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EEG ASYMMETRY IN MUSICIANS AND NON-MUSICIANS DURING SUBJECTIVE REACTIONS TO MUSIC

by

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Abstract

EEG ASYMMETRY IN MUSICIANS AND NON-MUSICIANS
DURING SUBJECTIVE REACTIONS TO MUSIC

by

Marjorie S. Wiener

Adviser: Professor Howard Ehrlichman

EEG alpha was recorded from bilateral Frontal and Temporal-Parietal sites while 12 musicians and 12 non-musicians listened to eight musical excerpts previously categorized as "High Arousal" vs. "Low Arousal" and either "positive" (i.e., "joyful" or "soothing") or "negative" (i.e., "violent" or "sad") in mood. Following each excerpt, subjects rated their reactions to musically evoked moods and also rated: Involvement, Arousal, Visual Imagery, Verbalization, Familiarity and Liking. Results indicated that (1) Arousal ratings are associated with changes in Frontal EEG amplitude, (2) ratings of positive affect are related to Frontal left hemisphere activation. Excerpts categorized as "joyful" in mood evoked greater than average Frontal left hemisphere activation in comparison to other excerpts, and across all excerpts, higher Liking ratings were consistently associated with relative left hemisphere Frontal activation.

In addition to musical excerpts, two spoken excerpts were presented. Musicians and non-musicians showed similar patterns of greater left hemisphere Temporal-Parietal asymmetry during listening to speech than during listening to music. However, during music-listening, musicians and non-musicians exhibited different patterns of correlations between Arousal ratings and mood ratings for excerpts which elicited relative right vs. relative left hemisphere asymmetry. The data suggest that musicians and non-musicians may differ from each other in regard to the nature of left hemisphere involvement in reactions to music.

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Introduction

The rapidly expanding literature on the asymmetrical functioning of the cerebral hemispheres has recently included reports of laterality effects in emotional response (Tucker, 1981). Although still controversial, the hypothesis has been proposed that the left hemisphere may be more involved in positive emotional experience and the right hemisphere more involved in negative emotional experience. This hypothesis is based on evidence from clinical descriptions of emotionality following unilateral brain dysfunction (Gainotti,1972; Flor-Henry,1976; Sackheim,1980), and from studies of normal subjects responding to verbal or visual emotion-arousing stimuli. For example, among the latter studies, Ahern & Schwartz (1979) found that lateral eye movements in response to questions designed to elicit positive or negative emotional reactions suggested, respectively, left or right hemisphere activation. Reuter-Lorenz (1979) presented happy or sad faces tachistoscopically to either left or right visual fields and found that subjects responded more accurately and faster to happy faces than to sad faces when presentation was to the right visual field (left hemisphere). Dimond et al. (1976), using special contact lenses, showed motion pictures to either the left or right retinal hemi-fields. Films presented to the left half-fields (right hemisphere) were rated more negatively (more "horrific") than the same films presented to the right hemi-fields.

The usefulness of the EEG method for studying laterality in emotion was demonstrated by Davidson et al. (1978). These investigators recorded bilateral EEG from Frontal and from Parietal sites while subjects indicated their ongoing affective reactions to a television program by pressing a lever. Parietal EEG did not reflect lateralized effects, although activity over the right hemisphere was observed during both positive and negative emotional reactions. The Frontal leads, however, did show increased activation (lower alpha) over the left hemisphere during positive emotion and increased activation over the right hemisphere during negative emotion. These results were replicated by the same researchers in a second study where subjects generated positive or negative feelings, thoughts, or images associated with personal experiences.

The present study was designed to replicate and extend the results of Davidson et al. (1978) to the domain of affective response to music. EEG alpha measures were recorded from bilateral anterior and posterior sites while subjects listened to musical excerpts previously categorized as being either predominantly positive ("joyful" or "soothing") or negative ("sad" or "violent") in mood.

Emotional reactions to music exhibit many similarities to emotional reactions to "real-life" events. For instance, it has long been known that reactions to music are accompanied by the same signs of autonomic arousal that are seen during non-musical emotion. Early investigators demonstrated that music elicits changes in respiration rate, cardiovascular activity, and galvanic skin response (Gamble & Foster, 1906; Weld,1912; Wechsler,1925; Hyde,1927; Misbach,1932; Phares,1934; Landis & Hunt,1935). Contemporary researchers (Harrer & Harrer,1977) have provided additional confirmation that persons responding to music display extensive changes in indices of autonomic arousal.

It is also common practice to describe musical affective experiences with the same positive (e.g., "joyful", "triumphant", "exuberant") or negative (e.g., "sad", "melancholy", "tragic") emotional terms that are used to describe non-musical emotional states. However, "negative" affect in music may not be analogous to the non-musical negative affect (primarily depressed states) that have been associated with right hemisphere asymmetry. A specific difficulty with musical "negative" moods is that listeners who report that a composition evokes a "melancholy" mood may also paradoxically rate the same music as "very enjoyable" (Pratt,1968).* Laterality researchers have not yet been able to differentiate between varieties of negative emotions in terms of asymmetry effects so that it is not clear whether asymmetry

*The paradox may be related to a difference between musical and non-musical emotion which Meyer (1956) has pointed out: in music, tensions are aroused but also resolved during the course of the musical work; however in life tensions often go unresolved.

when music is not liked (i.e., "irritating", "unpleasant") might be different from asymmetry when music is experienced as "sad" albeit enjoyable. Consequently, subjects in this study were asked to rate their reactions to musically evoked moods and also to rate how much they liked or disliked each musical excerpt. Relationships between subjects' ratings and their EEG measures were subsequently analyzed and the following hypotheses were tested:

I. Ratings of affective reactions to music will be related to Frontal EEG measures, but not necessarily to Temporal-Parietal EEG measures.

I.A. Ratings of "positive" ("joyful", "soothing", or Liking) affective reactions to music will be related to Frontal left hemisphere asymmetry.

I.B. Ratings of "negative" ("sad", "violent", or Disliking) affective reactions to music will be related to Frontal right hemisphere asymmetry.

In addition to investigating whether EEG asymmetry is systematically related to musically evoked positive or negative affect, a second purpose of the present study is to compare the asymmetry patterns of musicians and non-musicians. The asymmetry of the cerebral hemispheres in music perception and the influence of musical training on that asymmetry are related topics that are of considerable interest to laterality researchers (Gates & Bradshaw,1977a; Bradshaw & Nettleton,1981). Much of the interest comes from comparisons between asymmetry for music and asymmetry for speech since music and speech are both temporally organized, auditory codes which require sequential processing for comprehension. The left hemisphere is widely believed to be specialized for sequential, analytic cognitive processing, and left hemisphere "dominance" for speech perception is usually observed. However, important aspects of music perception, especially melody recognition (Kimura,1967), have often been found to involve the right hemisphere more than the left. This apparent contradiction to the prevailing concept of left hemisphere specialization has led to a search for intervening variables which might mediate the relationship between direction of asymmetry and performance on musical tasks. In a seminal paper, Bever & Chiarello (1974) pointed to the sophistication of the listener as being of critical importance. These authors, using a monaural presentation method with normal subjects, demonstrated that ear (hemisphere) dominance for melody recognition could be biased to the right or to the left depending on the subject's level of musical experience. In the study by Bever & Chiarello (1974), each experimental trial consisted of a twelve-note "melody" (following Western music conventions, but without rhythm) and then a two-note sequence. Amateur-musician subjects exhibited a right ear (left hemisphere) superiority for accurate melody recognition, while musically naive subjects showed the more usual left ear (right hemisphere) superiority. Furthermore, the musician subjects also showed a trend (non-significant) towards right ear superiority for recognizing whether or not the two-note sequence had been embedded within the previously heard melody, but the non-musicians performed at only chance level with either ear on this excerpt-recognition task. The investigators interpreted these results as indicating that musical training promotes involvement of left hemisphere "analytic" cognitive processes, while untrained persons rely on right hemisphere, "holistic" processes.

Attempts to replicate Bever & Chiarello's results have produced some confirming support (Johnson,1977; Davidson & Schwartz,1977; Hirshkowitz,1978), but there are also several studies finding no differences between musician and non-musician subjects (Zatorre,1979; Gates & Bradshaw,1977b; Dowling,1978), and other studies where the results have been in direct opposition to Bever & Chiarelllo's hypothesis, i.e., studies where musicians have shown a left ear (right hemisphere) advantage and non-musicians a right ear (left hemisphere) advantage (Darwin,1969; Doehring & Ling,1971; McDonough,1973). Moreover, Bartholomeus (1974), Kimura (1967), Reineke (1981), and Goodglass & Calderone (1977) found a left ear (right hemisphere) superiority for highly-skilled musician subjects. Apparently, musical training does not necessarily lead to increased left hemisphere involvement in music perception, and the question of differences between musicians and non-musicians in regard to hemispheric activation remains unresolved.

