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ABSTRACT

This study examined the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained during a psychomotor response to musical stimuli. Subjects were 9 children, with mean age of 5.2 years old. Electrophysiological differences between two different musical conditions were also compared. EEG was recorded during 3 conditions: 2 minutes of sitting quietly with eyes open; 1 minute tapping in rhythm to classical music; and 1 minute tapping in rhythm to an Irish folk song. Thirty seconds of artifact-free data were edited for each of the conditions for each child. A Fast Fourier Transformation was performed on each edited EEG segment, and the relative power for each of the 21 electrodes was recorded for Delta, Theta, Alpha, and Beta brainwave frequencies. One-way ANOVA was performed for each of the frequencies for each electrode site. Results indicated a significant increase in the relative power percentages for the theta frequency in the eyes-open condition, and significant differences within the theta frequency at the right temporal sites and the left anterior temporal site between the eyes open and music conditions. Alpha activity decreased at all of the reported sites from the eyes open to music conditions, possibly due to the motoric output causing increased cognitive involvement. Results suggest that a basic step in understanding how to better educate children in music perception and production is to better understand how the brain responds to music. (JPB)

This paper was presented at the 1995 Texas Music Educators Conference in San Antonio, '
It is an extension of the 1993 study.

Developmental Quantitative EEG Differences During Psychomotor Response to Music

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The purpose of this study was to examine the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained during a psychomotor response t(music stimuli. Additionally, electrophysiological differences between two different musi(conditions were compared. Generally, results of experiments involving music processing have been highly dependent upon interacting variables such as the nature of the musical material or the nature of the task. In an earlier study differences were found between mu and baseline conditions. Nine of the thirteen children from the earlier study were given same task three years later. The children had EEG recorded during three conditions: 1) tw minutes of sitting quietly with their eyes open; 2) one minute tapping in rhythm to "Vivaldi:Allegro" at 130 m. m.; and 3) one minute tapping in rhythm to an Irish folk son "O'Keefe Slide/Kerry Slide" at 120 m.m. Thirty seconds of artifact-free data were edited f each of the three conditions for each child. A Fast Fourier Transformation (FFT) was performed on each edited EEG segment and the relative power for each of the 21 electrod(was recorded for the Delta, Theta, Alpha, and Beta frequencies. One-way ANOVA's were performed for each of the frequencies for each electrode site. Significant developmental differences were found in the Alpha frequency across the majority of the electrode sites.

Quantitative EEG Differences Between Baseline and Psychomotor Response to Music

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ABSTRACT

The purpose of this study was to examine the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained during a psychomotor response to music stimuli. Additionally, electrophysiological differences between two different music conditions were compared. Generally, results of experiments involving music processing have been highly dependent upon interacting variables such as the nature of the musical material or the nature of the task. Initially, one hundred children between the ages of four and six were selected to participate in a developmental research study. These children were individually evaluated using tests of cognitive ability, academic achievement, academic readiness, etc. Thirty-two of these children were randomly selected to participate in a brain mapping study. A subgroup from this population was selected for inclusion in this study based upon the artifact-free nature of the data. Thirteen children had EEG recorded during three conditions: 1) two minutes of sitting quietly with their eyes open; 2) one minute tapping in rhythm to "Vivaldi:Allegro" at 130 m. m.; and 3) one minute tapping in rhythm to an Irish folk song "O'Keefe Slide/Kerry Slide" at 120 m.m. Thirty seconds of artifact-free data were edited from each of the three conditions for each child. A Fast Fourier Transformation (FFT) was performed on each edited EEG segment and the relative power percentage for each of the 21 electrodes was recorded for the Theta, Alpha, and Beta II frequencies. One-way ANOVA's were performed for each of the frequencies for each electrode site. The bilateral central sites (C3 & C4) which reflect sensory motor activation and the bilateral temporal lobe sites (T3, T4, T5 and T6) which reflect auditory perception were reported in this study. There was a significant increase in the relative power percentages for the theta frequency in the eyes open condition compared to the two music conditions in the sensory motor strip sites (C3 and C4). There were also significant differences within the theta frequency at the right temporal sites and the left anterior temporal site between the eyes open and music conditions which supports previous research findings. Alpha activity decreased at all of the reported sites from the eyes open to music conditions. The motoric output requirement of the task seemed to cause greater cognitive involvement therefore, less alpha activation. Beta II activation decreased at the same sites that showed theta increases which suggest a related effect.

