Music Processing and Hemispheric Specialization in Experienced Dancers and Non-Dancers: An EEG Study of High Frequencies

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Abstract

The current study used electroencephalography (EEG) techniques to explore music processing in dancers and non-dancers in terms of the brain's hemispheric specialization and high-frequency electrical activity. Twelve Argentine tango dancers and twelve non-dancers listened to preferred and non-preferred music as their EEG activity was recorded and filtered across seven frequency bands: delta (1-4 Hz), theta (4-8 Hz), low-alpha (8-10 Hz), high-alpha (10-12 Hz), low-beta (12-22 Hz), high-beta (22-32 Hz), and gamma (32-59 Hz). Change in power in each band was quantified by calculating power density differences between music conditions in reference to baseline activity. Dancers were hypothesized to show more powerful alpha and beta activity in the left than in the right hemisphere, or show no asymmetry, whereas non-dancers were projected to have right hemisphere-dominant alpha and beta activity. The results did not support the predictions but showed differences in other respects, especially in beta and gamma. A preferred music effect was observed in low beta, high beta, and gamma bands, and across all subjects, gamma power was more pronounced in the left than in the right hemisphere. Unique among the dancers listening to preferred music were a contrast between anterior and posterior sites in high-beta power, and a sex difference in gamma, which was pronounced in the posterior right site of the scalp. The results suggest listening to music can affect the brain electrophysiologically, and expertise can change cortical organization.

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The psychological effects of music have raised many questions regarding their function and link to cognitive performance. How does listening to music act on the brain? Do different kinds of music affect people differently? Does experience or training in dance affect brain activity?

In examining how individuals listen to music, the current study explored hemispheric specialization (also called *lateralization*, *cerebral specialization* or *asymmetry*), which refers to the functional differences in cognitive processing of the left and right hemispheres of the brain. In general, the left hemisphere is involved in analytical thinking, and linear or sequential processing of stimuli, as in language and mathematical information. The right hemisphere, on the other hand, is implicated in holistic processing of information, such as the appreciation of music or other art forms (Zillmer, Spiers, & Culbertson, 2008).

The current study explored music processing through electroencephalography (EEG), a technique that measures electrical activity coming from neurons in the brain. Cortical signals are evident as EEG waves which vary in terms of frequency, the number of oscillations per second (Hz). Thus, EEG waves can be characterized by different frequency bands that correspond to different brain states. The delta (less than 4 Hz) and theta (4 to 8 Hz) bands are the slowest rhythms, and are most evident at times of deep sleep and drowsiness, respectively. Alpha waves are high-amplitude, slow waves (8 to12 Hz) that are present during times of quiet but wakeful resting (Zillmer et al., 2008). Alpha oscillations have been shown to occupy a larger area in the brain during meditation, becoming more and more concentrated in the frontal area, and shifting to the slower delta and theta waves the more meditation training one receives (Buzsaki, 2006).

Beta waves are low-amplitude and faster than alpha waves (12 to 32 Hz), and are related to states ranging from overarousal and active, alert thinking, to quiet attention. Gamma activity is the fastest among the oscillations (greater than 32 Hz), associated with high engagement in a task and sensory binding (Zillmer et al., 2008).

Both alpha and beta activity seem to be associated with music processing. Hirshkowitz, Earle, and Paley (1978) investigated differences in EEG alpha activity between musicians and non-musicians when they were exposed to different kinds of auditory stimuli such as noise, music, and verbal material. They found that in terms of the duration of alpha activity over each hemisphere in each listening condition, the music exposure showed a significant difference: non-musicians showed more activity in the right hemisphere than the left, whereas such hemisphere difference was not present in the musician group. The authors suggest that musicians, perhaps due to their extensive training in music, processed music by analyzing and segmenting it in a similar fashion to language. On the other hand, non-musicians seemingly processed the music differently, possibly in a holistic fashion.

Beta activity has also been implicated in music processing. Using EEG coherence measures, which indicate the magnitude of the affinity of two separate EEG signals coming from intra- or inter-hemispheric electrodes, Petsche, Richter, Von Stein, Etlinger, and Filz (1993) found that listening to music was associated with coherent connectivity in the beta band. The researchers assigned different tasks to musicians and non-musicians, such as listening to a favorite classical piece, performing arithmetic problems, and mentally composing a piece. High coherence in the beta band was a general finding when their participants listened to music. An exploratory study, Petsche et al.'s (1993) investigation did not find conclusive evidence for hemispheric specialization in music processing. However, the authors observed higher left-hemisphere coherence when their musically-trained participants imagined playing a piece or listened to a preferred piece self-reported to be analyzed temporally (i.e. thinking about and expecting musical structure and tones). They also found strong left-hemisphere coherence in the beta band when their untrained participant performed mental arithmetic, especially in the beta band. On the other hand, higher right-hemisphere coherence was found for preferred music self-reported to be enjoyed holistically.