In the studies cited above where musicians and non-musicians have been compared, the focus has been exclusively on musical cognitive operations. Typically, laterality effects have been assessed while subjects performed some sort of musical memory task with quasi-musical stimuli, recognizing or discriminating melodic fragments, single tones, chords, rhythmic patterns, etc. Musically trained persons have an advantage in such experiments since they have learned various mnemonic devices: verbal labels ("major third", "diminished chord", etc.); visualization of heard music (the imagined appearance of the music on the page); kinesthetic imagery (associations of performance motions with musical sounds). To perform the experimental task, the trained subject will probably resort to using any or all of the mnemonic aids at his disposal and various effects on laterality measures may ensue. Thus whenever musicians have shown an opposite pattern to that of non-musicians, it is not clear whether the result reflects a qualitative difference in the way musicians normally process music, or whether musician subjects are employing non-usual mnemonic strategies in response to the special demands of the particular experimental task. That is, when musical stimuli are presented as cognitive memory tests with right or wrong answers, attentional deployment and cognitive strategies may be very different from what they would be under normal circumstances.

This is especially likely for trained musicians who have a fund of "extra-musical" (e.g., verbal, imagic) strategies available for remembering whatever the Experimenter has delineated as important to remember.

Normally, comprehension of musical "meaning" involves a complex blend of both cognitive processes and affective reactions (Meyer,1956). For many listeners, regardless of training, the communication of affect is probably the most salient feature of musical experience. Indeed, music has often been called "the language of emotion" (Cooke,1959). In the present study, musician and non-musican listeners were compared in order to investigate whether musical training influences relationships between cerebral asymmetry and response to music when affective and cognitive processes are simultaneously engaged. To make the music-listening situation as normal and as "un-testlike" as possible, recordings of actual musical works were presented and it was emphasized to subjects that there were no "right" or "wrong" judgments since reactions to music are highly individual. The intent was to create a music-listening situation such that any difference between musicians and non-musicians in laterality patterns might be more clearly interpreted as representative of actual differences in normally-used musical processes.

To clarify interpretation of potential asymmetry differences between musicians and non-musicians during music-listening, a control condition of listening to speech was included in this study. It was anticipated that listening to spoken passages would elicit the usually observed left hemisphere asymmetry from our right-handed subjects. If musicians habitually use a more "analytic", left-hemisphere music-listening mode than non-musicians, then the difference between asymmetry in the speech-listening condition vs. asymmetry in the music-listening condition should be smaller for musicians than for non-musicians. On the other hand, if increased left hemisphere involvement in music perception results more from unusual task demands than from musical training per se, one would expect no difference between musician and non-musician subjects in asymmetry for speech vs. asymmetry for music. On the basis of previous EEG research (Osborne & Gale,1976; Doyle et al.,1974; McKee,1973) which has shown that posterior locations are sensitive to asymmetry differences to linguistic vs. non-linguistic stimuli, it was expected that speech vs. music asymmetries would be reflected primarily by the Temporal-Parietal leads. The following hypotheses were formulated:

I. Listening to speech vs. listening to music will be reflected in relatively greater Temporal-Parietal left hemisphere asymmetry for speech. Frontal EEG measures will not necessarily distinguish between speech vs. music conditions.

I.A. Musicians and non-musicians will not differ from each other in comparisons of asymmetry for speech-listening vs. asymmetry for music-listening.

Summary of Hypotheses

I. Listening to speech vs. listening to music will be reflected in relatively greater left hemisphere Temporal-Parietal asymmetry for speech. Frontal EEG measures will not necessarily distinguish between the speech vs. music listening conditions.

I.A. Musicians and non-musicians will not differ from each other in comparisons of asymmetry during speech-listening vs. asymmetry during music-listening.

II. Ratings of musical affective reactions will be related to Frontal EEG measures, but not necessarily to Temporal-Parietal EEG measures.

II.A. Ratings of "positive" ("joyful", "soothing", or Liking) affective reactions to music will be related to left hemisphere Frontal asymmetry.

II.B. Ratings of "negative" ("sad", "violent", or Disliking) affective reactions to music will be related to right hemisphere Frontal asymmetry.

Method

Subjects:

Twenty-four men and women, ranging in age from approximately 20 years to 50 years, participated in this study. Each person was interviewed on the telephone prior to the study in order to recruit 12 musicians and 12 non-musicians. A 'musician' was defined as a person currently performing or teaching music professionally and who had had at least ten years of formal training in music theory and instrumental technique. A 'non-musician' was defined as a person who had never played or sung professionally, and who had not had any formal training in music for at least ten years prior to participation in the study. All non-musicians, however, were required to be habitual classical-music listeners who said that at least 50% of the music they customarily listened to was classical music. Within each group of 12 musicians and 12 non-musicians, 6 were male and 6 were female.

The short form of the Annett Handedness Questionnaire was administered to each subject during the telephone interview, and only those persons who reported using the right hand for writing and also for at least nine of the other eleven activities on the questionnaire were asked to participate as subjects. Eleven subjects (6 musicians, 5 non-musicians) reported having one or more immediate family members who were left-handed.

Subjects were recruited through ads placed in newspapers and in New York City music conservatories.

EEG recording:

Beckman cup electrodes were affixed with Grass electrode cream to left and right Temporal-Parietal (TP) sites (midway between T_3 and P_3 and between T_4 and P_4) and to left and right Frontal sites (F_3 and F_4). Each of these four electrodes was referenced to vertex (C_z). In addition to scalp-recorded EEG, two Beckman disk electrodes were affixed to the outer canthi of each eye in order to record eye movements for later editing of eye-movement artifacts. Electrodes were reapplied, if necessary, until resistances were less than 9 K.

EEG from TP and Frontal sites and EOG were recorded simultaneously on an 8-channel Beckman Type R polygraph and on a Vetter 8-channel Model C8 FM cassette recorder. All EEG recording was done while the subject's eyes were closed.

Half an hour prior to each subject's EEG recording session, the input levels of the FM recording channels were calibrated so that a standard oscillator-generated 50 uv, 10 Hz. sine-wave signal registered an identical zero-Db peak-meter reading on each of the four EEG recording channels. Following the EEG recording session, the raw EEG polygraph record was visually inspected for the occurrence of gross artifacts (body or eye movements), and epochs containing artifacts were marked for deletion from further analyses.

The off-line analysis and a-d conversion of EEG data was done using an EEG analyzer (filtering and integration system) built specially for EEG asymmetry research. (A detailed description of this system can be found in Appendix A.) Integrator channels were calibrated so that the 50 μv, 10 Hz. oscillator signal recorded on the FM cassette at the beginning of the subject's session summed to 400 arbitrary units per 5-second epoch on each integrator output channel. The FM cassette recording of the raw EEG was then input to the EEG-analyzer where it was filtered for 8-13 Hz. activity and the filtered EEG integrated over an epoch-length of five seconds. At the end of each 5-second epoch, the digitalized output of the integration was displayed for each channel. For each of the twelve EEG recordings (i.e., 8 musical excerpts, 2 spoken excerpts, 2 silent periods) comprising a subject's session, 12 artifact-free 5-second epochs of filtered alpha activity from left and right Frontal and TP sites were integrated and digitalized for subsequent statistical analyses.

Procedure.

After attaching electrodes, the subject was seated in a comfortable armchair in an electrically-shielded, soundproofed, low-lighted cubicle adjoining the laboratory.

The experimenter in the lab was not visible to the subject, but the subject and the experimenter could easily converse with each other whenever necessary. EEG was recorded while the subject listened to 8 musical excerpts (MUSIC) and 2 spoken excerpts (WORDS). EEG was also recorded during two intervals where the subject sat quietly in silence. All musical and spoken excerpts were presented to the subject through Sennheiser light-weight earphones. Earphone placements on right and left ears were alternated so that each earphone channel went to the right ear for half the subjects and to the left ear for the other half of the subjects. Each musical or spoken excerpt was 80-85 seconds in duration, and during listening to each excerpt the subject had eyes closed.

For half the subjects, the spoken (WORDS) excerpts were presented first, followed by the MUSIC excerpts, and for half the subjects the MUSIC excerpts came first, followed by the WORDS excerpts. Subjects listened to one "practice" spoken excerpt before the two WORDS excerpts, and to one "practice" musical excerpt before the eight MUSIC excerpts. For all subjects, two rest-periods occurred where the subject sat in silence with eyes closed. One Silence period came after the WORDS excerpts, and one Silence period occurred between the 4th and 5th MUSIC excerpts.

In order to avoid arousing anticipatory or extra-musical associations, subjects were not told the title or the composer of a musical excerpt in advance of listening to it. Accordingly, it was to be expected that many subjects might try to guess the composer's identity while listening to the music. To make the spoken and musical passages more comparable in this respect, subjects were deliberately encouraged, "just for fun", to try to guess the identity of the unnamed composers being described in the spoken excerpts.

Stimuli.

