego, CA: Thompson Learning.

Spector, C. C. (1997). *Saying one thing meaning another: Activities for clarifying ambiguous language.* Eau Claire, WI: Thinking Publications.

Spielberger, C. D., Lambert, N.M., McCombs, B.L., Alexander P.A., Murphy, P. K., & Frisby, C.L., et al. (1998). *How students learn*. Washington, D.C.: American Psychological Association.

Spolin, V. (1998). *Theater games for the classroom* (4^{th} ed.). Evanston, IL: Northwestern University Press.

Springer, S. P., & Deutsch, G. (1997). *Left brain/right brain* (3^{rd} ed.). New York: W.H. Freeman.

Stahl, S. M. (1998). *Psychopharmacology of antidepressants* (2^{nd} ed.). San Diego, CA: Martin Dunitz.

Staudacher, C., Hadley, J. (1996). *Hypnosis for change* (1^{st} ed.). Oakland, CA: New Harbinger.

Stefanatos, G.A. & Wasserstein, J. (2001) Attention deficit/hyperactivity disorder as a right hemisphere syndrome. Selective literature review and detailed neuropsychological case studies. *Annuals of New York Academy Science,* 931:172-95.

Steiner, R. (1991). *Old and new methods of initiation*. United Kingdom: Rudolf Steiner Press.

Sterman, M.B., Wyrwicka, W., & Howe, R. (1969). Behavioral and neurophysiological studies of the sensorimotor rhythm in the cat. *Electroencephalogram in Clinical Neurophysiology,* 27:678-9.

Stordy, B. J., & Nicholl, M. J. (2000). *The LCP solution: The remarkable nutritional treatment for ADHD, dyslexia, and dyspraxia*. New York: The Ballantine Books.

Strong, C. J., & Strong, W. (1999). *Strong rhythms and rhymes*. Eau Claire, WI: Thinking Publications, Inc.

Suzuki, S., Mills, E., Ferro, M., Schreiber, M., Behrend, L.,& Jempelis, A., et al.(1973). *The suzuki concept: An introduction to a successful method for early education.* San Diego, CA: Diablo press.

Talbot, M. (1992). *The holographic universe* (2^{nd} ed.). New York: Haper Perennial.

Taylor, D. (1991). *Learning denied.* Portsmouth, NH: Heinemann educational Books.

Teeter, P. A., & Semrud-Clikeman, M. (1998). *Child neuropsychology: Assessment and interventions for neurodevelopmental disorders*. Boston, MA: Allyn & Bacon.

Thatcher, R.W. (1995). Tomographic electroencephalography / magnetoencephalography. dynamics of human neural network switching. *Journal of Neuroimaging,* 5: 35-45.

Thatcher, R.W., Camacho, M., Salazar, A., Linden, C., Biver, C., & Clarke, L. (1997). Quantitative MRI of the gray-white matter distribution in traumatic brain injury. *J Neurotrauma,* 14:1-14.

Thatcher, R.W., Moore, N., John, E.R., Duffy, F., Hughes, J.R., & Krieger, M. (1999). QEEG and traumatic brain injury: Rebuttal of the american academy of neurology 1997 report by the EEG and clinical neuroscience society. *Clinical Electroencephalogram,* 30: 94-8.

Thompson, L, & Thompson, M. (1998). Neurofeedback combined with training metacognitive strategies. *Applied Psychophysiology and Biofeedback,* 23:243-263

Turkington, C. (1996). *The brain encyclopedia* (1st ed.). New York: Checkmark Books.

Umriukhin, E. A., Dzhebrailova, T.T., & Korobeinikova II. (1995). Physiological evaluation of the resultant activity of school children working with computers. *Vestn Ross Akad Med Nauk*., 11: 47-52.

Unsworth, C. (1999). *Cognitive and perceptive dysfunction: A clinical reasoning approach to evaluation and intervention*. Philadelphia, PA: F.A. Davis.

Upledger, J. E. (1997). *Your inner physician and you*. Berkeley, CA: North Atlantic Books.

Valiant, L.G. (1994). *Circuits of the mind*. New York: Oxford University Press.

Vanderwolf, C.H. (2000). Are neocortical gamma waves related to consciousness? *Brain Res*., 855:217-24.

Van der Kar, L. D., & Behtea, C.L. (1982). Pharmacological evidence that serotonergic stimulation of prolactin secretion is mediated via the dorsal raphe nucleus. *Neuroendocrinology,* 35: 225-230.

Van der Kolk, B.A., & Fisler, R.E. (1993). The biologic basis of posttraumatic stress. *Primary Care*, 20: 417-32.

Vogel, D., Carter, J.E., & Carter, P.B. (2000). *Effects of drugs on communication disorders* (2nd ed.). San Diego: Singular Publishing.

Waldkoetter, R. (2000). Use of hemi-sync audiotapes to reduce levels of depression for alcohol-dependent patients. *Hemi-Sync Journal*, 18: 1-3.

Webb, J. T., Meckstroth, E.A., & Tolan, S.S. (1994). *Guiding the gifted child* (1st ed.). Scottsdale, AZ: Gifted Psychology Press.

Weinburger, N. M. (1998). *The powers of music*. Retrieved December 8, 2001. from http://www.musica.uci.edu.

Welch, E. T. (1998). *Blame it on the brain?* Phillipsburg, New Jersey: Presbyterian and Reformed Publishing.

West, T. G. (1997). *In the mind's eye* (2nd ed.). Amherst: Prometheus Books.

Wigram , T., & DeBacker, J. (1999). *Clinical applications of music therapy in psychiatry*. London, England: Jessica Kingsley.

Wise, A. (1995). *The high-performance mind: Mastering brainwaves for insight, healing and creativity*. New York: Penguin Putnam.

Yost, W. (1994). *Fundamentals of hearing: An introduction*. San Diego, CA: Academic

Tables

Appendix