Given the findings of Hirshkowitz et al. (1978) and Petsche et al. (1993), it seems that in general, when people are listening to music simply for enjoyment and are paying attention to it as a whole, hemispheric specialization occurs with more powerful alpha and beta activity in the right hemisphere relative to the left. On the contrary, when listeners are structurally analyzing the music, the hemispheric specialization of alpha and beta becomes left-dominant or disappears. Furthermore, music-related training or specialization appears to be related to altered ways of music processing, such that experienced musicians listen to music differently from non-musicians.

The main research question in this study explores how experienced dancers (Argentine tango dancers) and non-dancers differ in alpha and beta power and hemispheric dominance while listening to preferred and other music. Power denotes the amplitude or strength of the EEG signal. Little research has been done on the relationship between dance expertise and music. Brown, Martinez, & Parsons (2006) explored the neural correlates of movement in Argentine tango dancers through PET (positron emission tomography). Brown et al. found that cortical areas such as the motor, somatosensory and premotor regions as well as subcortical regions such as the cingulate motor area and basal ganglia were activated when their participants moved their legs to music. Experienced dancers and non-dancers, like trained musicians and non-musicians, have been shown to display differences in EEG alpha activity when performing improvisation and creativity tasks. Fink, Graif, and Neubauer (2009) found that when instructed to freely imagine and mentally improvise a dance, novice dancers showed a weak increase in the upper bounds of the alpha band, compared to the professional dancers who displayed a stronger increase in upper-alpha. The current study aims to investigate how dance experience affects the power of alpha waves and higher frequency waves (beta and gamma) when people listen to music. It explores brain activity as modulated by dance experience, a music-related expertise, which has rarely been investigated when music processing is concerned.

The proposed hypothesis is that experienced dancers, like musicians, will have either more powerful alpha and beta activity in the left hemisphere than in the right hemisphere, or no hemispheric specialization at all. Akin to the non-musicians, non-dancers are projected to show more alpha and beta power in the right hemisphere. Experienced dancers are expected to be more analytic when they listen to their own music because they would process music structures as they are trained to demonstrate music interpretation through their body movements while they listen to the music, whereas non-dancers would listen to the music holistically or simply for pleasure.

Method

Participants

Twenty-four participants (ages 20 to 60) took part in this study. All participants were screened for their experience in dance, and two groups (tango dancers, non-dancers) were identified. Twelve participants (six females) were assigned to the tango group, and twelve participants (six females) to the non-dancer group. All participants were right-handed and had no neurological abnormalities.

All dancers in the tango dancer group had at least five years of experience in their respective dance types, and practiced dance regularly. Non-dancers had no formal training in dance and did not practice any particular dance regularly. Non-dancers were lovers of either classical music (N=6) or jazz music (N=6).

Dancers were recruited from local Bay Area dance halls and from personal contacts of the investigators. Non-dancers were selected from the local Saint Mary's College community.

Stimuli

Participants listened to two-minute wordless music excerpts (total of nine songs) that were either preferred or non-preferred. Three of the nine songs were preferred music pieces selected by the subject: non-dancers chose music either from classical or jazz genres; dancers chose music related to their dance type. Six of the nine songs were non-preferred music, which included pieces from the two groups that the subject did not belong to (e.g. jazz/classical and foxtrot for the tango dancer; tango and foxtrot for the non-dancer; etc.). The songs were pseudo-randomized across the three sets, such that one set contained one preferred song and two distinct non-preferred songs.

Each song was cut to 2 minutes, 2 seconds, and faded out during the last 2 seconds using Soundforge. All non-preferred music was provided by the researchers.

Procedure

Participants were comfortably seated in a dimly-lit sound-dampened room. Music was presented through closed-ear headphones (Beyerdynamic DTX900) at a comfortable volume determined by the participants beforehand. The stimuli were presented through Presentation software (www.neurobs.com).