Musical excerpts:

One of the major goals of this study is to see whether different musically-induced moods can be meaningfully related to hemispheric EEG asymmetry. On the basis of previous research on dimensions underlying verbal descriptions of reactions to music (Hevner,1935; Lundin,1967; Wedin,1972), four categories of musical moods were chosen to be used in this study. The four mood categories combine the "Arousal" factor which has been found to account for approximately 43% of the variance in ratings of reactions to music (Wedin, 1969,1972) with the "positive-negative" affect contrast which has been found to be associated with asymmetry effects. The resulting four mood categories are: (1) Positive affect-High arousal (e.g., "joyful", "jubilant"); (2) Positive affect-Low arousal (e.g., "soothing", "peaceful"); (3) Negative affect-High arousal (e.g., "violent", "stormy"); (4) Negative affect-Low arousal (e.g., "sad", "mournful").

Eight musical excerpts, two representing each of the mood-categories, were selected to be stimuli. The selection of the eight musical excerpts was done on the basis of three pre-test sessions conducted prior to the EEG study. Over the three pre-tests, a total of 40 persons rated 33 different musical excerpts. Each excerpt was rated on each of the four mood-categories, and the ratings were subsequently converted to 5-point scales. The two excerpts which both received high ratings in the same mood-category and relatively low ratings in the other categories were selected. (The 33 excerpts used in the pre-tests along with their mean ratings are listed in Appendix B.)

The adjectives representing each mood-category and the pair of excerpts* selected for the category are:

(1) Positive affect - High arousal:

Adjectives: joyful, exuberant, jubilant, exhilarated, vivacious.

Excerpts: (a) Bach: Suite #2 in b minor, Badinerie.

(b) Lalo: Symphonie Espagnole, Finale.

(2) Positive affect - Low arousal:

Adjectives: soothing, serene, peaceful, angelic, sweet.

Excerpts: (a) Bizet: Arlesienne Suite #2, Minuet.

(b) Schubert: Notturno.

*A list of the commercial recordings used in this study appears in Appendix D.

(3) <u>Negative affect - High arousal</u>:

Adjectives: violent, raging, stormy, wild, turbulent.

Excerpts: (a) Wagner: <u>Flying Dutchman, Overture</u>.

(b) Mahler: <u>Symphony #1, Finale</u>.

(4) <u>Negative affect - Low arousal</u>:

Adjectives: sad, melancholy, dark, brooding, mournful.

Excerpts: (a) Beethoven: "<u>Eroica" Symphony #3, Funeral March</u>.

(b) Fauré: <u>Élégie</u>.

<u>Spoken excerpts</u>:

Two brief passages were excerpted from Paul Henry Lang's <u>Music in Western Civilization</u> (1954). Each passage consisted of a description of a famous composer (Schubert in one excerpt, Chopin in the other) and his music. The same female voice was heard reading each passage.

Both musical and spoken excerpts had been previously tape-recorded and were played to subjects on a TEAC model A-3300S tape-recorder. Musical excerpts were taped directly from commercial stereo recordings, and overall volume levels were made as comparable as possible by ensuring that the loudest peak during any excerpt was equivalent to that of any other excerpt. Peak volume for each musical excerpt registered 0 Db on the TEAC vu-meter. Spoken excerpts were prerecorded at volume levels equivalent to that of the music.

Silence episodes:

During each of the two Silence episodes, subjects were simply asked to sit quietly with eyes closed for approximately 85 seconds.

Ratings of musical excerpts:

Subjects were asked to listen to each musical excerpt "as you normally listen to music", and then to complete a short rating form. In going over the rating form with subjects, it was repeatedly emphasized that there were no right or wrong answers, that each person's reactions to music are highly individual, etc. The rating form presented four groups of adjectives (i.e., four mood-categories) labelled A,B,C,D. For each group of adjectives, the subject gave two ratings: (1) how well the adjective-group described the music; (2) how much of that mood-effect was personally experienced by the subject. It was explained to subjects that the first rating-scale referred to a relatively "objective" recognition of the composer's intentions, while the second rating-scale represented a more "subjective", personal reaction to the intended mood-effect. For each adjective-group rating, the subject made a slash-mark along a continuous 17 cm line marked at one end, "Not at all", and at the other end, "Very much".

In addition to ratings of musical mood-effects, the subject also gave ratings on six other scales: (1) Involvement; (2) Visual Imagery; (3) Verbal thoughts; (4) Arousal; (5) Familiarity; (6) Liking. Each of these scales was also presented as a 17 cm continuous line. All ratings were subsequently converted to a 17 point scale where 1=Not at all and 17=Very much. (See Appendix C for the rating form used by subjects.)

EEG data analysis:

Each subject had 12 different EEG recordings (8 musical excerpts, 2 spoken excerpts, 2 silence periods), and each EEG recording was itself comprised of 12 5-second epochs of cumulative left and right hemisphere alpha activity. Each 5-second epoch was converted into a ratio score of asymmetry, R-L/R+L, for each pair of homologous recording sites separately, and the mean asymmetry ratio over the 12 epochs was computed. Thus each subject had one Frontal mean ratio and one TP mean ratio for each excerpt, musical, spoken, or silent. More positive ratios indicate relative left hemisphere asymmetry and more negative ratios indicate relative right hemisphere asymmetry.

Results

1. <u>EEG asymmetry during WORDS vs. MUSIC</u>:

In order to compare asymmetry during listening to speech (WORDS) to asymmetry during listening to music (MUSIC), for each subject an overall mean asymmetry ratio for the two WORDS excerpts was computed and an overall mean asymmetry ratio for the eight MUSIC excerpts was computed. Separate ANOVA's for each EEG site, TP and Frontal, were done with Excerpt-type (WORDS, MUSIC) as two repeated measures, and Sex nested within Group (Musician, Non-musician) as between-group factors. Table 1 shows the mean TP ratio and the mean Frontal ratio scores for WORDS and for MUSIC for each of the four subgroups of subjects, Musicians-Non-musicians and Male-Female. More positive ratios indicate relatively greater left hemisphere activation. (See Table 1 on p. 22.)

Over the TP recording site, WORDS vs. MUSIC produced a significant main effect ($F=18.94, df=1,20, p<.0003$) indicating that listening to WORDS was associated with relatively greater left hemisphere TP asymmetry than listening to music. Over the Frontal recording site, however, the same ANOVA did not indicate a significant effect for WORDS vs. MUSIC. Therefore, Hypothesis I is confirmed.

Hypothesis I.A., that in a "non-testlike" music-listening condition, the WORDS vs. MUSIC comparison would show no difference between musicians and non-musicians, was supported

Table 1

Mean TP and Frontal ratios for WORDS and for MUSIC excerpts.

Group	Sex	$\bar{x}$ TP ratio WORDS	$\bar{x}$ TP ratio MUSIC	$\bar{x}$ Frontal ratio WORDS	$\bar{x}$ Frontal ratio MUSIC
Musicians	Male	+.0363 (.0833)	-.0340 (.0856)	+.0084 (.0725)	+.0257 (.0581)
	Female	+.1686 (.1636)	+.1441 (.1773)	+.0299 (.0421)	+.0244 (.0560)
Non-Musicians	Male	+.0243 (.0922)	-.0189 (.1148)	+.0300 (.0715)	+.0242 (.1039)
	Female	+.0840 (.1016)	+.0175 (.1580)	+.0807 (.1741)	+.0076 (.0706)
Mean ratio: (n=24)		+.0783	+.0272	+.0373	+.0205

since the interaction of Group x Excerpt-type is not significant.

No other main effects or interaction effects on TP asymmetry were significant, but a main effect for Sex came close to significance ($F=4.03, df=1,20, p=.058$). Table 1 shows that female subjects in both musician and non-musician groups, especially female musicians, had relatively greater left hemisphere mean TP asymmetry than male subjects for both WORDS and MUSIC. This result, although not anticipated, is consistent with other evidence (McGlone,1978; Inglis & Lawson, 1981) suggesting that females tend to use left hemisphere mechanisms for both verbal and nonverbal activities.

The two episodes of Silence provide a "no-stimulus" comparison measure for ascertaining whether the difference in TP asymmetry between the two auditory stimuli, WORDS and MUSIC, is due to a left hemisphere bias for speech stimuli or to a right hemisphere bias for musical stimuli. Separate t-tests were done comparing the mean TP ratio for MUSIC against the mean TP ratio for Silence, and comparing the mean TP ratio for WORDS against Silence. The t-tests show that TP asymmetry during Silence is not distinguishable from TP asymmetry during MUSIC (for musicians, $\bar{x}$ TP ratio for Silence=+.0638, and for MUSIC=+.0551; for non-musicians, $\bar{x}$ TP ratio for Silence=+.0060, and for MUSIC=-.0070). However, the difference between WORDS vs. Silence is significant ($t=3.33, p<.01$), indicating that the observed difference between WORDS vs. MUSIC is entirely due to greater left hemisphere asymmetry during listening to WORDS. EEG TP asymmetry thus appears to be sensitive to the presence or absence of linguistic stimuli, but relatively insensitive to the presence or absence of musical, nonverbal stimuli.

