THE EFFECTS OF MUSIC TRAINING ON ELECTROENCEPHALOGRAPHIC

COHERENCE OF PRESCHOOL CHILDREN

DISSERTATION

Presented to the Graduate Council of the

University of North Texas in Partial

Fulfillment of the Requirements

For the Degree of

DOCTOR OF PHILOSOPHY

By

Roger J. deBeus, M.S.

Denton, Texas

August, 1999

The purpose of this study was to examine the effects of music training on electroencephalographic (EEG) coherence of preschool children. EEG coherence is a measurement of brain wave activity that reflects anatomical and neurophysiological parameters and functional connectivity between areas of the brain. Participants were 4- to 6-year-old children divided into two groups: one received music training for 20 minutes twice a week for 10 weeks while the other group served as controls. Nineteen channels of EEG data were collected from each child pre- and post-training. Data were collected from three conditions: eyes-open resting, listening to music, and performing the Object Assembly subtest of the Weschler Preschool and Primary Scale of Intelligence - Revised (1989). The hypothesis was that the music training group would show increased EEG coherence as compared to controls.

The EEG data was reduced into seven bandwidths and analyzed separately for each condition. Multiple ANCOVAs were used to factor out pre-test variability and to maximize connectivity changes between the two groups. The dependent measures were the post-QEEG electrode pairs and the covariates were the pre-QEEG electrode pairs.
Results indicated the eyes-open and listening to music conditions showed more significant changes between the groups than the Object Assembly condition. Overall, each condition showed increased connectivity for the music training group versus controls. The eyes-open condition differentiated children with and without music training during a resting condition, and showed similar patterns as those identified by other researchers comparing musicians versus nonmusicians. The listening to music condition identified connections including a topographical pattern of auditory analysis, increased working memory activation, increased activity between musically sensitive areas, and increased interhemispheric activity. Findings with the Object Assembly condition were not as robust as expected. However, patterns of increased connectivity associated with visuospatial processing were found with the music training group.
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CHAPTER I

INTRODUCTION

The U.S. Congress (1990) labeled the past decade as the "Decade of the Brain," and accordingly research on the brain received much attention and focus. One area still receiving attention is the effect of music on the development of neural circuitry in children's brains (Begley, 1996; Breitling, Guenthert, & Rondot, 1987; deBeus, 1998; Flohr & Miller, 1993, 1995; Flohr, Miller, & Persellin, 1996; Graziano, Shaw, & Wright, 1997; Gromko & Poorman, 1998; Hancock, 1996; Leng & Shaw, 1991; Leng, Shaw, & Wright, 1990; Miller & Flohr, 1995; Miller, Flohr, & Persellin, 1996; Rauscher, Shaw, & Ky, 1993; Rauscher, Shaw, Levine, Wright, Denis, & Newcomb, 1997; Rideout & Laubach, 1996; Rideout & Taylor, 1997; Sarnthein, von Stein, Rappelsberger, Petsche, Rauscher, & Shaw, 1997). This study will examine the effects of music training on neurophysiological activity of preschool children as measured by electroencephalographic (EEG) coherence. The following review of literature related to this research topic covers neurophysiological and educational windows of opportunity, the electroencephalograph (also known as EEG) and brain wave activity, EEG coherence, coherence activity in children, and coherence activity of the effects of music training.
Neurophysiological and Educational Windows of Opportunity

Researchers have found circuits in different regions of the brain mature at different times (Barkovich, Kjos, Jackson, Norman, 1988; Brody, Kinney, Kloman, & Gilles, 1987; Dietrich, 1990). These findings have suggested that different neurological pathways are most sensitive to life’s experiences at different ages. The window of opportunity for learning, particularly music training, has been found to occur between the age of 3 and the age of 10 (Chugani, 1998; Chugani, Phelps, & Mazziotta, 1987; Hancock, 1996). Information related to the discovery of this window has been found through an integration of the literature and findings of neurophysiology, education, and music training.

During the first decade of life an abundance of neurological growth has been found to occur in the brain that has involved two phases: (a) an additive phase and (b) a subtraction and selection phase (Kandell, Schwartz, & Jessell, 1991). The additive phase involves neurogenesis, synaptogenesis, and myelination. Except for two brain areas, neurogenesis, the growth of neurons, has been found to be completed during prenatal development (Dobbing & Sands, 1973). The olfactory bulb (Graziadei & Monti-Graziadei, 1979) and the hippocampus (Eriksson, Perfilieva, Bjork-Eriksson, Alborn, Nordborg, Peterson, & Gage, 1998) have been found to generate throughout the life span. While this new finding related to the hippocampus has great heuristic value, neurogenesis overall may not be as strong a contributor to the window component as synaptogenesis and myelination.
Synaptogenesis, the making of connections, has been found to take place both prenatally and throughout life (Janowsky & Carper, 1996). Some connections were found to be predetermined genetically and others were found to be developed from environmental influences, as suggested by genetic and EEG coherence studies (Ibatoullina, Vardaris, & Thompson, 1994; van Baal, de Geus, & Boomsma, 1998). These findings have suggested the possibility of environmental influences on the synaptogenesis process. In a positron emission tomography (PET) study, Chugani (1998) found that there was a rise in the rates of glucose utilization, representative of functional activity, from birth until about four years of age. During this time the child’s cerebral cortex was found to use over twice as much glucose as that of adults. From ages 4 to 10 years these high rates of glucose consumption were found to be maintained and then began a gradual decline of glucose metabolic rates, which reached adult values by ages 16 to 18 years. Chugani (1998) also discussed the correlations between glucose utilization rates and synaptogenesis, suggesting that these findings have important implications regarding human brain plasticity and “critical periods” of maximal learning capacity.

During the process of synaptogenesis, the axons of the neurons become myelinated. It has been found that myelin is made of special glia cells and insulates axons to increase the speed of signal transmission. Periods of myelination that correlates with increases in metabolic activity have been seen in PET scans (Dietrich, 1990). Studies have shown that increasing myelination is associated with increases in brain function and signal the functional maturation of cortical systems (BateI, Forster, Fendel,
Naegele, Fink, & Kenn, 1988). Other researchers have observed that myelination of axons coming from cortical neurons begin in the first year of life and continued into school-age years (i.e., up to 16 years-old) (Salamom, Raynaud, Regis, & Rumeau, 1990). It was thought that this process might contribute to behavioral transitions. In the corpus callosum, the bundle of fibers that has been found to be responsible for communication between hemispheres, myelination has been observed to continue until at least 7 to 10 years of age and it was thought that this process might continue slowly after the first decade (Yakovlev & Lecours, 1967). Myelination has also been observed to occur within integrative cortical connections between and within hemispheres (Kandell, Schwartz, & Jessell, 1991). It was hypothesized that this process increased the efficiency of conduction between neurons in the entire cortex and might contribute to a cognitive shift by facilitating the development of complex or abstract thinking and learning by increasing the speed of information processing between regions (Janowsky & Carper, 1996).

With the possible exception of myelination, all of the additive and growth processes, neurogenesis and synaptogenesis, are followed by a period of subtraction and selection as shown in Figure 1 (Bates, Thal, & Janowsky, 1992). During subtraction and selection, normal neurons have been observed to die off and to retract multiple axons leaving only one in the end (Innocenti & Clarke, 1984; Ivy, Akers, & Killackey, 1979). The numbers of synapses have been observed to begin to decrease through adolescence as well as the aging process (Huttenlocher, 1979, 1990). Processes of subtraction and selection might have been as responsible for developmental behavioral change as were
Figure 1. Approximation of the time course of additive and regressive events in brain development. The figure is a substantial modification of the original, which appeared in Bates, Thal, and Janowsky (1992).

additive processes (Janowsky & Carper, 1996). From the additive processes, the basic genetic programming provided a rudimentary framework for guiding neurons throughout the brain in when and how to make connections. Activity-dependent selection of neurons and synapses have then shaped the final networks, microarchitecture, and therefore function of the brain (Changeux & Danchin, 1976). This shaping process is a competitive one. Neurons must compete with each other for synaptic space and trophic factors. This competition was shown to require neural activity (Oppenheim, 1981). For example, sensory deprivation studies of the visual system in humans and animals have shown that stimulation was needed early in development in order to generate parallel representational systems in the cortex (von Senden, 1932; Weisel & Hubel, 1963;
Weisel, 1982). In other words, if the neurons responsible for certain activities do not get stimulated, they die off and become insufficient to do their job. Similarly, if neurons are challenged and utilized through music training during their critical period, then these neurons will be "selected" accordingly and remain intact. Otherwise these neurons will be dedicated to other tasks.

The additive processes and the subsequent subtraction of neural elements serve the purpose of selection and stabilization of connections (Changeux & Danchin, 1976). This window of synaptic selection and hypermetabolism may occur in the cortex at approximately the same time children begin preschool. The window may be a mediator that enables school-age cognitive and behavioral transitions. It is the richest time in terms of neural hardware and activity available to the child. The window is also the richest time, possibly with the exception of birth, for new experiences and challenges to the child's brain (Janowsky & Carper, 1996).

As the neurophysiological literature suggested in the previous discussion, the first decade of life, and in particular the preschool years, is a window of opportunity for influencing brain development. Another area with obvious implications for effects on the window of learning is educational intervention.

Campbell and Ramey (1995) studied long-term outcomes in intellectual development, school program, and academic achievement related to early childhood educational intervention. This intervention was known as the Abecedarian Project. The project provided intensive early education in a day-care center to children from 4 months to age 8. The activities were designed to enhance cognitive, language, social or motor
development. The children were divided into four different groups: (a) preschool and early elementary treatment (infancy to 8 years of age), (b) preschool treatment only (infancy to 5 years), (c) early elementary treatment only (5 to 8 years of age), and (d) untreated controls. When the children reached age 15 they were tested again. Participants who received preschool treatment scored significantly higher on individually administered tests of reading and mathematics than other treatment groups. These preschool children also retained an average IQ edge of 4.6 points. In addition, the students received fewer instances of grade retention and assignments to special education classes compared with controls. These results supported the relative efficacy of preschool intervention over that given in early elementary school.

Although the brain essentially retains the ability to learn throughout life, "children whose neural circuits are not stimulated before kindergarten are never going to be what they could have been," according to Joseph Sparling, who designed the Abecedarian curriculum (p.55, Begley, 1996). This educational intervention adds support to the neurophysiological model and helps to reaffirm that the window of opportunity for children to learn is during the preschool years. The educational research results will now be integrated with music training research to develop the concept known as the window of opportunity further.

Music training has been identified as a formal process, usually involving training in voice or an instrument, that has lasted for several years (Petsche, Lindner, Rappelsberger, & Gruber, 1988). Most music studies have explored the differences between musicians and nonmusicians. However, very few have examined variables
immediately before and after the music training process. The following review discusses
music training with preschool children and fourth graders, and then a magnetic resonance
imaging (MRI) study of professional musicians and nonmusicians.

Scientists believe music trains the brain for higher forms of thinking such as
complex math and engineering skills. According to Shaw, "Early music training can
enhance a child’s ability to reason," (p. 58, Hancock, 1996). A study by Rauscher, Shaw,
Levine, Wright, Dennis, and Newcomb, (1997) showed that music training caused long-
term enhancement of preschool children’s spatial-temporal reasoning. These authors
defined "long-term" as one day. Seventy-eight preschool children participated in the
study. Thirty-four children received private piano keyboard lessons, 20 children received
private computer lessons, and 24 children were in the control group. The researchers
administered four standard, age-calibrated, spatial reasoning tests to the children before
and after training. One test assessed spatial-temporal reasoning (Object Assembly
subtest of the Wechsler Preschool and Primary Scale of Intelligence - Revised (WPPSI-
R) (1989)), and three tests assessed spatial recognition. The spatial-temporal reasoning
test measured the ability to reason in space and time. The researchers found significant
improvement (34%) on the spatial temporal test for the keyboard only group. No group
improved significantly on the spatial recognition tests.