Quantitative EEG Differences Between Baseline and Psychomotor Response to Music

It has been commonly suggested that the right cerebral hemisphere plays a dominant role in the processing of musical sounds. Early studies served to distinguish hemispheric functioning during the processing of speech and nonspeech sounds. Milner (1962) tested adult patients with the Seashore Measurement of Musical Talent after temporal lobectomies were done for epilepsy. She discovered that timbre and tonal memory were impaired in those patients with right temporal lobectomies, but not so much by those with left temporal lobectomies. These findings suggested that tonal perception depended more on right temporal activity. Milner also noted that rhythmic elements seemed to be less hemispherically specialized.

By the 1970's it was becoming evident that the processing of musical sound was much more complex and dependent on individual characteristics. Studies began to focus more on functional brain tasks rather than generalized hemispheric dominance. During this decade the evolution of knowledge and technology allowed for more elementary and detailed research. A study by McKee, Humphreys, and McAdam (1973) examined the alpha activity over temporal-parietal sites while adult subjects were engaged in a musical task or in linguistic tasks of varying difficulty. Alpha ratios were found to be highest for the musical task and to decrease progressively with increasing difficulty of the linguistic tasks.

Bever and Chiarello (1974) examined cerebral dominance in musicians and nonmusicians. This important study disputed the generalization that speech activity occurred predominantly in the left hemisphere and that the right hemisphere was specialized for many of the nonlinguistic functions. This study was a leader in differentiating types of musical perceptions and suggesting the hypothesis that the left hemisphere dominates analytic processing and the right hemisphere is active in more holistically or spatially oriented processing. This hypothesis was supported by other studies conducted Davidson and Schwartz (1977), Gates and Bradshaw (1977), Johnson (1977), and Shannon (1980).

Dichotically presented stimuli of musical materials, such as melodies, chords, and musical tones, popular songs, singing, and whistling have produced a left-ear advantage. San Martini & Rossi (1988) found a moderate degree of EEG power asymmetry favoring the left hemisphere during a chord recognition task in a sample of adults aged 17 - 30 yrs. However, their data failed to support the hypothesis that individual differences of ear advantage in a dichotic chord test significantly affect the EEG frequencies.

The effects of two musical stimuli and silence were measured by monitoring the EEG within the temporal lobes of 30 children (Furman, 1978). The experiment also investigated the effects of music with text (a children's story), music alone, and text alone, on temporal lobe alpha production during the silence condition, with no significant difference evident between the two aural conditions. Other comparisons revealed no significant difference between age groups in the total number of seconds spent in alpha, but did find a significant correlation between age group and aural conditions.

A study that measured the auditory perception of music by topographic brain mapping (Breitling, Gunenther, & Rondot, 1987), examined right-handed normal, adult subjects. Musical material was broken down into a single note, a scale, and a melody. The results of this study revealed a predominance of left midtemporal electrical activity for the note and scale conditions, and a predominance of right midtemporal and frontal electrical activity for the melody. Later, Heft (1990) used brain mapping to measure the effect of music relaxation training on brain wave activity using two right-handed, college-age, female subjects. No significant differences were found in the brain wave activity under silence and contrasting music conditions.

Alpha wave production in musicians and nonmusicians has been examined in several studies (Wagner, 1975; Wagner & Menzel, 1977; McElwain, 1974, 1979). Consistent findings in these experiments reveal that musicians characteristically produce overall higher levels of alpha rhythms than nonmusicians. Prior research suggests that although there is a general tendency for the right hemisphere to process musical sounds, the functional lateralization is ultimately determined by the listener's interest, skills, and relationship to the stimuli. Ross (1992) summarizes that the neurology underlying musical and artistic creativity is a very complex affair that involves the participation of the whole brain, rather than just the right hemisphere, as currently popularized in the press.

Rhythmic training is an important part of early childhood music education (Weikart, 1989). Weikart contends that there is a relatinship between early rhythmic training and enhancement of preacademic skills. Research is needed to provide baseline data of how music perception is manifested within the brain. A clearer understanding of how music and music-related tasks are manifested in the electrical activity of the brain is the first step in developing better instructional strategies for early education in music.