Three sets, each including three songs, were presented to the subjects. Each set contained one preferred and two non-preferred pieces of music. Participants rated their enjoyment of each piece on a scale of 1 to 10 (1 = *least enjoyable*, 10 = *most enjoyable*) before they were exposed to the next song. Participants were asked to close their eyes and sit in silence at rest for two minutes to record baseline activity, which took place before each set. A trial was paused in case technical difficulties arose.

Prior to EEG recording, participants were asked to refrain from swallowing, excessive eye movement, fidgeting, or squinting due to their effect on the waveform.

After EEG recordings, each participant was asked questions about the study in general (examples of questions were, “What were you thinking when you were listening to your preferred music?” and “How did you listen to the music?”).

EEG recording started 3 s before song onset, and ended 2 s after each two-minute song. Each trial in turn lasted at least 124 s.

EEG Recording

EEG was recorded from 32 Ag-AgCl electrodes mounted in an electrocap (Compumedics Quik-Cap) referred to the right and left mastoid bones (Figure 6). Eye movement was monitored by electrodes placed below and above the left eye, and in the right and left canthi. The signal was band pass filtered between 0.05 and 100 Hz. Data acquisition was continuous with a sampling rate was 1000 samples per second (NeuroScan Synamps Model 5083 amplifier). Impedances were kept below 11 kΩ. Data was acquired using NeuroScan Scan 4.1.

Frequency Analyses

Power spectra for each frequency band in each participant were analyzed using EEGLab (v9.0.4.4b, The Swartz Center for Computational Neuroscience, Institute for Neural

Computation, UCSD). Each frequency band was defined as follows: delta, 1-4 Hz; theta, 4-8 Hz; low alpha, 8-10 Hz; high alpha, 10-12 Hz; low beta, 12-22 Hz; high beta, 22-32 Hz; and gamma, 32-59 Hz. Mean power density for each frequency band was computed for each condition (Baseline, Tango, Jazz/Classical, Foxtrot) across all subjects.

Differences in power density between baseline and each music condition were analyzed for each participant at each electrode in terms of percent change effect. This was computed by subtracting power at baseline from power at a music condition and dividing this difference by power at baseline, for each electrode in each participant.

Results

Behavioral Results

Mean rating scores for the tango dancers were 9.5 for tango music, 5.8 for foxtrot music, and 6.3 for jazz/classical music (Figure 1). Dancers' rating scores for tango music were significantly different from their ratings for foxtrot music [$F(2, 44) = 43. 52$, $p < 0.0001$] and for jazz/classical music [$F(2, 44) = 32.34$, $p < 0.01$]. There was no significant difference between the dancers' foxtrot ratings and jazz/classical ratings.

Non-dancers had mean rating scores of 5.4 for tango music, 5.9 for foxtrot music, and 8.8 for jazz/classical music (Figure 1). The non-dancers' ratings for jazz/classical music were significantly different from their foxtrot music ratings [$F(2, 44) = 25.75$, $p < 0.0001$] and from their tango music ratings [$F(2, 44) = 36.01$, $p < 0.0001$]. Non-dancers' ratings for foxtrot music and for tango music were not significantly different from each other.

Dancers' ratings for tango music and non-dancers' ratings for jazz/classical music were not significantly different from each other. Thus, there was a preferred music effect within each group, but not across both.

EEG Results

Preprocessing.

EEG data was preprocessed using EEGLab. Data was resampled from 1000 samples per second to 320 samples per second. The high-pass filter was changed from 0.05 Hz to 0.2 Hz. Each trial was fit to a time window of 120 s in length. Data from each trial was manually filtered for non-stereotyped drift such as muscle artifacts, horizontal and vertical eye movements, and drift caused by possible technical connection problems. If in each trial, more than 12 s of non-stereotyped or rare drift (10% of a trial) was to be rejected, the trial was excluded from further analysis. However, a trial was kept if artifacts that remained were eye channel-related or systematic (stereotyped); these problems would be handled by independent component analysis (ICA) later. This stage of manual rejection led to an average rejection rate of 3.6% of the trials. The individual trials for each subject were then concatenated into one dataset, and subjected to ICA.

After ICA, the data was manually filtered for any leftover artifacts due especially to muscle tension, eye movement, and problematic channels. This led to an average rejection rate of 35.6% of the components. After component rejection, epoch windows of 108 s each were extracted from each trial in the concatenated dataset.