Costa-Giomi (1998) looked at longer term effects of music instruction with 117
fourth-grade children. The average age of the children at the beginning of the study was
9 years old. Children in the experimental group (n = 63) received 30- to 45-minute
individual piano lessons weekly at their schools for 3 years and received an acoustic
piano to take home at no cost to their families. Children in the control group \((n = 54)\) did not receive any music training. The author administered five standardized tests to children in both groups at the beginning of the project and at the end of 1, 2, and 3 years of piano instruction. Results showed participation in piano lessons affected children’s cognitive abilities, especially their spatial abilities. These results occurred after 1 and 2 years of instruction. However, the author found no differences in general or in spatial abilities between the groups after 3 years of instruction. In addition, piano instruction did not affect children’s verbal and quantitative cognitive abilities. These results contributed support to the notion of affecting children’s cognitive abilities in the first decade of life. One possibility for the normalizing of the groups at the end of the study may be that the piano training began too late in the window of opportunity.

Neurophysiologically, by the ages of 9 to 10 the neural elements of children’s brains are most likely selected and the stabilization of connections is in process. For example, at the ages of 5 to 6 EEG correlates of attention showed connections between various areas of the cortex were diffuse. While in the ages of 9 to 11 a more organized form of local activity was found (Alferova, 1977). Therefore, the connections can still be influenced, but not enough to produce a significant effect as when children are started earlier in their music training, particularly during preschool.

Another study integrated MRI with the effects of music training in adults. Researchers in Germany (Schlaug, Jancke, Huang, Staiger, & Steinmetz, 1995) investigated whether the midsagittal area of the corpus callosum, the center from front to back, would differ between 30 professional musicians and 30 age- and sex-matched
controls using in-vivo magnetic morphometry. The results showed that the anterior half of the corpus callosum was significantly larger in musicians. This difference was mostly due to the subgroup of musicians who began musical training before the age of 7. These results are also comparable to the changes of components of the corpus callosum during the brain developmental period within the first decade of human life as noted in the neurophysiological review. Furthermore, this study supported the idea that the window of opportunity may be as narrow as 3 to 6 years of age for music training.

Thus far this paper has reviewed an abundance of evidence from the areas of neurophysiology, education, and music training that support an ideal time for learning and growth, showing that the best window of opportunity for children to be exposed to music training is the preschool years. The next step to support this window of opportunity is to collect more information that examines the effects of music training on children's brains. A major instrument for examining children's brain wave activity is the EEG. The EEG has been proposed as a noninvasive index of developmental changes (Kaiser & Gruzelier, 1996; van Baal, et al., 1998). A brief explanation of the functions of the EEG and brain wave activity will be provided. Then the literature review will discuss brain wave coherence and its relationship to patterns of activity in children.

The EEG and Brain Wave Activity

The EEG measures the electrical activity of the human brain. The bioelectrical activity of a person's brain is recorded by making an electrical connection between the person's scalp and the electrodes of the EEG. This is accomplished by attaching skin surface electrodes to the scalp with a wire or cable connecting these electrodes to the
EEG machine (Duffy, Iyer, & Surwillo, 1989). The placement of electrodes is based on the 10-20 International System (Jasper, 1958). The term "10-20" is used because the electrodes are placed either 10% or 20% of the total distance between a given pair of skull landmarks. Electrode positions are designated in terms of underlying brain areas (i.e., frontal pole, Fp; frontal, F; central, C; parietal, P; occipital, O; and temporal, T). A single digit number goes along with the letters with odd numbers designating left-sided and even numbers right-sided locations. Please see Figure 2 for a graphical representation of the 10-20 system.

![Figure 2. The 10-20 System.](image)

In 1929, Hans Berger's first report of the human EEG characterized the EEG as a mixture of rhythmic, sinusoidal-like fluctuations in voltage (Gloor, 1969). These
changes in voltage were described in terms of two parameters. The first parameter is how many cycles or fluctuations in voltage occur in one second. This is also known as hertz or Hz. The second parameter is the magnitude or amplitude of the fluctuations in voltage and is measured in microvolts (millionths of a volt, µV). The amplitude of the fluctuations in the EEG may range from two to several hundred microvolts (Duffy, Iyer, & Surwillo, 1989).

The complex patterns of rhythmic, sinusoidal-like fluctuations in voltage noted by Berger are broken down into simpler sine waves to aid in interpretation. This process, known as frequency analysis, separates a waveform into its different frequency components. That is, it delineates the amplitudes of the different frequency sine waves of which the waveform is composed. This method of analysis is known as Fourier series analysis or Fast Fourier Transform (FFT). The data are plotted with frequency on the horizontal axis and amplitude on the vertical axis.

Besides plotting frequency and amplitude, the FFT process aids in the interpretation of the power (amplitude squared) and coherence of the EEG signals in relation to themselves and other regions of the head. Absolute power can be interpreted as the intensity of brain electricity (ordinate of the power spectrum) at a given frequency (abscissa of the power spectrum) (Petsche, Lindner, Rappelsberger, & Gruber, 1988). Coherence is equivalent to the absolute value of the cross-correlation function in the frequency domain. Coherence reflects the number and strength of connections between spatially distant generators (Otnes & Enochson, 1972; Bendat & Piersol, 1980).
Furthermore, FFT allows the frequency spectrum of the EEG to be broken down into usually four arbitrary subcategories or bandwidths. The bands of frequencies are identified by the Greek letters Alpha, Beta, Theta, and Delta. Please see Figure 3 for an example of each band.

![Figure 3: The four subcategories of the EEG spectrum. The sample tracings show, from top to bottom, typical activity in the beta, alpha, theta, and delta bands.](image)

The Delta band contains frequencies under 4 Hz. Delta activity is normally seen in the deeper stages of sleep and is a commonly observed abnormality in the waking state in adults. Delta may be either rhythmic or irregular and its activity has the highest amplitude of any activity recorded in the EEG.
The Theta band consists of electrical activity with a frequency of 4 Hz to under 8 Hz. Theta activity is normally seen in drowsiness and during the lighter stages of sleep, but may also be present in wakefulness. It may be strictly rhythmic as is the case with Alpha rhythm, or highly irregular in character. Irregular Theta activity is sometimes referred to as being arrhythmic or polymorphic.

The Alpha band defines electrical activity in the range of 8 to 13 Hz. This includes the "Alpha rhythm" or posterior-dominant rhythm, which is rhythmic activity normally recorded in the awake individual. Amplitude is variable, ranging from 5 to 100 μV, but is mostly below 50 μV. It is best seen when the individual's eyes are closed and under conditions of physical relaxation and relative mental inactivity. The amplitude of the Alpha rhythm is attenuated or decreased by eyes opening, attention, and mental effort.

The Beta band includes frequencies over 13 Hz. The most common component of this band is the Beta rhythm, which is rhythmic activity consisting of a variety of frequencies greater than 13 Hz. Amplitude is variable but is mostly below 30 μV. Beta rhythms are seen under a wide range of conditions and especially with attention and mental effort.

The EEG measures the bioelectrical activity of the human brain. With the aid of modern computers and FFT, the fluctuating signals of the brain are transformed into different frequencies, amplitudes, power, coherence, and bandwidths for interpretation and analysis. The next section covers EEG coherence in more depth.
EEG Coherence

Functional relationships between brain regions have been one of the key areas of study since the development of the EEG. EEG coherence has had applications in a number of different areas of research. Some authors believe that coherence demonstrates evidence of anatomical connections (Fein, Raz, & Merrin, 1988), functional coupling (Thatcher, Krause, & Hrybyk, 1986), and information exchange between two sites (Petsche, Rappelsberger, & Pockberger, 1988). Coherence studies have been successfully conducted in many fields, including those dealing with cognitive functions and psychiatric disorders (for a review, see: French & Beaumont, 1984).

As early as 1951, the cross-correlation function was used to study the similarity between two EEG signals (Brazier & Casby, 1951, 1952). The EEG coherence concept was based on the assumption that the higher the correlation, the stronger the functional relationships between two main sites (Shaw, 1981, 1984). Since the development of digital computation and new computational algorithms, such as the FFT, the use of coherence gradually replaced correlation. Coherence gives similar information as correlation, but has the advantage of showing the covariation between two signals as a function of frequency and in a rather short time.

A few important features distinguish coherence from correlation. Coherence is calculated by dividing the numerical square of the cross-spectrum by the product of the autospectra. Therefore, it is sensitive to both a change in power and a change in phase relationship. Consequently, if either power or phase changes in one of the signals, the coherence value is affected. Another important feature is that the value of coherence for a
single epoch is always one, regardless of the true phase relationship and the differences in power between the two signals. Over successive epochs the coherence measure is dependent on power and phase of the two signals along the epochs. If there is no variation over time in the original relationship between the two signals, the coherence value remains the same. This means that coherence does not give direct information on the true relationship between the two signals, but only on the stability of this relationship with respect to power asymmetry and phase relationship (Guevara & Corsi-Cabrera, 1996).

In contrast to correlation, coherence is a very complex measurement and is not easy to understand. Its physiological relationships seem to be different for different frequency bands and probably also for different brain regions (Gasser, Jennen-Steinmetz, & Verleger, 1987). However, the coherence value implies, with high probability, at the amount of coupling between the electrical activities of two brain sites. In terms of neuronal processes one could also claim that coherence gives an indication of the amount of information exchange between the two brain regions recorded. Whether this information exchange is done via cortical connections or via thalamus and/or basal ganglia, however, cannot be decided yet (Petsche, Lindner, Rappelsberger, & Gruber, 1988).

Overall, coherence as a measurement of brain wave activity has shown great potential in reflecting anatomical and neurophysiological parameters. These parameters may include axonal sprouting, synaptogenesis, myelination, and pruning of synaptic connections (Kaiser & Gruzelier, 1996). Some authors believe that measuring the degree
of functional interrelatedness of brain areas by coherence estimates has turned out to be more efficient than amplitude mapping (Petsche, Richter, von Stein, Etlinger, & Filz, 1993). The next part of the literature review will cover EEG studies in more depth, discussing EEG coherence as it relates to growth patterns, genetic factors, and environmental influences in preschool children.

Coherence Activity of Children

Cerebral maturation is not a smooth process of steady growth. One can observe certain quantum jumps during prematurity, as well as infancy and childhood (Kellaway, 1957). The peak period of EEG maturation is well into adulthood (after age 30), at a time when biological aging of body tissues has already started and physical capabilities of athletic performances have clearly passed their peak (Niedermeyer, 1993). Therefore, being aware of maturational differences of the EEG when working with children is important. The population of this study will be children of preschool age (3 to 6 years), so only EEG coherence characteristics differentiating this group will be discussed.

Thatcher and colleagues (Thatcher, Walker, & Guidice, 1987) have conducted a large-scale, cross-sectional, developmental study of EEG coherence. A total of 577 children, ranging in age from 2 months to early adulthood, with a full range of IQ and no obvious neurological disorder were tested using standard EEG procedures. EEG coherence was assessed for electrode pairings (based on 16 electrodes without the vertex sites FZ, CZ, and PZ) in four frequency bands (Delta, 0.5 to 3.5 Hz; Theta, 3.5 to 7 Hz; Alpha 7 to 13 Hz, and Beta, 13 to 22 Hz).
Overall, the authors found five dominant growth periods in intrahemispheric corticocortical coupling from birth to adulthood. Only the first two will be discussed as they relate to the focus of this study. The first period, from birth to 3 years of age, was a topographically scattered developmental change, which primarily involved a decrease in coherence and phase. Beyond 3 years of age a much more uniform and synchronized pattern of development was observed. The second period, from 4 to 6 years, involved a marked increase in phase of the left frontal-occipital coupling (Fp1-O1 versus Fp2-O2). By the age of five the left frontal-occipital pair achieved 90% of adult value in contrast to the right similar pair achieving 90% of adult value by 9 years of age. This is an example of the left hemisphere leading the right hemisphere in development. Another area of significant development was noted in the right frontal intrahemispheric derivations between the ages of 3 and 5 (Fp2-F4, Fp2-C4, and Fp2-P4). Finally, the magnitude of the biennial increment in coherence in the right frontal region (Fp2-F4) was nearly three times that from the homologous left hemisphere (Fp1-F3). This study provided evidence of differential rates of human cerebral development and relatively specific anatomical connections within the left and right hemispheres developing at different rates and at different postnatal onset times.