2. Ratings of musical excerpts:

The question of whether the two kinds of mood ratings, (1) "Mood conveyed by the music", and (2) "Personally experienced mood effect", would produce different results was resolved upon inspection of individual subjects' intercorrelations between these two sets of ratings over the 8 musical excerpts. Every subject showed very high positive correlations ranging from r=+.60 to r=+1.00 between the two rating-scales for each of the four mood categories. Table 2 shows the correlations for the 12 musicians and for the 12 non-musicians between the two rating-scales for each mood category.

Table 2

Individual subjects' correlations over 8 musical excerpts between mood ratings: (1) "Mood conveyed by the music", and (2) "Personally experienced mood-effect".

	Mood Categories			
	Soothing	Joyful	Sad	Violent
Musicians:				
1	.82	.74	.87	.92
2	.99	.99	.98	.99
3	.88	1.00	.87	.92
4	.74	.94	.93	.75
5	.99	.98	.97	.70
6	.75	.93	.83	.98
7	.99	.95	.93	.98
8	.97	.99	.98	1.00
9	.97	.79	.82	.92
10	.98	.93	.98	.92
11	.78	.70	.87	.81
12	.60	.75	.80	.80
Mean r	.87	.89	.90	.89
Non-musicians:				
1	.63	.93	.99	.77
2	.99	.97	.99	.99
3	.96	.98	.93	.98
4	.72	.76	.96	.88
5	.97	.94	.98	.99
6	1.00	1.00	1.00	1.00
7	1.00	1.00	1.00	1.00
8	1.00	1.00	1.00	1.00
9	.84	.95	.78	.99
10	.99	.94	.98	.95
11	.85	.99	.93	.98
12	.98	.96	.96	.90
Mean r	.91	.95	.96	.95

The very high correlations shown in Table 2 indicate that subjects did not discriminate very much between the two kinds of ratings. To reduce redundancy, it was decided to drop one of these sets of ratings. The purpose of the study is to explore relationships between subjective reactions to music and EEG measures. Therefore, since the "Personally experienced mood effect" ratings are presumably the more "subjective" of the two, only that set of ratings will be used in further analyses.

Mood-pairs of excerpts:

The attempt to select mood-synonymous pairs of musical excerpts such that both pair-members would receive high ratings in the same mood category and low ratings in the other categories was generally successful. Table 3 shows the mean ratings for "Personally experienced mood effect" for each excerpt separately. Each rating-scale ranged from 1 ("Not at all") to 17 ("Very much"). (See Table 3 on p. 26.)

As Table 3 shows, each excerpt was rated highest in the expected mood category. Moreover, with the exception of the Beethoven-Fauré pairing, the two excerpts pre-selected to be mood-synonymous pairs received very comparable ratings in all four mood categories. The Fauré excerpt was not as unambiguously "sad" as the Beethoven since the Fauré also received relatively high ratings in the "Soothing" category. However, the difference between the mean ratings for "Sad"

Table 3

Expected predominant mood-effect and actual mean ratings of mood-effects for each of eight musical excerpts. (n=24)

Expected predominant mood effect	Excerpt	Mood Categories			
		Soothing	Joyful	Sad	Violent
Joyful	Bach	5.13	15.67	2.00	4.54
"	Lalo	5.04	14.50	1.54	4.04
Sad	Beethoven	4.54	1.83	14.83	4.25
"	Fauré	10.21	3.33	13.75	2.88
Violent	Mahler	2.33	8.79	4.67	13.21
"	Wagner	1.79	5.92	6.63	14.00
Soothing	Bizet	12.79	7.04	4.13	1.67
"	Schubert	13.67	5.79	6.38	1.71

vs. "Soothing" for the Fauré excerpt is significant ($t=2.60$, $p<.02$).

Other rating scales:

Ratings of experiences other than mood effects included: Involvement, Visual Imagery, Verbalization, Arousal, Familiarity, and Liking. Table 4 presents the group mean ratings for these scales for each excerpt. (See Table 4 on p. 27.)

Comparisons between musicians and non-musicians on the ratings shown in Table 4 revealed that over all eight excerpts, musicians rated themselves as more familiar with the musical excerpts than non-musicians did ($t=2.24$, $p<.05$), and musicians reported more Verbalization than non-musicians ($t=2.25$, $p<.05$).

Table 4

Musician (MUS) and non-musician (NONMUS) group mean ratings: Involvement (INV); Visual Imagery (VIS); Verbalization (VBL); Arousal (ARO); Familiarity (FAM); Liking (LIK).

Excerpt	INV	VIS	VBL	ARO	FAM	LIK
Bach						
MUS	14.92	7.17	8.75	15.42	14.42	15.92
NONMUS	12.25	9.25	7.42	11.58	10.25	13.25
Lalo						
MUS	14.58	10.17	8.25	11.92	9.92	14.75
NONMUS	12.75	7.00	7.42	10.33	6.83	13.33
Beethoven						
MUS	12.33	7.17	7.33	7.83	12.58	11.50
NONMUS	12.42	9.58	6.33	7.67	10.50	12.17
Fauré						
MUS	14.33	11.75	10.08	10.25	6.92	14.16
NONMUS	13.08	6.83	6.75	5.50	4.17	12.25
Mahler						
MUS	12.33	7.58	7.08	11.33	10.08	10.33
NONMUS	12.92	11.58	8.17	14.08	6.92	10.58
Wagner						
MUS	13.33	9.50	7.58	11.92	9.92	10.83
NONMUS	12.83	9.83	7.58	13.17	8.83	10.50
Bizet						
MUS	11.25	5.92	9.33	8.17	8.33	11.83
NONMUS	12.08	9.92	8.67	3.58	6.00	13.08
Schubert						
MUS	12.25	7.17	8.58	7.42	7.83	12.42
NONMUS	14.42	6.08	5.67	5.58	3.92	14.00
Mean rating: (n=24)	13.00	8.53	7.81	9.73	8.59	12.56

The means for the important Arousal scale turned out as expected. Both the musician and the non-musician groups rated the four fast-tempo, "High Arousal" excerpts (Bach, Lalo, Wagner, Mahler) as significantly more "arousing" than the four slow-tempo, "Low Arousal" excerpts (Beethoven, Fauré, Bizet, Schubert). Among musicians, $\bar{x}$ Arousal rating for the four "High Arousal" excerpts = 12.81, and for the four "Low Arousal" excerpts, $\bar{x}=8.42$ ($t=4.30, df=11, p<.01$). Among non-musicians, $\bar{x}$ Arousal rating for "High Arousal" excerpts = 12.29, for "Low Arousal" excerpts $\bar{x}=5.58$ ($t=7.06, df=11, p<.001$).

The high means for Involvement in Table 4 suggest that subjects were able to attend to the music despite the novel environment and electrodes. It should also be noted that although some individual excerpts evoked somewhat higher ratings for Visual Imagery than for Verbalization, or vice versa, the overall means for the two scales are comparable to each other, indicating that there was no particular bias towards either visual or verbal covert mentation during listening to music.

3. Relationships between EEG measures and ratings of musical excerpts.

Two different approaches were taken to investigate relationships between the ratings of musical excerpts and the EEG measures. One approach is to compare the mean EEG measures associated with the pre-selected mood and arousal categories. These analyses are described in sections (a) and (b) below under the headings: Relationship of mood-paired excerpts to EEG asymmetry, and Relationship of Arousal ratings to EEG amplitude.

The other approach is to begin with individual subject's reactions to the eight excerpts, and examine how arousal and mood ratings were related to each other when excerpts evoked either relative right or relative left hemisphere EEG asymmetry from individuals. Section (c) below entitled: Relationships between ratings and EEG asymmetry on the basis of individual patterns of behavior, presents findings from that approach.

(a) Relationship of mood-paired excerpts to EEG asymmetry.

Table 5 (see p. 30) presents the mean TP ratio and the mean Frontal ratio for each excerpt and for musicians and non-musicians separately. The predominant mood, i.e., the mood-category receiving the highest rating, for each pair of excerpts is also shown.

Table 5

EEG ratio means over TP and Frontal sites for musicians and non-musicians (MUS and NONMUS) for each of eight musical excerpts.