Analysis.

EEG were data were analyzed using repeated measures analyses of variance (ANOVAs) performed on the percent change effect of power from baseline in each of the following frequency bands: low beta (12-22 Hz), high beta (22-32 Hz), and gamma (32-59 Hz). The principal factors used in the ANOVAs were the between subjects variable Dance Type (dancer, non-dancer), and the within subjects variables Electrode (30 levels), Hemisphere (Left [O1, P3,

P7, CP3, TP7, C3, T7, FC3, FT7, F3, F7], Right [O2, P4, P8, CP4, TP8, C4, T8, FC4, FT8, F4, F8]), Region (Anterior [FP1, FP2, F7, F3, Fz, F4, F8, FT7, FC3, FCz, FC4, FT8]), Posterior [O1, O2, P8, P4, Pz, P3, P7, TP7, CP3, CPz, CP4, TP8]), Site (Anterior Left [FP1, F7, F3, FT7, FC3], Anterior Right [FP2, F8, F4, FT8, FC4], Posterior Left [O1, P7, P3, TP7, CP3], Posterior Right [O2, P8, P4, TP8, CP4]). These variables were nested under the within subject factor Music (Tango, Foxtrot, Jazz/Classical). When interactions with Electrode occurred in the Dance Type × Electrode ANOVA, subsequent ANOVAs were performed to include Hemisphere, Region, or Site. (See Figure 6 for electrode positions on the scalp. See Figure 7 for a visual example of frequency spectra at an electrode.)

Other ANOVAs were performed to ensure other uncontrolled variables did not contribute strongly to possible differences in the principal ANOVAs. These variables were sex and musicianship; each was nested under Dance Type, creating four levels for either factor (Sex [Dancer Female, Dancer Male, Non-dancer Female, Non-dancer Male]; Musicianship [Dancer Nonmusician, Non-dancer Nonmusician, Dancer Musician, Non-dancer Musician]).

The probability of a Type I error was maintained at 0.05. Degrees of freedom in the ANOVAs were corrected through the Greenhouse Geisser method. Post-hoc tests were performed using Scheffe (for equal numbers of observations) or LSD-*t* (for unequal numbers of observations). A Bonferroni correction was applied to LSD-*t* post hoc tests. Only statistically significant (or marginally significant) results are reported.

Gamma (32-59 Hz).

A Dance Type × Electrode ANOVA yielded a significant Music × Dance Type interaction [$F(2, 44) = 9.48$, $p = 0.0004$, Greenhouse-Geisser corrected] (Figure 2). Post-hoc analyses using Scheffe showed a significant music effect within each dance type. In dancers, tango music elicited an increase in gamma power percent change from baseline, whereas foxtrot and jazz/classical elicited a decrease. The differences between tango and foxtrot [$F(2, 44) = 15.01$, $p < 0.0001$] and between tango and jazz/classical [$F(2, 44) = 12.36$, $p < 0.0001$] were significant. Jazz/classical music was not significantly different from foxtrot. Within non-dancers, jazz/classical elicited an increase in percent change, whereas foxtrot and tango elicited a decrease. The difference between jazz/classical music and tango [$F(2, 44) = 6.50$, $p = 0.0034$] was significant; the difference between jazz/classical and foxtrot was marginal [$F(2, 44) = 6.05$, $p = 0.0048$]. Tango and foxtrot were not significantly different. The above indicate a preferred music effect within each group. However, this effect was not significant between both groups ($p = 0.84$).

A Dance Type × Hemisphere ANOVA returned a main effect of Hemisphere [$F(1,22) = 5.72$, $p = 0.026$], indicating a greater decrease of power from baseline in the right compared to the increase in the left hemisphere in all subjects listening to all music.

Analyses were performed to account for sex and musicianship, and yielded significant differences. A Sex/Dance Type (Dancer Female, Dancer Male, Non-dancer Female, Non-dancer Male) × Site ANOVA revealed a marginal Music × Sex/Dance Type interaction [$F(6, 40) = 3.01$, $p = 0.16$]. This interaction was further investigated by performing separate Sex × Site analyses in the dancer and non-dancer groups. No significant interaction with Sex was found in the non-dancers. However, a marginally significant Music × Site × Sex interaction was found within the dancers [$F(6, 60) = 2.40$, $p = 0.038$]. Post-hoc Scheffe analyses showed a marginally significant difference between female dancers and male dancers in the posterior right site when listening to tango music [$F(6, 60) = 9.97$, $p < 0.0001$] (Figure 4). This indicates a sex difference in in the posterior right area of the scalp when tango dancers listen to their preferred music. A marginal difference between the anterior left and posterior right regions in female dancers was also obtained [$F(6, 60) = 8.95$, $p < 0.0001$] (Figure 4). Differences between sexes in the dancer group listening to tango music in the other sites were not significant.