Other researchers have also found interrelations between various cortical zones developing gradually in the course of ontogeny (Ibatoullina, 1987; Venger & Ibatoullina, 1989). For example, from 4 to 6 years of age, the number of statistically significant intrahemispheric and interhemispheric functional connections (expressed in EEG coherence at rest) doubled. Analyses of the EEG correlates of attention in children have
shown that, at the ages of 5 to 6, connections between various areas in the cortex are diffuse (Alferova, 1977; Ibatoullina, 1987; Venger & Ibatoullina, 1989). However, in 7- to 8-year-old children a more organized form of local activity was seen primarily in the frontal-central cortical area of the right hemisphere (Alferova, 1977). These findings suggest that there is a developmental strengthening in the functionality of cortical relations, as well as increasing possibilities for functional integration between cortical zones as a child gets older.

The previous studies have shown developmental hemispheric differences in growth rates, onsets of growth, and the effect of age on the strength of cortical connections. Since coherence reflects synchronized activity between different areas of the brain, determination of the basis of this activity is important. It would be useful to ascertain how much of the coherence activity is a reflection of genetic influences, experiential or environmental factors, or both. The following two studies have examined the effects of genetics and environment on the EEG coherence activity of 5- and 6-year-old twins.

The first study involved 20 pairs of monozygotic (MZ) twins and 17 pairs of dizygotic (DZ) twins 5 and 6 years old (Ibatoullina, Vardaris, & Thompson, 1994). EEG was recorded from 8 electrodes (F3, F4, P3, P4, C3, C4, O1, and O2) during a resting condition and an orienting response (OR) condition. The OR condition consisted of pure tones of various frequencies in 5 second durations with intervals between stimuli varying randomly between 15 and 30 seconds. The two frequency bands of interest were 3.9 to 6.7 Hz and 7.1 to 10.3 Hz. Although the authors collected frequencies from 0 to 45 Hz
they did not give a rationale for choosing these frequencies. The authors chose to employ structural equation modeling to test different genetic and environmental models. There were 32 coherence pairs in each condition.

In the resting condition, results showed more than one third (14) of the coherence pairs manifested significant twin resemblance. Five of these were affected by shared environmental factors (3.9-6.7 Hz: F3-C3; 7.1-10.3 Hz: F3-C3, F4-C4, C3-C4, and P3-P4) and one by both shared environmental and additive genetic factors (7.1-10.3 Hz: F3-F4). The last eight significant connections were influenced by additive or dominant genetic factors (3.9-6.7 Hz: F4-C4, F4-P4, C3-P3, C4-P4, P3-O1; 7.1-10.3 Hz: C4-P4, P3-O1, C3-P3). During the OR condition, results showed about one third (13) of the coherence pairs exhibited significant twin resemblance. Three of these were affected by shared environmental influences (3.9-6.7 Hz: F3-C3; 7.1-10.3 Hz: F3-C3, P3-P4). Two were affected by both shared environmental and additive genetic factors (3.9-6.7 Hz: C4-P4; 7.1-10.3 Hz: F4-C4). Eight were influenced by genetic factors (3.9-6.7 Hz: F3-P3, F4-C4, F4-P4, F4-O2, C3-P3, C4-O2, P3-O1; 7.1-10.3 Hz: P3-O1).

The study also calculated coherence for homologous zones (between corresponding sites in opposite hemispheres, e.g., F3 and F4, C3 and C4) across hemispheres as for all pairings within hemispheres. Three of eight interhemispheric connections showed environmental influences (3.9-6.7 Hz: F3-F4; 7.1-10.3 Hz: C3-C4, P3-P4) and one shared environmental and genetic factors (7.1-10.3 Hz: F3-F4) during the resting condition. One significant connection was found during the OR condition that
showed environmental influences (7.1-10.3 Hz: P3-P4). Overall, genetic influences had little effect on interhemispheric coherence.

According to Thatcher, Krause, and Hrybyk (1986), intrahemispheric connections can be classified into two groups: short-distance connections, which are connections between adjacent zones (e.g., frontal and central), and long-distance connections, which are connections between nonadjacent, or separated zones (e.g., frontal and occipital). During the resting condition of the twin study (Ibatoullina, et al., 1994), three short-distance connections were environmentally influenced and seven connections were genetically determined. Only one long-distance connection was genetically determined. The short-distance connections were more genetically determined than long-distance during the resting condition. During the OR condition four short-distance connections were environmentally influenced and five were genetically determined. Three long-distance connections were genetically determined. The short-distance connections were mixed in relation to influences while all long-distance connections were genetically determined during the OR condition.

The overall results of this study showed functional connections in the cortex of 5- and 6-year-old twins during resting and OR conditions were determined by both genetic and environmental factors. The first finding was that during the OR compared with the resting condition, genetic factors tended to dominate activity particularly in intrahemispheric long-distance connections. The second finding was that long-distance connections intrahemispherically were more genetically determined than short-distance
connections. The final finding was that interhemispheric connections were primarily environmentally determined.

The second study examined environmental and genetic influences in intrahemispheric coherences during a resting condition with eyes closed (van Baal, de Geus, & Boomsma, 1998). This study involved 167 5-year-old twin pairs consisting of 33 monozygotic males (MzM), 34 dizygotic males (DzM), 37 monozygotic females (MZF), 32 dizygotic females (DZF), and 31 dizygotic opposite gender (DOS) twins. EEG was recorded from 14 electrodes but only 10 were used for the analysis (Fp1, Fp2, F3, F4, P3, P4, C3, C4, O1, and O2). The frequency band of interest was 4.0 to 7.5 Hz since Theta is a major frequency band for children (Niedermeyer & Lopes da Silva, 1993). These authors also chose to employ structural equation modeling to test different genetic and environmental models.

The authors calculated intrahemispheric coherences for the following 14 combinations of scalp locations. Short-distance coherences consisted of prefrontal to frontal (Fp1-F3, Fp2-F4), of prefrontal to central (Fp1-C3, Fp2-C4), of central to occipital (C3-O1, C4-O2), and of parietal to occipital (P3-O1, P4-O2). Long-distance coherences consisted of prefrontal to parietal (Fp1-P3, Fp2-P4), of prefrontal to occipital (Fp1-O1, Fp2-O2), and of frontal to occipital (F3-O1, F4-O2).

The results showed coherences between adjacent short-distance electrodes (e.g., Fp1-F3 & P4-O2) were mostly accounted for by environmental influences. Longer distances (e.g., Fp2-P4 & Fp2-O2) were influenced for the largest part by genetic factors. Broad heritabilities ranged from 30 to 71%, with a mean of 49%. That is, 30% of short-
distance connections were influenced by genetic factors and 71% of long-distance connections were influenced by genetic factors. Therefore, 70% of short-distance connections and 29% of long-distance connections could have been environmentally influenced intrahemispherically.

In summary of coherence activity in 3- to 5-year-old children, the above literature review noted a couple of trends. The first trend identified was that hemispheres develop at different rates. The next trend noted a growth of functional connections that are diffuse between various areas of the cortex. The genetic studies showed both environmental and genetic influences in intrahemispheric as well as interhemispheric connections. Intrahemispherically, long-distance connections are determined more genetically than short-distance connections. This finding occurred in both studies across both resting and orienting response conditions. Interhemispherically, connections were primarily environmentally determined. Now that children's inherent coherence activity has been identified, the literature review will focus on EEG coherence studies performed in relation to music training.

Coherence and Music Training

As stated previously, most studies on EEG and music training have examined older populations who have had either several years of music training or none at all. Reviewing these studies will help to generate some hypotheses in relation to what direction children's neurophysiological connections may grow. The following section will first review EEG coherence studies in relation to musicians and nonmusicians. Then
the review will examine EEG coherence in children as they have been exposed to pre- and post-music training interventions.

Petsche, Lindner, Rappelsberger, and Gruber (1988) did one of the first published papers on the neurophysiological studies of brain processes related to music perception. These authors conducted an EEG coherence analysis comparing musically trained and nonmusical students. There were 75 students, 40 males (average age 24.6 years) and 35 females (average age 22.7 years), and of these, 52 had musical training which was defined as "having had instruction on a musical instrument or in singing for periods of at least 5 years, regardless of success" (p.140). Nineteen electrodes were used based on the 10-20 system connected with ear lobe electrodes as reference. Five frequency bands were chosen to reduce the data: Theta, 4-7.5 Hz; Alpha, 8-12.5 Hz; Beta1, 13-18 Hz; Beta2, 18.5-24 Hz; and Beta3, 24.5-31.5 Hz. The authors examined both local (intrahemispheric) coherence and interhemispheric coherence while the students listened to Mozart's string quartet KV 458. One minute test periods were interspersed between two periods of EEG at rest of the same length. For the analysis of EEG data, all possible pairings (171) for each frequency were examined using the Wilcoxon matched pairs test. The baseline condition was statistically compared to the listening to music condition and significant changes between the two conditions were reported.

Comparing the entire group of students, the authors found almost negligible local coherence but found considerable increases of interhemispheric coherence in the Beta2 band (18.5-24 Hz) between the posterior temporal and the parietal regions. In other
words, listening to Mozart in general links these areas of the two hemispheres functionally closer together than they are linked at rest.

The next part of Petsche and colleagues' (1988) study compared the musically trained versus nontrained group. With intrahemispheric coherence, only musically trained students showed zones of locally increased coherence in several frequency ranges whereas untrained students did not. In particular, these increased frequencies and areas included Theta (4-7.5 Hz) in left temporal area; Beta1 (13-18 Hz) in temporoparietal area; Beta2 (18.5-24 Hz) in the occipitoparietal area; and decreased Alpha (8-12.5 Hz) activity in the left frontal area.

In relation to interhemispheric coherence, only musically trained students displayed increased interhemispheric coherence mainly in the Beta2 (18.5-24 Hz) range and between the temporoposterior, the parietal, and the occipital regions. The untrained students showed a decrease of interhemispheric coherence in the occipital region in the Beta2 band (18.5-24 Hz). The authors proposed that in musically trained students larger areas are involved in arousal and there is a stronger functional coupling of the sensory brain regions. Between both musically and nonmusically trained groups the left temporal region seems to play a decisive role since the temporal regions are not involved in students without musical training. In addition, there were different levels of engagement of the Beta2 (18.5-24 Hz) ranges between trained and untrained students.

A study by Petsche, Richter, von Stein, Etlinger, and Filz (1993) addressed EEG coherence while listening to Mozart’s first movement of the string quartet KV 458. This study had a total of 39 participants (19 male and 20 female) from 13 to 68 years old with
different attitudes toward music (including some professional musicians). This study focused on interpreting hemispheric engagement while listening to music. The authors wanted to study all possible coherence values among the 19 electrodes (i.e., 171 values) and to report any significant changes among those values. The method of analysis was based on comparing the differences between a resting condition and task condition and only reporting the differences between the two. The same bandwidths were used as in the previously discussed study by Petsche and colleagues (1988).

Results from musically trained individuals showed that the most significant increases in coherence were found connected to the temporal electrodes on both sides of the head. The largest numbers of intrahemispheric coherence increases were found in the upper Beta bands (24.5-31.5 Hz) irrespective of the hemisphere. As for hemispheric asymmetry, the Theta (4-7.5 Hz) and Alpha (8-12.5 Hz) bands behaved more independently of the Beta bands (13-32 Hz). The fewest significant increases were found in the Theta band (4-7.5 Hz). The authors stated that the Theta band seemed to be less indicative of the hemisphere most involved in the processing of music. Although no hemisphere seemed to be preferred, the authors felt that the number of intrahemispheric increases was a good indicator of hemispheric activation while listening to music.

Johnson, Petsche, Richter, von Stein, and Filz (1996) examined differences in the spontaneous EEG signal in relation to music training. Coherence was inspected from participants being in an at rest condition. The participants were 49 males, 24 of them were musically trained (mean age = 26.7 years, SD = 9.5 years) and 25 had no music training (mean age = 21.2 years, SD = 8.0 years). Music training was operationally
defined by the authors as having at least five years of music training (i.e., 5 years of
private voice or instrumental lessons) before beginning puberty. Data was collected from
19 electrode sites referenced to the ear lobes. The spectrum of the EEG between 1.5 and
31.5 Hz was divided into six frequency bands: Delta (1.5-3.5 Hz), Theta (4.0-6.5 Hz),
Alpha 1 (7.0-9.0 Hz), Alpha 2 (9.5-12.5 Hz), Beta 1 (13.0-18.0 Hz), and Beta 2 (18.5-
31.5 Hz). Coherence values were estimated among all pairs of electrodes (171 values per
frequency band). The coherences were broken up into two groupings: intrahemispheric
(using the vertex electrodes within each hemisphere) and interhemispheric. Analysis
consisted of the Wilcoxon matched pairs test comparing the two groups and the
significant differences were reported.