Predominant mood	Mood-paired excerpts	$\bar{x}$ TP ratio MUS	$\bar{x}$ TP ratio NONMUS	$\bar{x}$ Frontal ratio MUS	$\bar{x}$ Frontal ratio NONMUS
"Joyful"	Bach	+.0572 (.1621)	-.0116 (.1490)	+.0221 (.0473)	+.0331 (.1333)
	Lalo	+.0377 (.1606)	+.0144 (.1380)	+.0293 (.0875)	+.0517 (.1241)
"Sad"	Beethoven	+.0617 (.1678)	+.0235 (.1318)	+.0381 (.0816)	+.0043 (.0954)
	Fauré	+.0342 (.1591)	+.0038 (.1392)	+.0502 (.1111)	+.0216 (.1192)
"Soothing"	Bizet	+.0564 (.1706)	-.0300 (.1419)	+.0125 (.0548)	+.0014 (.0923)
	Schubert	+.0588 (.1966)	-.0076 (.1229)	-.0071 (.0842)	+.0138 (.1107)
"Violent"	Mahler	+.0662 (.1574)	-.0058 (.1493)	+.0279 (.0386)	+.0091 (.1208)
	Wagner	+.0683 (.1637)	+.0073 (.1618)	+.0273 (.0844)	-.0079 (.0771)

It can be seen in Table 5 that, within each excerpt mood-pair, the two Frontal means tend to be similarly paired, especially for the musician group. To test whether the four excerpt-pairs representing the four mood categories had differentially affected EEG asymmetries, each subject's two ratio means for each pair of excerpts were collapsed into one overall excerpt-pair mean ratio. Each subject's four excerpt-pair means were then entered into a 2 x 2 x 4 design where the four excerpt-pair means were four repeated measures and Sex nested within Group were the two between-group factors. Hypotheses II, II.A., and II.B. were tested in a series of a priori contrasts with each recording site analyzed separately. The mean for each excerpt-pair was compared to the combined means of the other three excerpt-pairs, and each excerpt-pair mean was compared to each other excerpt-pair mean. Table 6 below shows the Frontal and TP mean ratios for each of the four mood-related excerpt-pairs.

Table 6

Frontal and TP ratio means for mood-paired excerpts. (n=24)

Recording site	Mood-related Excerpt-pairs			
	Bach Lalo ("joyful")	Beethoven Fauré ("sad")	Mahler Wagner ("violent")	Schubert Bizet ("soothing")
Frontal	+.0340	+.0285	+.0141	+.0052
TP	+.0244	+.0308	+.0340	+.0194

Hypothesis II predicted that ratings of mood effects would be related to Frontal, but not necessarily TP, EEG measures. Over the TP sites, none of the comparisons among the excerpt-pair means is significant, indicating that EEG asymmetry over TP areas is not closely related to ratings of musical mood effects. Over the Frontal sites, however, there is some support for Hypothesis II and, more specifically, for Hypothesis II.A., which predicted that "positive" mood ratings would be related to left hemisphere Frontal asymmetry. The a priori contrast between the mean Frontal ratio for the "joyful" Bach-Lalo excerpt-pair vs. the average mean ratio of the other three excerpt-pairs approaches significance in a two-tailed test, t=1.67, p=.10. That is, the "joyful" excerpt-pair tended to evoke relatively greater left hemisphere Frontal asymmetry than the three other excerpt-pairs considered together.

The mean Frontal ratio for the "soothing" pair, Bizet and Schubert, is also different from the three other ratio means (t=1.89, p=.06 in a two-tailed test), but this pair of excerpts elicited a relatively right hemisphere Frontal asymmetry, opposite to the prediction of Hypothesis II.A. The "soothing" excerpt-pair also received the lowest mean Arousal rating of any excerpt-pair, and it may be that the "soothing" music had a generally relaxing effect on subjects rather than having evoked a clearly positive affective state.

Hypothesis II.B., that "negative" ratings ("sad", "violent") would be related to right hemisphere Frontal asymmetry, is not confirmed by the a priori contrast tests, although the means for both the "Sad" and for the "Violent" excerpt-pairs are in the predicted direction when compared with the "Joyful" excerpt-pair.

Ratings of Liking and EEG asymmetry:

In addition to the mood rating-scales, the Liking rating-scale is relevant to relationships between affective response and EEG asymmetry. Since Liking ratings were free to vary (unlike ratings of mood which were constrained by the experimental manipulation), correlations between Liking ratings and EEG ratios within each excerpt indicate whether liking an excerpt was systematically related to a particular direction of asymmetry. Correlations between Liking ratings and EEG asymmetry ratios were computed for each excerpt, and separately for musicians and for non-musicians. Table 7 below presents these results. Positive correlations indicate that higher Liking ratings are associated with greater left hemisphere asymmetry, and negative correlations indicate that higher Liking ratings are associated with greater right hemisphere asymmetry.

Table 7

Correlations between excerpt Liking ratings and excerpt asymmetry ratios over Frontal and TP sites.

	Musicians		Non-musicians	
Excerpts	Frontal	TP	Frontal	TP
Bach	+.48	+.04	-.02	-.47
Lalo	+.53	+.30	+.28	.00
Beethoven	+.14	+.21	-.21	-.12
Fauré	+.57*	-.54	+.29	-.09
Bizet	-.09	-.23	+.42	+.24
Schubert	+.19	-.30	+.28	-.06
Mahler	+.34	+.06	+.24	-.52
Wagner	+.39	-.38	-.27	-.02

*$p < .05$

The signs of the correlations in Table 7 show a consistent tendency among musicians for Liking ratings to be associated with relative left hemisphere Frontal asymmetry. Among the musicians, the occurrence of 7 positive correlations out of eight excerpts is significantly greater than chance using the binomial test ($p<.03$). Among non-musicians, although there is a similar trend, the occurrence of 5 positive correlations out of 8 is not significantly greater than chance ($p=.22$).

(b) Relationship of Arousal ratings to EEG amplitude:

Changes in overall EEG amplitude have traditionally been related to changes in an individual's general state of alertness or arousal (Lindsley & Wicke,1974). Since an Arousal factor has been shown to contribute substantially to ratings of musical moods (Wedin,1972), it is of interest to investigate whether Frontal or TP EEG amplitude measures exhibit a relationship to ratings of Arousal. It may be recalled (p.27) that Arousal ratings were significantly higher for the four fast-tempo excerpts (Bach, Lalo, Mahler, Wagner) than for the four slow-tempo excerpts (Beethoven, Fauré, Bizet, Schubert). One would expect, therefore, that overall alpha amplitude (R + L) might be lower for the four "High Arousal" excerpts than for the four "Low Arousal" excerpts. The expectation is based on the traditional inverse relationship between EEG amplitude and estimates of subjective arousal (Lindsley & Wicke,1974). Table 8 (see p. 35) presents the amplitude means associated with the "High Arousal" and the "Low Arousal" excerpts.

Table 8

Mean amplitude (R + L) over Frontal and TP sites for excerpts grouped according to high or low ratings of Arousal.

	Site	Excerpt Groups: High Arousal	Excerpt Groups: Low Arousal
Musicians	Frontal	106.29 (64.04)	113.19 (71.42)
	TP	236.26 (95.57)	243.75 (101.53)
Non-musicians	Frontal	79.00 (46.29)	82.95 (50.09)
	TP	192.54 (79.17)	194.77 (78.69)

Although the musician subjects produced higher amplitude levels than the non-musicians from both Frontal and TP leads, the difference between the subject groups is not significant: for the TP site, $t=1.28, df=22, p>.10$, and for the Frontal site, $t=1.20, df=22, p>.10$.

The difference between EEG amplitude levels associated with the High Arousal vs. Low Arousal excerpt groups was tested by matched t-tests done for each recording site. TP amplitude levels are not significantly different between High vs. Low Arousal excerpt groups (for musicians, $t=1.75, df=11, p<.10$; for non-musicians, $t=1.62, df=11, p<.10$). Frontal amplitude levels, however, are significantly different: for musicians, $t=2.26, df=11, p<.05$, and for non-musicians, $t=2.75, df=11, p<.02$.

Hypothesis II again receives support. Arousal ratings are closely related to Frontal EEG amplitude levels but not closely related to TP EEG amplitude measures.

<u>Within-hemisphere effects of High Arousal vs. Low Arousal excerpt groups</u>:

Since overall Frontal amplitude measures were significantly related to Arousal ratings, a further analysis was done to investigate Frontal amplitude changes over each hemisphere separately. Each subject's 12 amplitude means for the right and for the left hemisphere corresponding to each of the 12 EEG recording episodes (2 WORDS, 2 Silence, 8 MUSIC) were converted to a set of 12 z-scores. The z-scores thus represent deviations around the subject's mean amplitude over that hemisphere during the course of the entire study. Figure 1 (see p. 37) shows the mean zL and zR over Frontal areas for the group of excerpts rated high on Arousal (HA) and for the group of excerpts rated low on Arousal (LA).

It can be seen in Figure 1 that Frontal alpha amplitude over both hemispheres decreased during the "High Arousal" excerpts and increased during the "Low Arousal" excerpts. Among musicians, zL scores are significantly different ($t=3.04, df=11, p<.01$) between the two groups of excerpts, while zR scores are not ($t=1.53, df=11, p>.10$). Among non-musicians, changes in mean zL ($t=1.85, df=11, p<.10$) and mean zR ($t=1.87, df=11, p<.10$) amplitude levels fall short of significance.