The purpose of this study was to examine the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained during a psychomotor response to music stimuli. Additionally, electrophysiological differences between two different music conditions were compared. It is a popular notion that whereas in most people language is processed in the left cerebral hemisphere, music is processed in the right. Generally, results of experiments involving musical processing have been shown to be highly dependent on a series of interacting variables such as: the nature of musical material (familiarity, complexity, melodic vs. rhythmical vs. harmonic), the nature of the task (delayed vs immediate recognition, single vs multiple choice, degree of difficulty) and individual differences (sex, musical skill).

Methodology

Subjects. Initially one hundred four, five and six year old children were individually evaluated using measures of intelligence, academic achievement, personality, and social-emotional history. The subjects were recruited from the Child Development Center at the Texas Woman's University and neighboring schools. Thirty-two of these children were selected at random from the larger sample for the brain mapping portion of the study. A subgroup of thirteen children from that population was selected for inclusion in this study based upon the artifact-free nature of their data. All thirteen subjects were caucasian, six were boys and seven were girls. The mean age was 5.2 years. Eleven of the subjects parents were married while two were single parents. Thirty-eight percent of the fathers had attended graduate school, 23% had graduated from college, 23% attended college, 8% Graduated from high school only, and 8% had educational status unknown. Fifty-four percent of the subjects mothers attended graduate school, 15% graduated from college, 8% attended college, 15% graduated from high school, and 8% had educational status unknown. The mean family income from the selected subjects was $51,692. The mean Broad Cognitive Ability Score from the Woodcock-Johnson Revised Tests of Cognitive Abilities was 108.23 (100 is average, with a standard deviation of 15).

Procedures. Thirteen children had EEG recorded during three conditions: 1) two minutes of sitting quietly with their eyes open; 2) one minute tapping in rhythm to "Vivaldi:Allegro" at 130 m.m.; and 3) one minute tapping in rhythm to an Irish folk song "O'Keefe Slide/Kerry Slide" at 120 m.m. The children were given a pair of rhythm sticks that they were instructed to tap together in rhythm to one each of the music samples that they heard. The thirteen subjects had their brain electrical activity recorded using an electrocap containing twenty-one sewn-in, tin electrodes placed on the head of each subject. Electrodes were sewn into the cap according to the International 10-20 system (Jasper, 1958). The ground was placed at a midline location between Fpz and Fz. Linked earlobes served as the common reference. Brain electrical activity from the twenty channels was amplified. The digitized A/D output and the DC offset was calibrated at the beginning of the data collection and was stored on each subject's record. The A/D converter, used by the Brain Atlas was an 8-bit unipolar converter which yielded accurate readings to +/- 2.5 volts. Amplifier and DC offset values were controlled within a 2% range. High and low pass filter setting were set at 100 and 1.0 respectively. The gain was set at 20,000 and the 60 Hz, notch filter was set at the "in" position. An EEG sampling rate of 200 Hz. was used for the data collection of the eyes open and the music conditions. The impedances were kept below 4 kohms and were balanced across all channels within 3 kohms.

Brain Atlas III. The Brain Atlas III (BioLogic System Corporation, Mudelein, IL) is a personal computer-based system designed to measure the electrical activity of the brain. The hardware consists of a Zenith® AT compatible 386 CPU, a NEC MultiSync® EGA monitor, a 20 megabyte IOMEGA® Bernoulli disk drive and a 20 channel subsystem for analog-to-digital conversion, filtering and amplification. The Brain Atlas III software, version #2.35, Model #172 was used in data collection and analyses.

Macintosh® IIcx. The Macintosh IIcx computer was used in this study to present the digitized recordings of the two music samples. MacRecorder (MacroMedia, 1991) was used to digitize the sound recordings. The digitized sounds were saved as resource files and played back to each subject using Hypercard™, an authoring program for the Macintosh computer.

Data Analysis: Two second segments containing artifacts (e.g., eye blinks) were deleted from each of the three records (eyes open, music sample 1, and music sample 2) and a Fast Fourier Transformation (FFT) was calculated on the remaining data. The FFT separates the brain electrical activity into frequencies ranging from .5 to 32 hertz. For each of the three conditions, the amplitudes were separated into eight frequency band widths each containing eight sampled points of data as shown in Figure 1.

Figure 1.