In relation to intrahemispheric coherence, participants with music training had
significantly higher coherence values (more coupling) in both hemispheres than subjects
without training. Of these the most striking differences occurred in the lower frequencies
(Delta and Theta) and the two highest frequency bands (Beta1 and Beta2), with
differences in Theta being most prominent. Both hemispheres showed significant
differences between groups. However, differences in the left hemisphere predominated in
Alpha1 and Alpha2 frequency ranges. Generally, the posterior regions of both
hemispheres showed more differences than the anterior parts, concentrated around P4, T6,
and T5.

Significant differences in interhemispheric coherence were also higher in
participants with music training. These differences primarily concerned the Delta, Theta,
Beta1, and Beta2 bandwidths in the posterior temporal and parietal regions. In the Theta
band (4-7.5 Hz), the coherence values between the right temporal and parietal regions and the left frontal regions were higher in participants with music training than those without training. This study has shown that distinctive coherence differences can be used to differentiate between participants with and without music training during a resting condition. Significant differences in coherence patterns suggest a higher level of cortical connectivity in participants with music training.

The previous three studies exploring the differences of EEG coherence in relation to musicians and nonmusicians identified some similar patterns. One study by Johnson et al. (1996) examined the groups at rest, while the other two examined the groups while listening to Mozart. While sitting at rest, participants with music training had significantly higher intrahemispheric coherence values (more coupling) in both hemispheres than subjects without training. The posterior regions of both hemispheres showed more differences than the anterior parts. Significant differences in interhemispheric coherence were also higher in participants with music training. In both intrahemispheric and interhemispheric connections the differences occurred in the lower frequencies (Delta, 1.5-3.5 Hz and Theta, 4.0-7.5 Hz) and the two highest frequency bands (Beta1, 13.0-18.0 Hz and Beta2, 18.5-31.5), with differences in Theta being most prominent.

In the two studies that compared resting to listening to Mozart, musically trained participants again showed the most increases in coherence activity. With intrahemispheric coherence, only musically trained students showed zones of locally increased coherence in several frequency ranges whereas untrained students did not. The most significant
increases in coherence were found connected to the temporal electrodes on both sides of
the head and independently in the Beta bands (13.0-31.5 Hz). In relation to
interhemispheric coherence, only musically trained students displayed increased
interhemispheric coherence mainly in the Beta2 (18.5-24 Hz) range and between the
temporoposterior, the parietal, and the occipital regions. In addition, there were different
levels of engagement of the Beta2 (18.5-24 Hz) ranges between trained and untrained
students.

These studies indicated that distinctive coherence differences can be used to
differentiate between participants with and without music training across conditions. In
addition, the significant differences in coherence patterns suggest a higher level of cortical
connectivity in participants with music training. The next part of the review details two
studies related to examining brain wave activity in relation to music training intervention.
The studies focused on younger populations but only examined power activity. Review of
these power studies will help identify parameters for this study.

Altenmuller, Gruhn, Parlitz, and Kahrs (1996) attempted to demonstrate changes
in cortical activation patterns after a five-week music training period. The purpose of the
music training was to increase the ability of students to differentiate correct and incorrect
musical periods. Nine students, ages 13 to 14, were put into three different groups. The
first group (a) was given verbal instructions. The second group (b) was instructed
musically by means of playing. The third group (c) received no instructions and served as
the control. The students’ Direct Current EEG (DC-EEG) activity was recorded both
before and after the music training. DC-EEG was recorded from 12 electrode sites over
left and right frontal (F3/F4), fronto-basal (F7/F8), anterior temporal (T3/T4), posterior temporal (T5/T6), parieto-temporal (PT3/PT4), and parietal (P3/P4) positions. While having brain activity recorded, students listened to sixty short melodies and were asked to judge each melody as balanced or not balanced.

Data on mean amplitudes were analyzed with a repeated measures ANOVA. Mean amplitudes were derived between the frequencies from DC to 30 Hz. Within-subjects factors included the type of music presented, correct or incorrect judgment, and electrodes. The repeated measures factor was the pre- and post-brain wave measurement. The between-subjects factor, group, was defined as the three levels of instruction. In order to detect differences in topographic distribution rather than in amplitude, the data were normalized and ANOVA was repeated on the normalized values.

Results from the first brain wave measurement indicated similar patterns in all three groups producing a widespread activation of both frontal lobes and the anterior temporal regions. Data from the second measurement clearly differed between the groups. In both training groups (A and B), the activity increased over the left and right frontal cortex. Group A additionally showed a pronounced increase over the left frontal region and a moderate increase over the entire left hemisphere. Significant sites included F3, T3, T5, PT3, and P3. Group B showed a pronounced increase over the right frontal regions and over posterior parietal regions of both hemispheres. Significant activity sites included F4, F8, P4, and P3. The nontraining group (C) showed a moderate global decrease of activity, a known effect related to habituation to the experimental procedure (Altenmüller, 1993). These results demonstrated that musical training produced certain
cortical brain activation patterns and that these activation patterns depend on the teaching strategies applied.

Flohr and colleagues (Flohr & Miller, 1993, 1995; Flohr, Miller, & Persellin, 1996; Miller & Flohr, 1995; Miller, Flohr, & Persellin, 1996) have done numerous studies with children on the relationship between music and electrophysiological responses. In one of their recent studies (Flohr et al., 1996), they explored the effects of music training on brain wave activity of preschool children. Twenty-two children, 4- to 6-years-old, were recruited from a local child development center for the study. Each child was placed randomly into groups receiving either music instruction or regular classroom instruction. The music instruction consisted of singing, playing instruments, moving, listening, and creating taught by a music teacher. The music group received seven weeks of instruction while the control group received regular classroom instruction.

After the music training period was completed the children’s brain wave activity was recorded. Quantitative EEG (QEEG) data was collected from 19 electrode sites based on the 10-20 system (Jasper, 1958). The frequencies consisted of Delta (.5-4 Hz), Theta (4.5-8 Hz), Alpha (8.5-12 Hz), Beta1 (12.5-16 Hz), Beta2 (16.5-20 Hz), Beta3 (20.5-24 Hz), Beta4 (24.5-28 Hz), and Beta5 (28.5-32 Hz). Brain wave activity was collected during four conditions: baseline eyes-open, listening to music, listening to nature sounds, and assembling puzzles from the Object Assembly subtest of the WPPSI-R (1989). The authors only examined the results of the puzzle condition since they were curious about the effects of music training on spatial-temporal ability. The results showed that children in the music group produced less Beta (12-16 Hz) activity in the right
posterior region than the children in the control group during the puzzle (Object Assembly) condition. These results have demonstrated that music training can influence preschool children’s performance on a spatial-temporal task as evidenced by brain wave activity.

Both of these studies have shown that brain wave activity in children, as measured by EEG power, can be affected by short-term music training interventions. The Altenmuller et al., (1996) study demonstrated that different teaching strategies promote different brain wave activation. The Flohr et al., (1996) study utilized a more comprehensive music training program on preschool children and found more efficient, albeit localized, brain wave activity. These last two studies provided a good foundation for studying the effects of music training on brain wave activity, in particular with preschool children. The next section will summarize the entire literature review and develop support for the purpose of this study.

Summary of Previous Studies

The neurophysiological and educational disciplines have identified a window of opportunity for children to learn. Although this window generally applied to the first decade of life, the recognized window for music training has been the preschool years, 3- to 5-year-olds. Since the preschool years have been shown as a time of abundant brain growth (Chugani, 1998), identifying the effects of music training on brain wave activity in children would be useful.

The EEG has been noted as an ideal noninvasive technique to measure these developmental and cognitive changes generated by music training, particularly with EEG
coherence. EEG coherence can more closely reflect anatomical and neurophysiological parameters such as axonal sprouting, synaptogenesis, myelination, and pruning of synaptic connections and may be used to index such processes (Kaiser & Gruzelier, 1996; van Baal, et al., 1998).

EEG studies have examined the effects of genetic factors and environmental influences on children's brain wave coherence activity (Ibatoullina, et al., 1994; van Baal, et al., 1998). Overall, these studies have found that some connections in the brains of 5-year-old children can be environmentally influenced. In particular, localized areas and interhemispheric connections present the best possibility for the influence of music training.

Studies comparing EEG coherences in musicians and nonmusicians have also identified patterns (Petsche et al., 1988; Petsche et al., 1993; Johnson et al., 1996). While resting and listening to music, musicians have shown increased coherence activity compared with nonmusicians. In particular, Theta differences were found in posterior regions during the resting condition. In addition, Beta differences were found interhemispherically while listening to music compared to the resting condition.

Only a few studies have compared the effects of music training as an intervention with children (Altenmuller et al., 1996; Flohr et al., 1996). Although these studies examined EEG power instead of coherence, they found some patterns of identifiable activity. The study conducted by Flohr and colleagues (Flohr et al., 1996) is of particular interest. They implemented an integrative music training program and used different
tasks to tap into different types of cognitive processing. To date, there have been no studies of the effects of music training on EEG coherence in preschool children.

Purpose of This Study

The purpose of this study was to examine the effects of music training on neurophysiological activity of preschool children as measured by EEG coherence. This study continued in the direction of Flohr, Miller, and Persellin, (1996) with a couple of additions. First, the music instruction period lasted for 10 weeks instead of seven weeks. Second, the QEEG measure examined coherence instead of power. Finally, brain wave activity was recorded both before and after the music training intervention. Connected areas of the brain were identified that played a part in cognitive processing while sitting at rest with eyes-open, listening to music, and while performing a spatial-temporal reasoning task.

The main hypothesis of this study was that neurophysiological parameters, and hence cognitive processing, were affected by music training as evidenced by EEG coherence activity. More specific hypotheses included:

1. During the eyes-open condition, the music training group will exhibit greater intrahemispheric and interhemispheric coherence than the control group in the Theta band.

2. During the listening to music condition, the music training group will show greater localized coherence activity than the control group in the Beta bands.

3. During the Object Assembly condition, the music training group will display greater global interhemispheric coherence activity, particularly in the Beta bands.
CHAPTER II

METHOD

Participants

A total of 20 preschool children, 10 girls and 10 boys, initially participated in the study. Two children dropped out during the music training period and two more children refused their post-test EEG recordings leaving a total of 16 children completing the study. See Table 1 for the children’s demographic information. The participants attended a child development center adjacent to a local university. The children were primarily Caucasian and from a middle-class environment. The children were recruited through an informational meeting at the school. All parents of 4- to 5-year-old children were invited and given a letter about the meeting and the study. Parents signed an informed consent form after reviewing it with their child.

Procedure

Participants’ brain wave activity was recorded individually between 9:00 A.M. and 2:00 P.M. throughout the week. The children were told that the experimenter wanted to take pictures of their brain while they listened to music and played a game. The children were then informed about putting the Electro-cap on their heads (Electro-Cap International, 1983). After the Electro-cap impedance reached below 5 Kohms for each site the child was moved to a testing area where they sat and performed the tasks.
Table 1

Demographic Information of Participants

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<th>Control Group</th>
<th>Music Training Group</th>
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<td>Sex</td>
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<tr>
<td>Boys</td>
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<tr>
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<td>Range</td>
<td>56 - 71 months</td>
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First, they stared at a smiley face to measure the eyes-open condition. Next, in the listening to music condition, they listened to a classical piano sonata (Mozart’s KV 448) through earphones placed over their head. Finally, in the Object Assembly condition, the children performed the Object Assembly test from the WPPSI-R (1989).