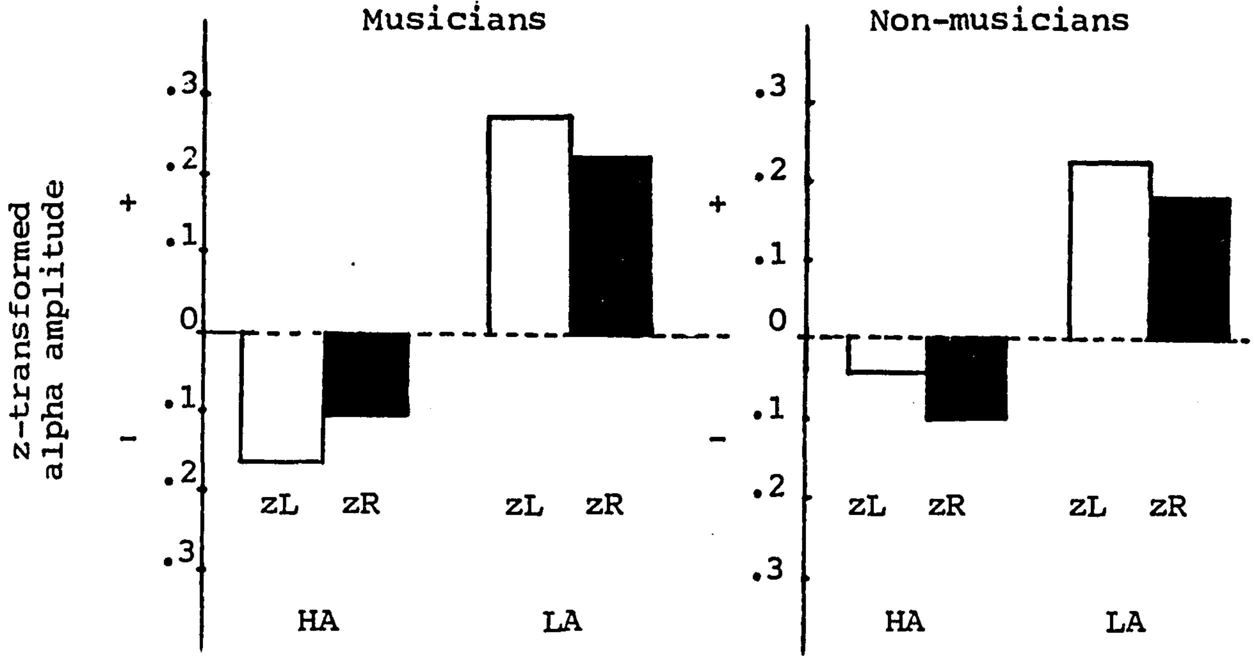

Figure 1. Mean zL and zR Frontal amplitude of musicians and of non-musicians for four musical excerpts rated high on the Arousal scale (HA) and for four excerpts rated low on the Arousal scale (LA). Points are relative to mean amplitude for each hemisphere over the entire EEG study.

(c) Relationships between EEG asymmetry and ratings on the basis of individual patterns of behavior:

An important issue in considerations of laterality in emotion concerns the relationship of the specialized cognitive contributions of the hemispheres to cortical arousal systems which underlie emotional experience. For example, several investigators (Davidson,1976; Tucker,1981; Heilman, 1979) have proposed that the right hemisphere is specially involved in mediating experiences of bodily arousal and mood. In this section, individual responses to the musical excerpts were used as the starting point for an examination of mood and arousal ratings under conditions of either relative right or relative left hemisphere asymmetry.

The effects of the eight musical excerpts on asymmetry ratios varied considerably from one subject to another. To assess individual patterns of response to the musical excerpts, each subject's eight excerpt ratio means were rank-ordered from most positive to most negative. The three most positive ratios are then considered to represent that subject's three "most left hemisphere" excerpts, and the same subject's three most negative ratios are considered to represent the subject's three "most right hemisphere" excerpts. This procedure generates four sets of excerpts, representing conditions of relative right or relative left hemisphere asymmetry over Frontal or over TP areas. Table 9 (see p. 39) shows, for each subject individually, the mean of the subject's three "left hemisphere" excerpt EEG ratios and the mean of the subject's three "right hemisphere" excerpt ratios.

Table 9

Mean of the three most positive ("most left hemisphere") excerpt EEG ratios, and mean of the three most negative ("most right hemisphere") excerpt EEG ratios for individual subjects.

	Mean Frontal Ratio		Mean TP ratio	
	"Left hemisphere"	"Right hemisphere"	"Left hemisphere"	"Right hemisphere"
MUS:				
1	+.0985	+.0201	-.0747	-.1593
2	+.0637	+.0066	+.0507	-.0203
3	+.0269	-.0382	+.1771	+.1138
4	+.1504	-.0157	+.2269	+.1106
5	+.1153	+.0330	+.2931	+.2382
6	-.0088	-.1351	+.4091	+.3726
7	+.0646	-.0771	+.0221	-.0943
8	+.1917	-.0044	+.0638	-.0594
9	+.0050	-.0450	-.0095	-.0520
10	+.0072	-.0099	+.0862	+.0058
11	+.0555	-.1016	+.0648	-.0467
12	+.1560	+.0640	-.1733	-.2282
$\bar{x}$	+.0772	-.0252	+.0947	+.0151
NONMUS:				
1	-.0497	-.1366	+.3194	+.2462
2	+.1958	-.1468	+.1420	+.0239
3	+.0655	+.0073	-.1225	-.1700
4	+.1253	+.0436	+.1387	-.0514
5	+.1297	-.0064	-.0694	-.1669
6	-.0150	-.1065	+.0087	-.1029
7	-.1039	-.1998	-.1194	-.1894
8	+.1933	+.0513	+.1147	+.0006
9	+.0142	-.0677	-.0460	-.1231
10	+.2081	+.0446	+.1367	+.0273
11	+.1230	-.0365	-.0645	-.1731
12	+.0684	-.0199	+.1651	+.0607
$\bar{x}$	+.0796	-.0478	+.0503	-.0515
$\bar{x}$ (n=24)	+.0784	-.0365	+.0725	-.0182

Table 10 below presents the group mean ratings associated with each of the four sets of excerpts.

Table 10

Mean ratings associated with subjects' "most left hemisphere" and "most right hemisphere" excerpt asymmetry ratios.

	Recording Site			
	Frontal asymmetry		TP asymmetry	
Rating Scales	"Left"	"Right"	"Left"	"Right"
Soothing	6.60	7.22	5.44	8.31
Joyful	8.10	7.51	7.56	7.67
Sad	6.78	6.61	7.18	6.60
Violent	6.26	5.94	5.88	4.83
Involvement	14.00	12.31	12.50	12.97
Visual Imagery	9.40	7.81	8.01	8.51
Verbalization	7.42	8.43	7.90	7.68
Arousal	10.54	9.50	10.11	9.46
Familiarity	9.43	7.82	8.43	7.49
Liking	13.47	12.03	11.47	12.58

The differences between rating means for "Left" vs. "Right" hemisphere excerpts were compared in matched t-tests. Looking first at Frontal asymmetries, across all subjects there are significant differences between the "Left" vs. "Right" mean ratings of Involvement ($t=2.14, df=23, p<.04$) and Familiarity ($t=3.00, df=23, p<.006$). Relative left hemisphere Frontal asymmetry is associated with higher ratings of Involvement and higher ratings of Familiarity.

The mood-rating means shown in Table 10 are not significantly different between "Left hemisphere" vs. "Right hemisphere" Frontal excerpts so that the association found previously between relative left hemisphere Frontal asymmetry and the excerpt-pair categorized as "Joyful" is no longer evident in the current analysis based on individual ratings of excerpts. However, within the Frontal "left hemisphere" excerpts, there is a trend towards rating the Joyful mood scale higher than any of the other three mood scales.

Over TP areas, comparisons of the mean ratings associated with "Left" vs. "Right" TP asymmetry showed significant differences between "Left" vs. "Right" ratings of Soothing ($t=-2.89, df=23, p<.01$) and Liking ($t=-2.15, df=23, p<.04$). Higher Soothing ratings and higher Liking ratings are each associated with greater right hemisphere TP asymmetry.

Direction of asymmetry and associations between ratings of Arousal and ratings of mood:

In order to investigate the possibility that the right hemisphere may be more involved than the left hemisphere in mediating arousal and mood experiences, one may compare the correlations between Arousal ratings and mood ratings under conditions of relative left hemisphere asymmetry to the correlations between Arousal and mood ratings under conditions of right hemisphere asymmetry. If the right hemisphere does contribute more than the left hemisphere to associations between bodily arousal and mood, then one would expect to find a closer relationship (i.e., higher correlations) between Arousal ratings and mood ratings under conditions of right hemisphere asymmetry than under conditions of left hemisphere asymmetry.

Table 11 below presents the correlations between Arousal ratings and mood ratings within "left hemisphere" excerpts and within "right hemisphere" excerpts for each recording site.

Table 11

Correlations between mean Arousal ratings and mean ratings of mood scales within excerpts which evoked either relative left hemisphere or relative right hemisphere asymmetry. (MUS=Musicians; NONMUS=Non-musicians).