FFT Band Widths Used in Data Analyses

Delta	.5 to 4 hertz
Theta	4.5 to 8 hertz
Alpha	8.5 to 12 hertz
Beta I	12.5 to 16 hertz
Beta II	16.5 to 20 hertz
Beta III	20.5 to 24 hertz
Beta IV	24.5 to 28 hertz
Beta V	28.5 to 32 hertz

Relative power was calculated for each FFT band width for each of the twenty-one electrode sites. Relative power is calculated by dividing the sum of the amplitudes for all frequencies by the sum of the amplitudes squared for each frequency range. Relative power represents the percentage of the total power found within a given frequency range at a particular site. The relative power percentages were calculated across subjects using the FFT Editing Program (Miller, 1993). The relative power percentages were averaged together across subjects for each of the conditions: eyes open, music sample 1, and music sample 2, then a repeated measures one-way ANOVA was computed for each electrode site. Since this task entailed the use of rhythmic motoric output in response to a musical input, the number of electrode sites discussed in this paper will be limited to bilateral temporal sites (T3, T4, T5, and T6) and bilateral motor strip sites (C3, C4). Previous research in this area has predominantly focused on alpha activity changes. For purposes of this study, three frequencies are discussed: theta, alpha, and beta II. The relative power mean and standard deviations for each of the three conditions and the ANOVA results for the theta frequency band (4.5-8 Hz) are presented in Table 1.

Table 1

Relative Power Statistics for the Theta Frequency Band (4.5-8 Hz)

	Eyes Open Condition		Music 1 Condition		Music 2 Condition		ANOVA	
Site:	Mean	S.D.	Mean	S.D.	Mean	S.D.	F value	p value
C3	23.23	1.86	27.87	0.71	28.70	0.40	126.42	**.001**
C4	24.74	1.83	26.16	0.69	28.00	0.28	26.25	**.001**
T3	20.65	1.26	22.48	0.44	23.85	0.32	56.99	**.001**
T5	24.13	1.70	27.18	0.40	28.57	0.43	68.04	**.001**
T4	21.98	0.67	22.01	0.34	23.85	0.55	64.23	**.001**
T6	26.17	1.56	25.75	0.81	26.50	0.39	2.44	.108

As shown in Table 1, the ANOVA revealed a significant difference ($p < .001$) between the three conditions for the sensory motor strip sites (C3 and C4). There was a significant increase in the relative power percentages from the eyes open condition as compared to the two music conditions. The ANOVA revealed a significant difference ($p < .001$) between the three conditions for the right temporal lobe sites (T3 and T5). There was a significant increase in the relative power percentages from the eyes open to the music conditions. The ANOVA revealed a significant difference ($p < .001$) between the three conditions for the left anterior temporal site (T4) but not the left posterior temporal site. There was a significant increase in the relative power percentages at T4 from the eyes open to the music conditions.

The relative power mean and standard deviations for each of the three conditions and the ANOVA results for the alpha frequency band (8.5-12 Hz) are presented in Table 2. As shown in Table 2 the ANOVA revealed significant differences ($p <.001$) between the three conditions for both sensory motor sites and each of the right and left temporal lobe sites. For each of the five

Table 2

Relative Power Statistics for the Alpha Frequency Band (8.5-12 Hz)

	Eyes Open Condition		Music 1 Condition		Music 2 Condition		ANOVA	
Site:	Mean	S.D.	Mean	S.D.	Mean	S.D.	F value	p value
C3	26.87	4.95	18.91	1.16	16.50	0.48	64.63	**.001**
C4	23.20	4.66	19.42	1.04	17.17	0.49	16.81	**.001**
T3	13.85	1.69	12.76	0.36	11.91	0.15	12.35	**.001**
T5	18.15	2.05	15.66	0.93	13.50	0.44	41.08	**.001**
T4	14.88	1.27	13.86	0.78	12.49	0.13	23.99	**.001**
T6	16.05	1.08	13.27	0.99	11.42	0.47	371.18	**.001**

sites, there was a decrease of relative power percentage within the alpha frequency band.

The relative power mean and standard deviations for each of the three conditions and the ANOVA results for the beta II frequency band (16.5-20 Hz) are presented in Table 3.