The children were randomly stratified to participate in a music training group (MT) or control group (CT) which did not receive music training. The music training took approximately ten weeks to complete. The music instruction included singing, playing instruments, moving, listening, and creating and was taught by a state certified music teacher. A group of four nationally known early childhood educators reviewed the music lessons and agreed they were typical early childhood music activities. A copy of each of the music training lessons and references can be found in the Appendix. At the end of the music training brain wave activity of each participant from both groups was
re-recorded. Brain wave activity was collected in a similar manner as in the pre-test recording. The children were given a picture of their brain map while listening to the music as compensation for participation.

Apparatus and Recording Procedure

The device used to collect the EEG information was the NeuroScan SCAN System. This is a computer-based system configured and distributed by NeuroScan Incorporated. It is designed to measure the electrical activity of the brain and to allow statistical analysis and topographic presentation of this activity. It consists of a computer called the SCAN computer for acquisition of EEG data, and a set of amplifiers called SynAmps.

The SCAN 4.0 computer consists of a Tangent IBM-Compatible 133 MHZ Pentium CPU, a Tangent SVGA monitor, keyboard, mouse, and SCAN software. The SynAmps (Model 5083) are a 24-channel amplifying system. The ACQUIRE software records and displays up to 24 channels of continuous EEG data. Saved EEG data then can be processed after the fact using an EDIT module.

An Electro-Cap, containing nineteen sewn-in tin electrodes, was placed on the head of each child and aligned correctly using the standard procedures recommended by the manufacturer (Electro-Cap International, Inc., 1983). Sewn-in electrodes correspond to the international 10-20 system (Jasper, 1958). The ground was placed in a midline location between FpZ and FZ. Linked earlobes served as the reference.

Amplifiers were calibrated at the beginning of the data collection using the manufacturer's internal calibration signal and results in the -.95 to 1.05 range were
acceptable. The Analog to Digital rate was set to 500Hz. Data were collected in the DC mode with DC correction of 70%. High and low pass filter settings were set for this study at 30 and 1.0, respectively, for data collection during the tasks. The gain was set at 1000× and the 60 Hz notch filter was off per recommendations of the manufacturer.

Impedance is the electrical resistance between the skin and the electrode with value expressed in kohms. Impedance was kept below 5.0 kohms and was balanced across all channels within plus or minus 3.0 kohms. Impedance was measured at the beginning and at the end of data collection as a control measure.

An EEG sampling rate of 256 Hz was used for the data collection. This rate provided maximum resolution of the data and was the recommended rate by NeuroScan for recording ongoing or spontaneous EEG data on their system.

EEG Data Analysis

Despite attempts to minimize artifact generation, raw EEG generally contains artifact. Two artifact rejection procedures were used to remove contaminated segments. First, visual editing for eye and movement artifact was done. Second, computerized rejection of artifacts took place on all epochs and removed epochs containing a reading greater than 75 microvolts in any of the 19 data channels at any time during the tasks performed. The 75 microvolts cutoff was chosen because children generally have EEG recordings up to that amplitude. Anything higher can be considered artifacted data (Neidermeyer, 1993). Editing was performed blind as to group membership.

After the editing was completed, each recording was epoched. Epoching is when the program removes the data with artifacts and places all the clean data continuously.
Then the data was averaged with the FFT algorithm to generate the different bandwidths. The frequencies from 1 Hz to 30 Hz were broken into seven bandwidths: Delta, 0.5-4.0 Hz; Theta, 4.5-8.0 Hz; Alpha, 8.5-12.0 Hz; SMR, 12.5-16.0 Hz; Beta1, 16.5-20.0 Hz; Beta2, 20.5-24.0 Hz; and Beta3, 24.5-28.0 Hz. The term SMR denotes sensory motor rhythm borrowed from animal research. SMR has been associated with the low Beta activity localized near the sensory motor strip in cats. After the FFT procedure coherence files were generated from the pre- and post-conditions for each participant. Finally, each record was exported individually for statistical analysis.

Data Transformation and Statistical Analysis

Coherence was analyzed separately for each bandwidth compared across conditions (eyes-open, listening to music, and Object Assembly). The reason for analyzing each bandwidth separately was that they represent different levels of cognitive engagement (Gasser, Jennen-Steinmetz, & Verleger, 1987). There were 171 coherence values generated for each bandwidth and condition.

The initial data distribution was both skewed and kurtotic. Therefore data were transformed using the formula "transformed coherence = log (untransformed coherence / 1 - untransformed coherence)" to obtain a normal distribution of the data (Thatcher, McAlaster, Lester, Horst, & Cantor, 1983, van Baal, de Geus, & Boomsma, 1998).

The normalized data were then submitted to multiple between group ANCOVAs for analysis. Multiple ANCOVAs were used to factor out pre-test variability and to maximize connectivity changes between the two groups after experimental manipulation. One ANCOVA was conducted for each electrode pair independently for each condition.
(eyes-open, listening to music, and Object Assembly) and frequency (Delta, Theta, Alpha, SMR, Beta1, Beta2, and Beta3). The independent measures were group, CT or MT. The dependent measures were the post-QEEG electrode pairs and the covariates were the pre-QEEG electrode pairs. This large number of ANCOVAs helped to identify significant trends in the data (Marosi, Harmony, Becker, Reyes, Bernal, Fernandez, Rodriguez, Silva, & Guerrero, 1995).
CHAPTER III

RESULTS

Eyes-Open Condition

The significant ANCOVA results for each frequency are reported in Table 2. Overall, 38 differences were found across all the frequencies between the two groups. The Delta band had 15 differences (39% of total), Theta band had 12 (32%), Alpha had 3 (8%), SMR had 2 (5%), Beta1 had 1 (3%), Beta2 had 3 (8%), and Beta 3 had 2 (5%). The significant differences for each frequency are displayed in a topographical and graphical format in Figures 4 through 10. The graphs on the figures show the pre- and post-coherence measures for each group to help identify trends in the data.

The general trend in the Delta band showed the CT group increased coherences while the MT group showed decreased coherences. Two thirds of the differences involved a frontal site in the electrode pair with the other site being either temporal, parietal, or occipital. The remaining one third were in the posterior regions of the brain. In the Theta band the trend switched and showed decreased coherences in the CT group and increased coherences in the MT group. All the differences were found to be in pairings between central, parietal, temporal, and occipital sites. The Alpha, SMR, and Beta1 bands showed similar patterns as the Theta band. The Alpha band showed significant differences in some central, temporal, and occipital connections. The SMR
and Beta1 bands showed frontal, central, and parietal connections. The Beta2 and Beta3 bands showed a mix of increases and decreases for each group. These occurred primarily with one site in the frontal region and the other site in the temporal and parietal areas.

Table 2

Analysis of Covariance Results of the Eyes-Open Condition Between the CT and MT Groups

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<tr>
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**Note:** Each ANCOVA has df of 1 and 13. Only significant results are presented.
Figure 4. Eyes-open condition - Delta bandwidth (0.5-4.0 Hz). Significant coherence differences displayed in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 5. Eyes-open condition - Theta bandwidth (4.5-8.0 Hz). Significant coherence differences displayed in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 6. Eyes-open condition - Alpha bandwidth (8.5-12.0 Hz). Significant coherence differences displayed in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 7. Eyes-open condition - SMR bandwidth (12.5-16.0 Hz). Significant coherence differences displayed in topographical and graphical format. Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 8. Eyes-open condition - Beta1 bandwidth (16.5-20.0 Hz). Significant coherence differences displayed in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 9. Eyes-open condition - Beta2 bandwidth (20.5-24.0 Hz). Significant coherence differences displayed in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 10. Eyes-open condition - Beta3 bandwidth (24.5-28.0 Hz). Significant coherence differences displayed in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Listening to Music Condition

The significant ANCOVA results for each frequency are reported in Table 3. Overall, 45 differences were found across all the frequencies between the two groups. The Delta band had 5 differences (11%), Theta band had 8 (18%), Alpha had 4 differences (9%), SMR had 7 (16%), Beta1 had 7 (16%), Beta2 had 6 (13%), and Beta 3 had 8 (18%). The significant differences for each frequency are displayed in a topographical and graphical format in Figures 11 through 17.

The general trend in the Delta band showed the CT group decreased coherences while the MT group showed increased coherences. These differences primarily occurred in connections between the frontal, central, temporal, parietal, and occipital areas. In the Theta, Alpha, and SMR bands the trends were similar to the Delta band. The Theta connections were found in the central, temporal, parietal and occipital sites. The Alpha connections were in the frontal, central, temporal, parietal, and occipital sites. The SMR connections showed predominantly one site in the frontal area and the other sites in the central, parietal, and temporal areas. The Beta1 and Beta3 bands showed a mix of increased and decreased coherences for each group. The Beta2 showed decreases in the CT group and increases in the MT group. The Beta1 and Beta2 connections showed a similar pattern as the SMR connections with one frontal site and the other site to the posterior regions. The Beta3 band showed diffuse connections in all areas.

Object Assembly Condition

The significant ANCOVA results for each frequency are reported in Table 4. Overall, 17 differences were found across all the frequencies between the two groups.
Table 3

Analysis of Covariance Results of the Listening to Music Condition Between the CT and MT Groups

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<td>.009</td>
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<tr>
<td></td>
<td>PZ-P4</td>
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<td>.034</td>
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<td></td>
<td>PZ-O2</td>
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Note: Each ANCOVA has df of 1 and 13. Only significant results are presented.
Figure 11. Listening to music condition - Delta bandwidth (0.5-4.0 Hz). Significant coherence differences in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 12. Listening to music condition - Theta bandwidth (4.5-8.0 Hz). Significant coherence differences in topographical and graphical format. 

*Note:* Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 13. Listening to music condition - Alpha bandwidth (8.5-12.0 Hz). Significant coherence differences in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 14. Listening to music condition - SMR bandwidth (12.5-16.0 Hz). Significant coherence differences in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 15. Listening to music condition - Beta1 bandwidth (16.5-20.0 Hz). Significant coherence differences in topographical and graphical format.
Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 16. Listening to music condition - Beta2 bandwidth (20.5-24.0 Hz). Significant coherence differences in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 17. Listening to music condition - Beta3 bandwidth (24.5-28.0 Hz). Significant coherence differences in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
The Delta band had 5 differences (29%), Alpha had 3 (18%), SMR had 5 differences (29%), Beta2 had 3 (18%), and Beta 3 had 1 (6%). The significant differences for each frequency are displayed in a topographical and graphical format in Figures 18 through 22.

The general trend in the Delta band showed both groups with increased coherences, with the MT group showing stronger increases than the CT group. These differences primarily occurred with one site in the frontal area and the other site in the temporal, parietal, and occipital areas. In the Alpha, SMR, and Beta3 bands the trends were similar to the Delta band. The Alpha connections were found in the fronto-temporal areas and centro-parieto-occipital areas. The SMR connections showed predominantly one site in the frontal area and the other sites in the central, parietal, and temporal areas. The Beta2 band showed a mix of increased and decreased coherences for each group. The Beta2 and Beta3 connections showed primarily frontal-frontal connections with one connection to the occipital region.
Table 4

Analysis of Covariance Results of the Object Assembly Condition Between the CT and MT Groups

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<td>.029</td>
</tr>
<tr>
<td></td>
<td>Fp1-O2</td>
<td>4.74</td>
<td>.049</td>
</tr>
<tr>
<td></td>
<td>F7-F4</td>
<td>5.23</td>
<td>.040</td>
</tr>
<tr>
<td>Beta3</td>
<td>Fp1-F7</td>
<td>10.25</td>
<td>.007</td>
</tr>
</tbody>
</table>

Note: Each ANCOVA has df of 1 and 13. Only significant results are presented.
Figure 18  Object Assembly condition - Delta bandwidth (0.5-4.0 Hz). Significant coherence differences in topographical and graphical format. Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 19  Object Assembly condition - Alpha bandwidth (8.5-12.0 Hz). Significant coherence differences in topographical and graphical format.

Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 20. Object Assembly condition - SMR bandwidth (12.5-16.0 Hz). Significant coherence differences in topographical and graphical format. 
Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 2.1. Object Assembly condition - Beta2 bandwidth (20.5-24.0 Hz). Significant coherence differences in topographical and graphical format.
Note: Untransformed coherences were used in the graph to aid in interpretation of results.
Figure 22. Object Assembly condition - Beta3 bandwidth (24.5-28.0 Hz). Significant coherence differences in topographical and graphical format. Note: Untransformed coherences were used in the graph to aid in interpretation of results.
CHAPTER IV

DISCUSSION

The main hypothesis of this study was that neurophysiological parameters would be affected by music training as evidenced by EEG coherence activity. As the results have shown, connections between different areas of the brain can be affected by environmental influences such as music training. Overall, the eyes-open and listening to music conditions showed more significant coherence changes between the groups than the Object Assembly condition. These differences between the conditions imply that the music training affected neuronal connections in unique ways. To identify the unique contributions of music training, each condition will be discussed in turn in relation to their hypotheses, in addition to other relevant findings. The discussion will end with the limitations of this study and future possibilities for this line of research.

Eyes-Open Condition

The hypothesis for this condition stated that the music training group would exhibit greater intrahemispheric and interhemispheric coherences than the control group in the Theta band (4.5-8.0 Hz). The Theta frequency connections were found significantly different between the groups. The MT group showed increased coherences with each electrode pair while the CT group had mostly decreased with some increased coherences. As displayed in Figure 5, the significant differences were all in the posterior
regions of the head. In addition, all seven of the significant intrahemispheric connections occurred in the right hemisphere. This finding was consistent with the findings from the Johnson, Petsche, Richter, von Stein, and Filz (1996) study. In their study, they found maximum coherence differences between musicians and nonmusicians at the right central and parietal regions.

Another finding in the study by Johnson, et al. (1996) concerned both intrahemispheric and interhemispheric connections. The differences occurred in the lower frequencies (Delta, 1.5-3.5 Hz and Theta, 4.0-7.5 Hz) and the two highest frequency bands (Beta1, 13.0-18.0 Hz and Beta2, 18.5-31.5 Hz), with differences in Theta being most prominent. The present study also found significant differences in the Delta (0.5-4.0 Hz) and Theta bands but not as many in the Beta (12.5-28.0 Hz) bands. Delta and Theta bands accounted for 71% of the differences while the Beta bands accounted for 21%.

The difference in findings between the present study and the Johnson et al. (1996) study can be explained by differences in the samples. For example, the average age in the study by Johnson, et al. was 27 years old for musically trained and 21 years old for untrained participants. In the present study, the average age for both groups was approximately 5 years old. Because of this age disparity, these differences may be developmental. Secondly, the musically trained group in the Johnson, et al. study had independently received at least five years of private voice or instrumental lessons before puberty. In the present study, the 10-week music training intervention was not as long as the Johnson et al. study. In addition, the children in the present study did not receive any
previous music training. These differences in experience would obviously generate
differences in brain activity.

Given the age of this study’s sample it makes sense that most of the differences
were found in the Delta and Theta bands. According to Petersen and Eeg-Olofsson
(1971), EEGs of preschool aged children show the posterior basic rhythm reaches 8 Hz
in this age range. Furthermore, the basic rhythm is frequently interrupted by
intermingled slow waves, mostly in the range of 1.5-4 Hz, extending from occipital into
the posterior temporal and, less markedly, into the parietal regions (Neidermeyer, 1993).

A relevant finding in this condition involved the pattern of activation changes in
the Delta band between the groups. Topographically, an activation pattern was found
similar to the occipital, posterior temporal, and parietal regions typically found in this
age range of children (Petersen & Eeg-Olofsson, 1971). The CT group showed mostly
increases while the MT showed mostly decreases in coherence values. These decreases
in Delta activity may suggest some type of EEG maturational process similar to the one
occurring in the second decade of life and characterized by the gradual reduction of the
intermixed slow activity (Neidermeyer, 1993). Taken one step further, music training
may help to generate more efficient growth of neuronal connections in the brain or to
speed up the developmental process. Overall, the present study has shown that
distinctive coherence differences can be used to differentiate children with and without
music training during a resting condition.
Listening to Music Condition

The hypothesis for this condition stated that the MT group would show greater localized or within hemisphere coherence activity than the CT group in the Beta bands. The Beta bands included SMR (12.5-16.0 Hz), Beta1 (16.5-20.0 Hz), Beta2 (20.5-24.0 Hz), and Beta3 (24.5-28.0 Hz). As stated previously, Beta rhythms are seen under a wide range of conditions and especially with attention and mental effort (Duffy, Iyer, & Surwillo, 1989). These frequencies accounted for 28 out of 45 (62%) of the significant differences between the groups. However, only 16 of the 28 connections were intrahemispheric while the other 12 were interhemispheric. The discussion will continue by examining functional relationships of the intrahemispheric and then interhemispheric connections.

The intrahemispheric or localized connections accounted for 16 of the differences with eight occurring in each hemisphere. Topographically, the significant localized connections are indicative of temporo-cortical connections used in processing auditory information (Kolb & Whishaw, 1990). These connections contain four distinct pathways that perform different functions in sensory analysis. The first is a hierarchical set of connections from the primary and secondary auditory areas (occipital and temporo-parietal areas or Heschl's gyrus and planum temporale respectively) ending in the temporal pole. This area is where the music is recognized by the children. The second set of connections goes from the auditory association areas (superior part of the temporal lobe) into the superior temporal sulcus. This is where the music is identified and classified. The third pathway projects from the auditory association areas into the medial
temporal regions. Although these third projections may not show up as coherence activity, they do play an important role in long-term memory. The fourth is a set of parallel projections from the association areas to the frontal lobes. Here the sensory analysis associates the music with motivational or emotional significance that is crucial for learning (Kolb & Whishaw, 1990).

Each hemisphere will now be examined in turn to identify more particular activations between the groups and centers of coherent activity. The left hemisphere showed more activation in the left frontal region especially between FP1 and F7 in all the Beta bands. This area of the brain has been shown to be involved in carrying out the operations of working memory (Goldman-Rakic, 1992). Working memory provides short-term activation and storage of symbolic information as well as manipulation of that information. In particular, the prefrontal cortex temporarily stores information against which current stimuli are judged. For example, a study by Knight (1984) examined EEGs of patients whose frontal lobes were injured. The patients compared current auditory stimuli with recently presented ones in order to detect whether they were the same or different. Frontal lobe patients displayed electrical activity unlike those of healthy participants performing the same task. These results suggested that patients did not store recent auditory information in memory the same way as did normal people. In the present study, the MT group showed an increase in activity within each Beta band while the CT group showed a decrease in the left prefrontal area. One interpretation of this is that the MT children were more adept at comparing the music they were listening to with previously heard music than the CT children.
The right hemisphere showed more of a temporo-frontal connectivity. The particular sites involved were T6, FZ, and F4. These connected sites are indicative of the projections from the auditory association areas to the frontal lobe involved in assigning significance to the music. In particular, studies have shown musical abilities related to the premotor areas (Lezak, 1995). For example, expressive amusia or avocalia (inability to sing) has been seen with lesions of either frontal lobe but occurs most often in association with aphasia when lesions are on the left (Benton, 1977). Impaired capacity to process musical elements such as pitch, rhythm, and phrasing tends to occur with right-sided anterior lesions (Shapiro, Grossman, & Gardner, 1981). Again, the MT group showed an increase in coherences with the CT group decreasing in coherence. The only exception was C4-T6, where the CT group showed more of a decrease in coherence than the MT group. Overall, the MT group showed increased connectivity in musically sensitive areas of the brain compared with the CT group.

Another relevant finding in this condition involved the 12 interhemispheric connections. These connections showed an increase of activation between hemispheres as well as anterior and posterior connectivity. In fact, nine of the 12 significant connections contained one site in the frontal lobe. Overall, the MT group showed increases while the CT group showed decreases in connectivity. These connections most likely go through either the thalamus or contralateral corticocortical association fibers (Nunez, 1981; Thatcher, Krause, & Hrybyk, 1986). The thalamus modulates activity coming in from the senses and in turn, projects to the neocortex (Kolb & Whishaw, 1990). The corticocortical association fibers are responsible for long distance feedback loop
connections between different regions of the brain (e.g., fronto-occipital fasiculi; Carpender & Sutin, 1983). In either case, it appeared that music training (a) increased activity within the feedback loops throughout the brain, and (b) increased functional connectivity between different contralateral regions of the brain while listening to music.

Another event that explains the interaction of the two hemispheres involves an emotional component. Heller (1990) proposed that feelings are associated with relative patterns of cortical activation of the right and left frontal and parietal regions. The right parietal lobe appears to play a special role in the mediation of arousal (Heilman, 1979), and the frontal lobes play a special role in emotional valence (Davidson, Schwartz, Saron, Bennett, & Goldman, 1979). Therefore when someone has a positive emotional response, the left frontal and right parietal regions would be more active (high arousal, positive valence) than the right frontal and left parietal regions. When someone has a negative emotional response, (low arousal, negative valence) the left frontal and right parietal would be less activated than the right frontal and left parietal areas. In the present study the connections Fp1-P4 were increased and Fp2-P3 were decreased for the MT group, while the opposite pattern occurred for the CT group. This activation pattern may suggest that the MT children had a more favorable emotional response and were more engaged while listening to the music than the CT children.

In summary, in the listening to music condition there were several interpretations made in relation to significant coherence differences between the groups. These differences have identified a topographical pattern of auditory analysis, increased working memory activation, increased activity between musically sensitive areas, increased
interhemispheric connectivity, and an activated emotional component while listening to music.

**Object Assembly Condition**

Contrary to the hypothesis, connectivity while performing this task was not as evident as the previous conditions. The hypothesis stated the MT group would display greater global interhemispheric coherence activity, particularly in the Beta bands. The results showed nine out of 17 significant differences were in the Beta bands. Out of these only three were interhemispheric and one of those showed decreased activity in both groups. The lack of a robust finding may be explained by: (a) gender differences in performing the Object Assembly test, and (b) the task itself and its relationship with the EEG parameters examined.

The gender differences can be explained from a study by Rappelsberger and Petsche (1988). In their study participants were asked to rotate cubes mentally, a task that purportedly tapped into visuo-spatial ability. The authors found different processing styles between males and females. The males showed increased coherence predominantly in the right parietal region, whereas the females showed predominant activity in the left parietal region. Interhemispheric coherence also showed distinct patterns between the males and females in almost all frequency bands. This difference in strategies employed by males and females may account for the lack of conclusive differences between the CT and MT groups. In other words, the performance variability between genders could statistically negate any meaningful differences.
The Object Assembly task itself and how it affects the EEG parameters examined may offer another explanation for the lack of a robust finding. In a study by Giannitrapani (1985), children between the ages of 11 and 13 performed the entire Wechsler Intelligence Scale for Children (WISC) (Wechsler, 1949) while EEG data was collected. Results showed that the Object Assembly subtest had the fewest correlations with EEG parameters as compared with the other subtests of the WISC. This suggests the task may require more than just a few neuroanatomical systems and defies localization (Gloning & Hoff, 1969). In addition, there may be other ways of examining the EEG that would explain the activity such as asymmetry or relative power.

Although this condition did not have as many significant activity differences between the groups, there were some identifiable patterns of activity. First, there was the left frontal working memory activation being more predominant in the MT than CT group. This was seen similarly in the music condition. Second, the working memory showed connections with the premotor and visual areas. Third, nonverbal memory was activated in the temporal lobes with increased connectivity to the premotor areas in the MT group. Simultaneously, the visual and association areas increased connectivity to the somatosensory strip in the MT group. Examined collectively and topographically, all these differences suggest the MT group showed increased connectivity in visuospatial processing compared with the CT group (Kolb & Whishaw, 1990).

Summary of Findings

In the eyes-open condition the results showed coherence differences between the MT and CT groups at the right central and parietal regions. These differences were found
Limitations and Future Directions

There are a few limitations of the present study, which when addressed can improve the quality of future research. These include statistical considerations and sample characteristics. Considerations of other factors can also lead to new areas of research.

The first of the statistical issues relates to sample size. This study had 16 boys and girls of various ages. For statistical purposes and power, having a larger sample size would be beneficial (e.g., at least 16 girls and 16 boys of one age for each group). There are always everyday problems in collecting data with children, so a group twice the size should initially be recruited to better guarantee a larger sample size. In addition, it would be prudent to have at least 5 to 10 cases for each variable (Tabachnik & Fidell, 1989). In the present study there were 1197 variables (171 for each of the seven frequencies) for each condition. Although this kind of statistical violation cannot always be prevented, a few data reduction techniques can be applied to help reduce the number of variables (e.g., factor analysis, principal components analysis, or multidimensional scaling).