Recording Site	Mood Scales	"Left hemisphere" excerpts		"Right hemisphere" excerpts	
		MUS	NONMUS	MUS	NONMUS
Frontal	Joyful	+.45	-.01	+.35	+.66**
	Violent	-.39	+.38	+.68**	+.69**
	Soothing	+.38	-.55	-.59*	-.56
	Sad	-.33	-.26	+.10	-.47
TP	Joyful	+.26	-.06	+.17	+.21
	Violent	+.29	+.71**	+.32	+.64*
	Soothing	+.08	-.56	-.84***	-.64*
	Sad	+.32	-.56	-.35	-.44

*$p<.05$

**$p<.01$

***$p<.001$

It is apparent that most of the substantial or significant correlations occur within the "right hemisphere" excerpts rather than within the "left hemisphere" excerpts. This result supports the previous speculation that bodily arousal and mood may be more closely associated when the right hemisphere is predominant.

Although greater left hemisphere asymmetry produces lower correlations between Arousal ratings and mood ratings, it is interesting that within "left hemisphere" excerpts, non-musicians still exhibit substantial mood-Arousal correlations, especially within TP "left hemisphere" excerpts. Among musicians, however, the "left hemisphere" correlations between Arousal and mood ratings are generally low for both recording sites. This pattern suggests that non-musicians may experience arousal as a component of mood regardless of the direction of asymmetry. Musicians, on the other hand, seem to dissociate arousal from mood under conditions of relative left hemisphere activation.

Discussion

This study has given a degree of support to the hypothesis that Frontal EEG asymmetry reflects positive vs. negative affective experience. Musical excerpts categorized as "joyful" in mood tended to evoke relative left hemisphere Frontal asymmetry compared to Frontal asymmetry for excerpts in other mood categories. This finding is in accordance with results of other research where verbal or visual positive and negative affective stimuli have been used. The relationship between positive affect and left hemisphere Frontal asymmetry found here is not as strong as in some of the reports cited above, however that is not surprising since the nonreferential, relatively intangible nature of purely musical emotional experience obviously differs from the "real-life" emotional experiences connoted by visual or verbal affective stimuli. For the same reason, the fact that the "negative" musical moods used in this study did not elicit right hemisphere asymmetry is not necessarily discrepant with previous reports of right hemisphere involvement in negative affective experience. The paradox that "sad" music can be simultaneously described as enjoyable makes it very improbable that musical "negative" moods are comparable to the truly negative experiences, e.g., profound depression, fear, revulsion, which have been associated with right hemisphere Frontal activation. The music used here was generally liked by subjects, even when excerpts were rated high for "sad" or "violent" mood effects. Indeed, several subjects who gave the Fauré excerpt high ratings in the "sad" mood category commented afterwards that the cello solo was lovely, or that the music evoked a pleasantly "nostalgic" feeling. Probably the only times that music evokes really negative reactions are when the listener finds the music irritating or unpleasant. The Liking rating-scale, therefore, might be the clearest positive vs. negative affect scale in this study. Again, the relationship between ratings of Liking and Frontal asymmetry tended to be in the predicted direction. Higher Liking ratings were consistently associated with left hemisphere Frontal asymmetry, particularly among musician subjects.

The finding that music categorized as "soothing" elicited a strong tendency towards right hemisphere asymmetry had not been predicted. In reporting this result, it was suggested that the right hemisphere association with "soothing" music was attributable to the music's having evoked a relatively neutral state of lowered arousal rather than a clearly positive mood. That interpretation is supported by results from a previous study in our lab (Ehrlichman & Wiener, 1980) where bilateral TP EEG was recorded while subjects engaged in 17 different mental activities. Some of the mental tasks required relatively active, concentrated thought (e.g., mental arithmetic) while others promoted a more quiescent, relatively receptive state (e.g., meditation).

When the tasks were rank-ordered from "most left hemisphere" to "most right hemisphere" in terms of task mean asymmetry ratios, "Meditation" elicited by far the most extreme right hemisphere asymmetry. In that study, the authors suggested that an "active - receptive" continuum seemed to underlie the ordering of the mental tasks. The finding here that a "soothing", "peaceful", "serene", etc. mood along with low arousal elicits right hemisphere asymmetry is reminiscent of the similar results when subjects engaged in meditation.

A major finding of this study was that musician subjects did not exhibit more left hemisphere involvement for music than non-musicians in the comparison between listening to speech vs. listening to music. To the author's knowledge, there is only one other published EEG asymmetry study (Hirshkowitz et al., 1977) where musicians and non-musicians simply listened to linguistic and musical stimuli with minimal experimental task demands. In that study, Hirshkowitz et al. recorded EEG alpha from left and right Parietal sites and did find that musicians showed more left hemisphere activation than non-musicians for the music-listening condition. However, there are several major differences between the present investigation and that of Hirshkowitz et al. which could account for the discripant results. The musical stimulus used by Hirshkowitz et al. was a popular song with words, and the musician subjects may have attended more to the lyrics than to the tune, which the authors described as a "somewhat simplistic melody". (In fact, the musicians did not exhibit any difference between asymmetry for the song and asymmetry for the verbal stimulus, a radio newscast.) Secondly, Hirshkowitz et al. used a Silence period as a "baseline" from which to estimate asymmetry effects, subtracting the baseline alpha ratio from the verbal and from the music alpha ratios. The concept of a stable EEG "baseline" has been criticized (Donchin, 1977), and it is not clear that one Silence period can be regarded as a meaningful zero reference point upon which to base comparisons. Finally, there are important methodological differences between the two studies in respect to EEG data collection. Hirshkowitz et al. computed the number of seconds alpha was present over each hemisphere whereas a measure of integration was used here, and Hirshkowitz et al. referenced their electrodes to contralateral ears while the present study used a vertex reference. Thus the two studies differ in many important respects, any or all of which might have caused the different outcomes. The results here indicate that in a passive listening situation which is not task-oriented, musicians show the same asymmetry pattern as non-musicians, shifting from relative left hemisphere asymmetry for speech stimuli to relative right hemisphere asymmetry for musical stimuli. This result does not conflict with evidence (Bever & Chiarello, 1974) that musical training promotes increased left hemisphere "analytic" processing of musical stimuli, since reports of left hemisphere activation in musicians have referred to situations where subjects were actively performing musical tasks (Davidson & Schwartz, 1977), or where subjects were confronted with an extremely difficult musical test (Bever & Chiarello, 1974). It is probable that musicians, either due to training or to innate factors, have more options available to them in terms of listening strategies and memory aids than musically naive listeners. When challenged by difficult experimental task demands, or when given quasi-musical stimuli to remember, musicians may resort to using mnemonic strategies to a much greater extent than when they are listening to music for enjoyment.

Nonetheless, the present results do suggest that the nature of left hemisphere involvement in music processing may not be the same for musicians as it is for non-musicians. The major distinction between the musicians and the non-musicians in this study was the difference in the way in which Arousal ratings were related to the mood rating-scales for excerpts which activated the left hemisphere. For both musicians and non-musicians there were substantial correlations between Arousal ratings and ratings of mood, but the significant correlations were almost exclusively found among subjects' relatively right hemisphere excerpts. Within the relatively left hemisphere excerpts, only non-musicians showed substantial correlations between Arousal ratings and mood ratings. Among musicians, within relatively left hemisphere excerpts Arousal ratings were largely independent of mood ratings. However, musicians did show a strong association between Arousal ratings and ratings of Involvement (r=+.55, p=.06) within their relatively left hemisphere Frontal excerpts. That is not the case for musicians' relatively right hemisphere Frontal excerpts where there is zero correlation between Arousal ratings and Involvement ratings. Perhaps as physiological arousal activates a musician's left hemisphere Frontal areas, the musician becomes more involved in following the sequential flow of the music. Among musicians' relatively right hemisphere Frontal excerpts, Arousal ratings are not related to Involvement ratings, but Arousal ratings do show significant associations with ratings of mood effects. These data suggest that, for musicians, physiological arousal may stimulate different processes on either side of the brain.*

For non-musicians, on the other hand, Arousal ratings are generally associated with mood ratings regardless of relative right or left asymmetry and ratings of Arousal show

*This suggestion may be related to a crucial feature of artistic emotional experience described by artists and philosphers (Kreitler,1972) as a kind of objective "distancing" or "detachment" which proceeds in parallel with the ongoing emotional response. For example, Toscannini once remarked that a conductor needed simultaneously "a heart of fire and a head of ice". In the present study, it is interesting that several of the musician subjects commented after the session that they sometimes wanted to mark the Arousal scale at both ends simultaneously.

no relationship to Involvement ratings. The comparatively uniform association between ratings of Arousal and ratings of mood among non-musicians suggests that, for musically naive listeners, right and left cortical regions may be less differentiated from each other in music processing than is the case for musicians.

For all subjects, Arousal ratings and ratings of mood reactions were more closely related to each other during relative right hemisphere activation than during relative left hemisphere activation. Assuming that Arousal ratings provide at least a rough estimate of the physiological arousal that music is known to evoke, the link between arousal, mood and right hemisphere activation is consistent with (a) evidence suggesting that the right hemisphere may be particularly involved with bodily processes (Davidson, 1976); (b) psychiatric case reports of affective disorders where the patient's mood level appears to covary with the right hemisphere's arousal level (Tucker, 1981); and (c) neuropsychological data (Heilman, 1979) indicating that the right hemisphere is especially important, perhaps even "dominant" for mediating an attention-arousal-activation response.