Table 3

Relative Power Statistics for the Beta II Frequency Band (16.5-20 Hz)

	Eyes Open Condition		Music 1 Condition		Music 2 Condition		ANOVA	
Site:	Mean	S.D.	Mean	S.D.	Mean	S.D.	F value	p value
C3	2.91	0.18	2.49	0.03	2.41	0.02	96.65	**.001**
C4	2.42	0.27	2.41	0.06	2.41	0.03	0.04	.960
T3	7.95	1.94	5.98	0.31	5.56	0.23	18.02	**.001**
T5	2.95	0.36	2.42	0.07	2.41	0.06	28.90	**.001**
T4	5.15	1.17	4.67	0.17	4.55	0.12	3.16	.061
T6	2.52	0.12	2.50	0.09	2.48	0.15	0.43	.655

As shown in Table 3 the ANOVA revealed significant differences ($p < .001$) between the three conditions for right sensory-motor strip area (C3) but not the left sensory-motor strip area (C4). There was a significant decrease in the relative power percentage within the beta II frequency band at C3 from the eyes open to the music conditions. The ANOVA revealed significant differences ($p < .001$) between the three conditions for the right temporal sites (T3 and T5) but not the left temporal sites (T4 and T6). In the right temporal region there was a significant decrease in the relative power percentages from the eyes open to the music conditions.

Discussion

The purpose of this study was to examine the electrophysiological differences between baseline EEG frequencies and EEG frequencies obtained during a psychomotor response to music stimuli. Electrophysiological differences between two different music conditions were also compared. Generally, results of experiments involving music processing have been highly dependent upon interacting variables such as the nature of the musical material or the nature of the task.

There was a significant increase in the relative power percentages for the theta frequency in the eyes open condition compared to the two music conditions in the sensory motor strip sites (C3 and C4). The eyes open condition involved no motor movements, the subject was instructed to sit quietly with eyes focused forward for two minutes. However, in the two music conditions the subjects were asked to tap a rhythm in time to an auditory presentation. The increased activation in the bilateral sensory motor strip area probabaly reflects the motoric output demanded by the music conditions.

In the right temporal lobe sites (T3 and T5), there was a significant increase in relative power from the eyes open to music conditions. In the left temporal lobe sites (T4 and T6), there was a significant increase in relative power only at T4, the anterior, left temporal region. These findings are consistent with previous research (Breitling, et. al., 1987) which indicated that perception of melody, as opposed to perception of a single note or scale, is localized in right midtemporal areas. The results of this study suggest that within the theta band there is an increase in activation in the right temporal regions and the anterior, left temporal regions in response to listening to music while maintaining a motoric output rhythm.

Consistent findings in previous research (Wagner, 1975; Wagner & Menzel, 1977; McElwain, 1974, 1979) revealed that musicians characteristically produce overall higher levels of alpha rhythms than nonmusicians. The present study used non-musician four, five and six year old children. Rather than an increase in alpha production during music perception, the subjects in the present study showed a significant decrease in the production of alpha activity. Alpha activation generally increases when the brain relaxes. If the subjects were simply asked to "sit back and listen" to the music, alpha activation would have probably increased. However, since there was an increased cognitive component to this task requiring the subjects to not only listen to the music, but also figure out the inherent rhythm, and produce a motoric output consistent with that rhythmic beat.

Since there was an increased cognitive component to this task as compared to previous research, activation changes in the beta frequencies were also evaluated. There is often an interaction between theta activation and beta activation depending upon the demands of the cognitive processing. There was a significant decrease in beta II frequency band (16.5-20 Hz) relative power percentages within the right sensory-motor strip area (C3) and the right temporal sites (T3 and T5). These decreases in relative power within the beta II frequency band may be associated with the concurrent increases within the theta frequency band. Moving from a baseline eyes open condition to a cognitive music condition, the subjects showed a increase in right, temporal lobe and right sensory-motor strip theta activation and a concurrent decrease in alpha and beta II activation.

The intent of this study was to evaluate the brain electrical activity associated with a music task involving listening to music while keeping a steady beat. Music education in rhythm has been shown to enhance other early educational achievement in young children (Weikart, 1989), yet many questions remain unanswered about how musical perception is received in the brain and how it may be enhanced. A basic step in understanding how to better educate children in music perception and production is to better understand how the brain responds to music. Future research will benefit from the advances in our ways of understanding the brain and measuring brain activity.

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