Other sample limitations included age and gender characteristics. The range of ages, which were from 4- to 6-years-old in this study, may have been problematic as research has shown profuse developmental brain growth during the first decade of life (Chugani, 1998). Segregating children into cohorts, particularly when they are in the first ten years of their life, would help reduce the variability between age groups. In addition to the developmental growth, boys and girls develop differently and essentially perform some tasks differently (Lezak, 1995). When boys and girls are examined together, the
in the Theta band similar to the finding with musicians and nonmusicians found in a study by Johnson, et al. (1996). The results also suggested a maturational neuronal component in the MT group versus the CT group. Finally, the present study has shown that distinctive coherence differences can be used to differentiate children with and without music training during a resting condition.

In the listening to music condition there were several interpretations made in relation to significant coherence differences between the groups. These differences identified a topographical pattern of auditory analysis, increased working memory activation, increased activity between musically sensitive areas, increased interhemispheric connectivity, and activation of an emotional component while listening to music. All the increased activity was predominantly found in the MT group versus the CT group.

The Object Assembly condition did not show as many coherence differences as the two previous conditions. The lack of differences in this condition may have been due to gender differences of performing the task and/or a difficulty in localizing EEG differences. However, there were some topographical activities indicative of a visuospatial process occurring with increased connectivity in the MT group versus the CT group.

As the results have shown overall, connections between different areas of the brain in preschool children can be affected by environmental influences such as music training as evidenced by EEG coherence activity.
differences in performing tasks could possibly negate the data while attempting to identify neuroanatomical connections through EEG coherence. Therefore, analyzing their data separately may be better.

Regardless of the above limitations to be considered in future research, this is an exciting area of study. First, there is a shortage of studies with children in relation to electrophysiology and the efficacy of music training. In fact, to the author's knowledge, this is the first study examining these parameters with preschool children. Second, because the first decade of life is a prime window of learning opportunity for children, research in this area could be beneficial to help identify directions for educators. Third, with the advances of technology, combining functional MRI with EEG to localize activated brain areas more efficiently would be possible. Finally, varying the length and type of instruction offers many more possibilities. Studies could involve music instruction over longer time spans, determine longitudinal effects, and/or could determine effects of different types of music and/or instrumental instruction.
APPENDIX

MUSIC LESSONS AND REFERENCES
Lesson 1

Objective:
By the end of the week, each child will have explored environmental animal sounds.

I) Hello song:
Performance - Students will sing hello with the teacher, and may respond after the teacher sings a phrase such as "hello boys and girls". Words and music by Charity Bailey.

Materials: none.
— melodic — matching pitches.
— rhythmic — shorter/longer words and phrases.
— aesthetic — dynamics: loud/quiet/inside voices, etc.
— listening/movement — may show pitches with hand movements.

II) "Six Little Ducks":
Movement - Students will sing and perform movements with teacher.
— melodic — matching pitches/ quack sounds.
— rhythmic — experienced through movements.
— aesthetic — singing.
— listening/movement — fingerplay; may also walk around room.

III) "Fox and the Crow":
Listening/pre-reading - Students will listen to the story and interact through making animal noises and answering questions.

Materials: fox and crow puppets, fake cheese.
— melodic — exploring voices through making animal noises.
— rhythmic — longer/shorter animal sounds.
— aesthetic — dynamics; quiet/loud.
— listening/movement — making noises at appropriate times.
(Flohr and Smith)

IV) Mozart activity:
Listening - Students will listen to short segments of a piece. The teacher asks, "Show me the way the music sounds with your hands, arms, and face."

Materials: tape, tape player.
— melodic — showing contour with physical movements (up, down, high, low).
— rhythmic — discerning fast/slow.
— aesthetic — listening to the music.
— listening/movement — listening and deciding if music may represent an animal.
Mozart piano piece in D major.

V) Goodbye song:
Same as the hello song.
Lesson 2

Objective:
Same as Lesson 1.

1) Hello song:
Same as Lesson 1.

2) "Matilda the Gorilla":
Performance - Students will listen to the song and make animal sounds at appropriate times.
   - melodic — matching pitches when singing sounds.
   - rhythmic — singing sounds in correct order, longer/shorter sounds.
   - aesthetic — singing.
   - listening/movement — listening for story/sounds and moving like the gorilla.
   Words and music by Mary Rice-Hopkins, (Anderson).

3) Mozart listening:
   Movement - Students will listen to same segments of same piece as lesson 1 and then move like
   the animal they chose that segment to represent while listening to the music.
   - melodic — listening and showing melody with physical movements.
   - rhythmic — moving as if they were the animal.
   - aesthetic — listening to the music.
   - listening/movement — listening to the "animal" and moving like it.

4) Rain song:
   Performance/instruments - Students and teacher will discuss what types of animals may play in
   the rain. Teacher will give each student a drum and play the rain song for each animal. The
   students will play the drums with the teacher to represent each animal. For example: for a quiet
   or small animal, they will play quietly or on the floor. If they play to represent a bird, they may
   play their drum above their heads.
   - melodic — exploring animals sounds.
   - rhythmic — moving drums while playing or playing at different levels.
   - aesthetic — may sing with the teacher.
   - listening/movement — deciding to play quiet/loud and where to play.
   Song: "It Rained a Mist"-traditional folk melody.
   (Wirth, Stassevitch, Shotwell, & Stemmler, p.210).

5) Goodbye song:
   Same as hello song.
Lesson 3

Objective:

By the end of the week, each student will demonstrate the rhythmic elements of fast/slow and will have experienced a steady beat.

1) Hello song:

Same as Lesson 1.

2) Story: "The Fast White Rabbit and Slow Green Turtle":

Pre-reading - Students will listen to the story and represent the characters by movements of fast/slow. The students may decide the movements for fast and slow.

Materials: white rabbit and turtle puppets, story.
   — melodic — imitating sounds and tempo of characters.
   — rhythmic — showing tempo of characters.
   — aesthetic — listening to the story.
   — listening/movement — showing correct movements for characters.

3) Mozart listening:

Listening - Students will listen to same piece as week 1 and decide whether the segments are fast or slow. They will demonstrate by telling the teacher which picture to display on a board, the rabbit or the turtle, and playing their sticks fast or slow.

Materials: Mozart piece, pictures of rabbit and turtle, tape player, sticks.
   — melodic — listening to speed of melody.
   — rhythmic — discerning whether segment of piece if fast/slow and putting beat "in their hands or on their knees."
   — aesthetic — listening to the music.
   — listening/movement — listening for tempo and showing it with their hands.

4) "Hiyah, Hiyah":

Movement - Teacher and students will sing the song and show a slow beat by clapping, patting knees, tapping toes, walking around room, etc. Song may get faster and faster.

Materials: none
   — melodic — listening for the speed of the melody.
   — rhythmic — experienced through movement.
   — aesthetic — singing.
   — listening/movement — listening for beat and showing it with hands.

5) Goodbye song:

Same as hello song.
Lesson 4

Objective:
Same as Lesson 3.

1) Hello song:
Same as Lesson 1.

2) Story: "Fast White Rabbit and the Slow Green Turtle":
Reading/writing - Students will listen to story again, but this time will play sticks to represent fast and slow. Students will choose to be the turtle or the rabbit. They will also listen for changes made in the story.
Materials: rabbit and turtle puppets, sticks.
— melodic — exploring instrument sounds.
— rhythmic — experienced through playing instruments and showing tempos.
— aesthetic — listening to story.
— listening/movement — listening for the character they chose to represent/playing instruments.
(Flohr and Smith).

2) Mozart activity:
Listening/creating - Students will listen to two segments and decide if they are fast or slow. They will show fast/slow with movements.
Materials: Mozart piece, tape player.
— melodic — exploring sounds as they move.
— rhythmic — experienced through movement.
— aesthetic — listening to the music.
— listening/movement — discerning tempo.

4) "Beat is Steady":
Movement - Students will sing move around the room keeping a steady beat as the teacher plays the beat on the drum. The teacher may change from fast to slow throughout the activity. The students must "freeze" each time the drum stops.
Materials: drum.
— melodic — exploring slow/fast sounds.
— rhythmic — experience tempo with movement.
— aesthetic — singing/chanting.
— listening/movement — listening for tempo/ moving with tempo.
Tune: "Frere Jaques."

6) Goodbye song:
Same as hello song.
Lesson 5

Objective:
By the end of the week, each child will experience and demonstrate dynamic elements of loud/quiet and types of voices.

1) Hello song:
   Same as Lesson 1.

2) "Aunt Dinah's Gone":
   Listening - Students will perform this echo chant with the teacher. They will experiment with loud/quiet, whisper, singing, and other types of voices through echoing the teacher.
   Materials: none.
   — melodic — experimentation with types of voices.
   — rhythmic — echo chant correctly; may show rhythm with hands or feet.
   — aesthetic — singing/listening to the chant.
   — listening/movement — listening to what the teacher chants/showing rhythm.
   (Wirth, Stasievitch, Shotwell, & Stemmler, p. 147).

3) Mozart instrument play:
   Performance - Students will listen to a segment of a Mozart piece, and decide whether it is loud or quiet. They will then move in a circle playing their sticks loud or quiet with the music.
   Materials: tape, tape player, sticks.
   — melodic — listening for dynamic level.
   — rhythmic — playing the sticks according to the dynamics/keeping a beat.
   — aesthetic — hearing Mozart piece.
   — listening/movement/creating — showing rhythm through playing, listening to dynamics, creating a way to play the sticks.

4) Keyboard activity:
   Performing - The teacher will sing a folk tune (i.e., "Skip to my Lou") and each two students will have a turn to play the keyboard. There will be stickers on the designated keys to play. Each two students will have 10 seconds to play any keys they want before the teacher sings the song.
   Materials: keyboard, stickers.
   — melodic — experiencing a pitched instrument.
   — rhythmic — playing the keys in a rhythmic pattern fitting the song.
   — aesthetic — playing the keyboard.
   — listening/movement — listening to the song, playing the appropriate keys.
   The teacher will choose a traditional folk tune.

6) Goodbye song:
   Same as hello song.
Lesson 6

Objective:
Same as Lesson 5.

1) Hello song:
Same as Lesson 1.

2) "Aunt Dinah's Gone":
Movement - Students will perform chant to review types of voices with the teacher. First, they will echo in order to learn it. The teacher will lead the students around the room (if time allows) performing movements and clapping for loud/quiet, etc., while keeping a steady beat with the students.

Materials: none.
— melodic — experiencing various dynamic levels with their voices.
— rhythmic — experienced through moving/clapping hands.
— aesthetic — experimenting with their voices.
— listening/movement/creating — listening for dynamics, moving with dynamics, and creating movements to represent the dynamic levels.
(Wirth, Slussetwitz, Shotwell, & Stemmler, p. 147).

3) Keyboard activity: "Finger Wiggler Game," "Copy Cat Rhythms."
Teacher will model for the students how to play the game (purpose of learning finger names-1, 2, etc.) and how to play the clap the rhythms. (Students will clap as they say, "clap with me, hurry with me" in rhythm).

Materials: 3 keyboards, pictures of hands for game, circle stickers on keys to play on keyboards.
— melodic — experimenting with 3 black keys on piano.
— rhythmic — repeating rhythms by clapping and then on black keys.
— aesthetic — experiencing sounds of keyboard.
— listening/movement — listening and repeating rhythms by clapping.
(Pace)

5) "Nutcracker Suite":
Students will listen to the "March" movement from this piece and choose movements with sticks to show loud and soft. The teacher will help them keep a steady beat.

Materials: sticks, tape player.
— melodic — students will listen to the melody of the piece.
— rhythmic — showing dynamics through playing sticks.
— aesthetic — experiencing classical music played by stringed instruments.
— listening/movement — students may stand up and move around while playing their sticks to show loud/soft in the music.
(Tchaikovsky On Modern Mandolin Quartet).

6) Goodbye song:
Same as hello song.
Lesson 7

Objective:

By the end of the week, each child will demonstrate a steady beat and experience rhythmic elements of longer/shorter.