The capacity to experience emotional reactions to artistic creations is an important and perhaps unique aspect of the human brain. The results of this study indicate that asymmetry patterns associated with affective reactions to music resemble asymmetry patterns associated with emotional reactions to "real-life" stimuli. At the same time, the data raise intriguing questions concerning the complex relationship of arousal to cortical asymmetry in emotion. For example, the results here suggest that the Frontal EEG asymmetry pattern of relative left hemisphere activation for positive affect and relative right hemisphere activation for negative affect may be more evident under conditions of high arousal than when arousal is comparatively low.

Further studies of laterality in affective response to music and to other aesthetic stimuli would be valuable for a more comprehensive understanding of hemispheric asymmetries in emotion. In a recent paper, Brownell & Gardner (1981) have also suggested that the moods evoked by music, poetry, painting, etc. provide a fertile area for investigation. Those authors point out that similar moods may be expressed by different media (e.g., music, painting and poetry can all be "melancholy" or "joyful"), and that comparisons of laterality effects between different modalities or different symbol systems would greatly aid attempts to characterize the general nature of hemispheric specialization for mood appreciation and response.

Appendix A

Description of EEG-analyzer*

EEG was amplified, passed through analog and digital filters, and integrated by a two-channel EEG analyzer built specially for EEG asymmetry research. The analog filters consisted of two sets of variable high and low pass 4-pole Butterworth type filters (3 db point, attenuation slope 24 db per octave) set a 6 and 15 Hz. When the digital filters detected activity within the range of 8 - 13 Hz. (as indicated by the rate of zero-crossings), rectified output from the active filters was integrated by Drohocki-type integrators. Thus, the digital filters served as a "gate" for the integration of the output of the analog filters. At the conclusion of each time-epoch, the EEG analyzer provided a numerical display of integrated activity from the left and right hemispheres. These values were proportional to the area subtended by the (rectified) waveform and were therefore a measure of the energy (amplitude) over the length of the epoch.

*The above is excerpted from Ehrlichman & Wiener, 1979.

Appendix B

Musical excerpts used in pre-tests and mean mood-ratings (n=40). (5 point scale: 1="Not at all", 5="Very much").

Excerpt	Mood Categories			
	A (Joy-ful)	B (Sooth-ing)	C (Sad)	D (Vio-lent)
Lalo: Symphonie Espagnole* (Finale)	4.74	2.01	1.07	1.27
Chabrier: Espana	4.67	1.61	1.06	3.53
Bach: Badinerie, Suite #2*	4.67	1.67	1.21	2.17
Mendelssohn: "Italian" Symphony (Finale)	4.50	1.61	1.67	3.39
Mozart: Horn concerto, K. 495 (Rondo)	4.36	2.56	1.17	2.92
Boccherini: Cello quintet, Op. 37,No 7 (Finale)	4.28	1.72	1.36	2.28
Bizet: Symphony in C (Finale)	4.20	3.19	1.36	2.17
Mozart: Fl & Harp concerto, (Rondo)	4.19	2.89	1.25	2.00
Mendelssohn: "Reformation" Symphony (Finale)	4.09	1.50	1.53	3.44
Mozart: Piano concerto, K. 453 (Rondo)	4.08	3.28	1.06	3.08
Beethoven: 7th Symphony, (Finale)	4.00	1.42	1.53	3.31
Beethoven: Septet (Finale)	3.89	2.89	1.22	2.58
Bizet: Entr'acte (between Acts II & III), Carmen	2.75	4.89	1.58	1.69
Debussy: Clair de Lune	2.36	4.86	2.28	2.06
Schubert: Notturno*	2.37	4.64	2.25	1.00
Bizet: Arlesienne Suite #2, (Minuet)	2.95	4.63	1.97	1.00
Brahms: Piano concerto #2, (2nd movement)	1.67	4.58	3.39	1.33
Mozart: Piano concerto, K. 488 (2nd movement)	1.28	4.25	3.30	1.61

Appendix B (2)

Pre-tests: Excerpts and Mean Mood Ratings (cont'd)

Excerpt	Mood Categories A (Joy-ful)	B (Sooth-ing)	C (Sad)	D (Vio-lent)
Beethoven: "Pastorale" Symphony (2nd movement)	2.75	4.00	2.22	2.31
Wagner: Siegfried Idyll	2.33	4.00	1.92	1.67
Beethoven: "Eroica" Symphony (2nd movement)*	1.08	2.44	5.00	2.28
Fauré: Élégie*	1.05	3.49	4.56	1.17
Schubert: "Death and the Maiden" quartet	1.31	4.00	4.50	1.19
Grieg: Ase's Death	1.20	4.20	4.20	1.00
Tschaikowsky: Vln concerto (2nd movement)	1.83	3.64	4.03	2.00
Boccherini: Cello concerto (2nd movement)	1.61	3.78	3.86	1.39
Tschaikowsky: "Pathetique" Symphony (2nd movement)	1.72	3.31	3.44	2.44
Wagner: Flying Dutchman* Overture	2.15	1.00	2.20	4.90
Mahler: Symphony #1* (Finale)	2.30	1.00	1.20	4.80
Moussorgsky: Night on Bald Mountain	2.42	1.22	2.67	4.77
Wagner: Ride of the Valkries	2.78	1.61	2.19	4.78
Moussorgsky: Baba Yaga (Pictures at an Exhibition)	2.60	2.00	1.60	4.20
Beenthoven: "Pastorale" Symphony (3rd movement)	2.36	1.50	2.25	4.19

*Excerpt selected for EEG study.

Appendix C

Rating Form

Please mark each line to show how much each group of adjectives applies.

A	B	C	D
______	______	______	______
Sweet	Joyful	Brooding	Violent
Soothing	Exuberant	Melancholy	Agitated
Angelic	Jubilant	Grieving	Turbulent
Peaceful	Exhilarated	Mournful	Raging
Serene	Vivacious	Dark	Stormy

Group A words
(describing the music)

____

Not at all   Very much

Group A words
(describing your own reactions)

____

Not at all   Very much

Group B words
(describing the music)

____

Not at all   Very much

Group B words
(describing your own reactions)

____

Not at all   Very much

Appendix C (2)

Rating Form (cont'd)

A	B	C	D
Sweet	Joyful	Brooding	Violent
Soothing	Exuberant	Melancholy	Agitated
Angelic	Jubilant	Grieving	Turbulent
Peaceful	Exhilarated	Mournful	Raging
Serene	Vivacious	Dark	Stormy

Group C words
(describing the music)

____

Not at all Very much

Group C words
(describing your own reactions)

____

Not at all Very much

Group D words
(describing the music)

____

Not at all Very much

Group D words
(describing your own reactions)

____

Not at all Very much

Appendix C (3)

Rating Form (cont'd)

(1) Did you become involved in the music?

____

Not at all Very much

(2) Did you experience visual imagery during the music?

____

Not at all Very much

(3) Did you experience verbal thoughts during the music?

____

Not at all Very much

(4) Did the music make you feel more relaxed or more aroused?

____

Very relaxed Very aroused

(5) Was the music familiar to you? Have you heard it before?

____

Not at all familiar Very familiar

(6) Did you like this excerpt?

____

Not at all Very much

Appendix D

Recordings used in the study:

Bach, Johann Sebastian

"Badinerie" from Orchestral Suite #2 in b minor for flute & strings, BWV 1067. William Bennett, fl., Neville Marriner, cond., Academy of St. Martin-in-the-Fields orchestra. ARGO ZRG 687-8.

Beethoven, Ludwig van

"Marcia Funebre" (2nd movement) from Symphony #3 in E flat major, Op. 55 ("Eroica"). George Solti, cond., Chicago Symphony Orchestra. LONDON CSP-9.

Bizet, George

"Menuet" from Arlésienne Suite #2. Alexander Gibson, cond., L'Orchestre de la Suisse Romande. LONDON STS15174.

Fauré, Gabriel

"Élégie" for cello and orchestra, Op. 24. Leonard Rose, cello, Eugene Ormandy, cond., Philadelphia Orchestra. COLUMBIA M30113.

Lalo, Edouard

"Rondo" from Symphonie Espagnole, Op. 21. Isaac Stern, vln, Eugene Ormandy, cond., Philadelphia Orchestra. COLUMBIA MS7003.

Appendix D (2)

Recordings used in the study (cont'd):

Mahler, Gustav

"Finale" from Symphony #1 in D major. Erich Leinsdorf, cond., Royal Philharmonic Orchestra. LONDON SPC21068.

Schubert, Franz

"Notturno" in E flat major, Op. 148. Eschenbach, piano, Koeckert, vln, Merz, cello. DGG136488.

Wagner, Richard

Overture to The Flying Dutchman. George Solti, cond., Vienna Philharmonic Orchestra. LONDON CS6782.

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