1) Hello song:

Same as Lesson 1.

2) "Octopus":

Movement/creating - The students will sing the song with the teacher in a circle. The students will choose movements to show longer/shorter for each type of fish in the song according to its size (little fish get short movements, etc.).


— melodic — singing.
— rhythmic — showing longer/shorter through hand and arm movements.
— aesthetic — singing.
— listening/movement/creating — listening to the song, showing rhythmic elements in movements, creating movements for longer/shorter.

(Diamond)

3) Keyboard activity:

Same as Lesson 6. Emphasize longer/shorter notes while clapping rhythm. Students will identify longer/shorter notes by playing them on the keyboards.

Materials: 3 keyboards, pictures of hands for game, circle stickers on keys to play on keyboards.

— melodic — experimenting with black keys on keyboard.
— rhythmic — clapping and playing rhythms.
— aesthetic — listening to notes played.
— listening/movement — repeating rhythms by clapping.

(Pace)

4) "Navajo Happy Song":

Listening - The teacher will perform the chant for the students while the students keep a steady beat with her. They will listen for the sound that does not sound like the others (the one that is accented). The students will perform the chant with the teacher after they have identified the accent, showing it by clapping louder on the accent. The students may move around in a circle while performing the chant. The accent will be on a whole word and a downbeat so the students will be able to identify it easily with their speech.

— melodic — chanting.
— rhythmic — shown through clapping, patting knees, etc.
— aesthetic — chanting.
— listening/movement — listening for the accent/showing it through clapping.

(Wirth, Stassevich, Shotwell, Stemmler, p. 116)

5) Goodbye song:

Same as hello song.
Lesson 8

Objective:
Same as Lesson 7.

1) Hello song:
Same as Lesson 1.

2) Octopus story:
Pre-reading - The teacher will read the story and the students will show the movements or "gulps" of the sea creatures. The "gulps" will be modified for longer/shorter according to the size of the fish. The students will move around the room to show longer/shorter.

   - melodic — making gulp sounds with voices.
   - rhythmic — showing gulps (longer/shorter) with hands.
   - aesthetic — listening to the story.
   - listening/movement — listening for longer/shorter and showing it with hands.

   (Diamond)

3) Keyboard activity:
Same as Lesson 7 - Students may explore other notes on the keyboard.
(Pace)

4) "Navajo Happy Song":
Movement/performance - The students will chant the song with the teacher, this time moving around the room to the beat of a drum the teacher plays. They will also (after example by teacher) play an accent on a key word given by the teacher each time.

   Materials: drum.
   - melodic — chanting.
   - rhythmic — experienced through moving.
   - aesthetic — chanting.
   - listening/movement — listening for the key word, moving to the beat.

   (Wirth, Stassevitch, Shotwell, Stemmler, p.116).

5) Goodbye song:
Same as hello song.
Lesson 9

Objective:

By the end of the week, each child will have experienced melodic elements of music through matching or imitating the pitches sol and mi.

1) Hello song:
   Same as Lesson 1.

2) "Down Came a Bat":
   Students will sing song with teacher and choose a movement to represent the "bat".
   Materials: none.
   - melodic — singing sol and mi.
   - rhythmic — making the bat movements.
   - aesthetic — singing.
   - listening/movement — listening for the pitches to sing and making the "bat" move up or down according to the pitch.

3.) So De-licious:
   Reading - The teacher will tell the story and the students will sing the title of the story on the pitches sol and mi at the appropriate times.
   Materials: So delicious puppets; story.
   - melodic — matching pitches.
   - rhythmic — showing sol and mi, with hand motions - up or down.
   - aesthetic — singing.
   - listening/movement — movements of hands and matching pitches.
   (Flohr)

4.) "Skeleton Jones":
   The teacher will play two examples from the song on tape and the students will identify whether the melody is going up or down. The teacher will then play the entire song while the students move around the room to the rhythm of the music.
   Materials: tape, tape player.
   - melodic — identifying "going up" and "going down".
   - rhythmic — shown through expressive movement to the music.
   - aesthetic — moving/dancing.
   - listening/movement — listening for up/down of melodic line and showing rhythm.
   (Adamson & Nakles).

5.) Goodbye song:
   Same as hello song.
Lesson 10

Objective:
Same as Lesson 9.

1) Hello song:
Same as Lesson 1.

2) "Down Came a Bat":
Same as Lesson 9.

3) "Boogie Man":
Same as Lesson 9 - "Skeleton Jones". Students will move around the room to the rhythm of the music. When teacher presses 'stop' button, students will "freeze". (Adamson & Nakles).

4) "Spooky Company":
Reading, writing/listening - The teacher tell the story and the students will show the movement of the melody with their hands while singing the "Old Lady's Song" with the teacher.
— melodic — showing melody.
— rhythmic — showing melody with hand movements.
— aesthetic — listening to the song story.
— listening/movement — listening for the melody and showing it with hands. (Flohr & Smith, p.58).

5) Goodbye song:
Same as hello song.
Lesson 11

Objective:
By the end of the week, each student will have explored and demonstrated through movement knowledge of various music mediums, specifically Native American, Dixieland, Folk, and Jazz.

1) Hello song:
   Same as Lesson 1.

2) "Boogie Man":
   Jazz - see Lesson 9 - freeze game.
   Materials: tape, tape player
   - melodic — exploring up/down.
   - rhythmic — free movement to the music.
   - aesthetic — listening to the music.
   - listening/movement — showing how the music sounds by moving around the room to the music.
   (Adamson and Nakles).

3) Mama Don't Allow:
   Listening/movement - Dixieland. The students will listen to the story and be allowed to move within the circle they are sitting in when they hear instruments play. The instruments will be recorded on a tape and will play at appropriate times during the story.
   - melodic — hearing the sounds of the instruments and the band in the story.
   - rhythmic — moving to the sounds of the instruments and the band.
   - aesthetic — listening to the story and instruments.
   - listening/movement — listening to the story and showing how the music sounds.
   (Hurd)

4) Listening activity by Leah Ordaz (Native American).

5) Goodbye song:
   Same as hello song.
Lesson 12

Objective:
Same as Lesson 11.

1) Hello song:
Same as Lesson 1.

2) "Wee Mah Weh":
Movement - folk. The teacher will put two lines of tape on the floor. The students will form two lines, one at each line of tape. When the music starts, the students will move to the music as they follow their line of tape to the other end of the room. One student from each line will go across then another student will start across, etc. When the students get to the end of the line, they will keep moving in one spot and watch their peers go across the tape. When everyone gets done, all students will be in a circle and continue to show how the music sounds until the end of the song.

Materials: tape, tape player, masking tape.
— melodic — showing how the melody moves (up/down).
— rhythmic — experienced through movement.
— aesthetic — listening to the music.
— listening/movement/creating — each student demonstrating how he/she thinks the music sounds.
(Griffith)

3) Mama Don't Allow:
Listening/movement - Dixieland - same as Lesson 11. This second time the students will play rhythm sticks when they hear the instruments or the band in the story.

— melodic — hearing the sounds of the instruments.
— rhythmic — playing the sticks when they hear the music.
— aesthetic — listening to the story and music.
— listening/movement — showing how the music sounds with the sticks.
(Hurd).

4) Listening activity by Leah Ordaz (Native American).

5) Goodbye song:
Same as hello song.
Lesson 13

Objective:
By the end of the week, each student will demonstrate a steady beat while interacting with rhythm through movement.

1) Hello song:
   Same as Lesson 1.

2) "Wee Mah Weh":
   Same as Lesson 12. This second time, the teacher will demonstrate a steady beat while students are moving across the tape. The students will continue with a steady beat when they have finished their turn and are watching their peers move to the music.
   Materials: tape, tape player, masking tape.
   — melodic — listening to the melody while moving across the tape.
   — rhythmic — showing how the music sounds through body movements.
   — aesthetic — listening to the song.
   — listening/movement/creating — each student demonstrating how he/she thinks the music sounds.
   (Griffith).


4) Activity: April

5) Goodbye song:
   Same as hello song.
Lesson 14

Objective:
  Same as Lesson 13.

1) Hello song:
  Same as Lesson 1.

2) "Run Molly Run".
  Movement/creating - The teacher will play the tape and the students will move freely around the
  room to the beat of the music (walking, jumping, hopping, clapping, etc).
  Materials: tape, tape player.
  — melodic — hearing the melody of the song.
  — rhythmic — demonstrating the movement of the music.
  — aesthetic — listening to the music, moving.
  — listening/movement — showing how the music sounds through hopping, jumping, etc.
  (Sweet Honey in the Rock).

3) Listening story by Leah Ordaz.

4) Activity: April.

5) Goodbye song:
  Same as hello song.
Lesson 15

Objective:
By the end of the week, each student will experience melody through singing and playing pitched instruments.

1) Hello song:
Same as Lesson 1.

2) "Beat is Steady":
Movement - The teacher will play a steady beat on the drum while the students move around the room keeping the steady beat and making up/down movements.

Materials: drum and mallet.
— melodic — movements of up/down.
— rhythmic — keeping a steady beat.
— aesthetic — responding to dynamics of the drum beat (loud/soft).
— listening/movement — listening to the drum and moving to the beat.

Tune: "Frere Jacques"

3) Mary Wore Her Red Dress:
Listening/performing - The teacher will read the story and the students will sing with the teacher. Each student will have a turn to play the guitar which will be tuned to a pentatonic chord.

— melodic — matching pitches while singing, playing a chord on a pitched instrument.
— rhythmic — exploring tempo on a pitched instrument.
— aesthetic — singing, playing a pitched instrument.
— listening/movement — listening to the story.

(Peek).

4) Goodbye song:
Same as hello song.
Lesson 16

Objective:
Same as Lesson 15.

1) Hello song:
Same as Lesson 1.

2) "Run Molly Run":
Movement - The teacher will play the tape. The students will be asked what movements they
would like to use to demonstrate the tempo of the music. Each movement will be done with up
and down motions.

   Materials: tape, tape player.
   — melodic — movements of up/down to the music.
   — rhythmic — demonstrating tempo through body movement.
   — aesthetic — listening to the music.
   — listening/movement — listening to the rhythm, choosing a movement to demonstrate.
   (Sweet Honey in the Rock).

3) "Mary Wore Her Red Dress":
Listening/performing - The teacher will read the story and the students will play the keys on the
keyboard that have a color sticker corresponding to color being sung about in the story. The
stickers will be on those keys that make up a pentatonic scale.
   — melodic — exploring pitches on the keyboard.
   — rhythmic — exploring tempo of the song while playing the keyboard.
   — aesthetic — playing the keyboard, listening to a pentatonic chord.
   — listening/movement — listening to the story, playing the correct keys.
   (Peek, M).

4) Listening activity: April.

5) Goodbye song:
Same as hello song.
Lesson 17

Objective:
By the end of the week, each student will have created a movement for a rhythmic activity.

1) Hello song:
   Same as Lesson 1.

2) "Little Red Caboose":
   Movement - The teacher will play the tape and the students will demonstrate how they think a train would move.
   Materials: tape, tape player
   — melodic — listening to the melody of the song.
   — rhythmic — creating movements of the "train".
   — aesthetic — listening to the music, showing phrases through movement.
   — listening/movement/creating — demonstrating how the train moves.
   (Sweet Honey in the Rock).

3) Who Stole the Cookies:
   Listening - The teacher will perform the chant. The students will decide on a way to keep the beat. The students will perform the chant and choose a peer who "stole the cookies" each time.
   — melodic — higher/lower inflections in the voice as the students chant.
   — rhythmic — matching accents in the chant, keeping the beat.
   — aesthetic — chanting.
   — listening/movement/creating — choosing a way to show the beat of the chant.
   (Wirth, Stassevitch, Shotwell, & Stemmler, p. 170).

4) "Shoo Fly":
   Movement - The teacher and students will perform the circle game and choose movements for the game.
   Materials: tape, tape player.
   — melodic — singing the song.
   — rhythmic — demonstrated through movements.
   — aesthetic — playing the game.
   — listening/movement/creating — choosing movements for the game.
   (Wirth, Stassevitch, Shotwell, Stemmler, p. 90).

5) Goodbye song:
   Same as hello song.
MUSIC REFERENCES


REFERENCES