Musicianship was examined by performing a Musicianship/Dance Type (Dancer Nonmusician, Non-dancer Nonmusician, Dancer Musician, Non-dancer Musician) × Electrode ANOVA, which yielded a significant Music × Dance Type/Musicianship interaction [$F(6, 40) = 4.32$, $p = 0.0019$]. Post-hoc LSD-*t* (for unequal *n*) tests were calculated with a Bonferroni adjusted alpha level of 0.00076 (0.05/66) per test. These tests showed that the interaction was due to the marginally significant difference between the Dancer Nonmusicians listening to foxtrot music and the Non-dancer Musicians listening to jazz/classical music [$t(40) = 2.43$, $p = 0.020$]. Other possible interactions were not significant. It appears that musicianship did not make relevant contributions to the observed music effects within each dance type.

High Beta (22-32 Hz).

Similar to the analysis in gamma, a significant Music × Dance Type interaction [$F(2, 44) = 5.19$, $p = 0.0095$) was obtained in the Dance Type × Electrode ANOVA for the high beta band (Figure 2). Post-hoc Scheffe analyses revealed a significant music effect within each dance type. In dancers, tango music elicited a smaller decrease in power than did foxtrot music [$F(2, 44) = 8.23$, $p = 0.0009$] or jazz/classical music [marginally significant, $F(2, 44) = 4.79$, $p = 0.013$]. Foxtrot music and jazz/classical music were not significantly different. Within non-dancers, jazz/classical elicited an increase in high beta power, while tango and foxtrot music elicited a decrease. Jazz/Classical music in the non-dancers was significantly different from foxtrot [$F(2, 44) = 9.030$, $p < 0.0005$] and marginally different from tango music [$F(2, 44) = 5.60$, $p = 0.0068$]. Tango and foxtrot were not significantly different. In sum, the preferred music effect was evident within each group, as was observed in gamma. However, this preferred music effect was not significant between both groups ($p = 0.046$).

A Dance Type × Region (Anterior, Posterior) ANOVA revealed a marginally significant Music × Region × Dance Type interaction [$F(2, 44) = 4.183$, $p = 0.022$]. Post-hoc Scheffe tests showed a significant difference between the anterior and posterior region within dancers in the tango condition [$F(2, 44) = 52.60$, $p < 0.0001$]. Non-dancers in the jazz/classical condition did not show such a regional difference. Moreover, a comparison of the anterior regions of the dancers listening to tango and non-dancers listening to jazz/classical yielded a significant difference [$F(2, 44) = 80.68$, $p < 0.0001$]. Their posterior regions did not show differences (Figure 3).

A Sex/Dance Type (Dancer Female, Dancer Male, Non-dancer Female, Non-dancer Male) × Site ANOVA found a marginally significant Music × Group interaction [$F(6, 40) = 2.60$, $p = 0.032$], which was attributed to the difference between male dancers listening to foxtrot and female non-dancers listening to jazz/classical [$F(6, 40) = 22.03$, $p < 0.001$]. No other significant differences were found. Sex did not appear to influence the relevant music effects observed within dancers and non-dancers.

A Musicianship/Dance Type × Site ANOVA yielded a marginally significant Music × Musicianship/Dance Type × Site interaction [$F(18, 120) = 1.70$, $p = 0.049$]. Post-hoc LSD-*t* (for unequal *n*) tests were calculated with a Bonferroni adjusted alpha level of 0.000044 (0.05/1128) per test. The tests revealed several significant or marginally significant interactions. When nonmusicians listened to tango music, dancers and non-dancers differed marginally from each other at the posterior left site [$t(120) = 2.32$, $p = 0.022$], but differed significantly at the posterior right site [$t(120) = 4.35$, $p = 0.000029$]. Among non-dancers listening to tango music, nonmusicians and musicians differed marginally in the posterior right site [*t*(120) = 2.68, *p* = 0.0084].

Among nonmusicians listening to jazz/classical music, dancers and non-dancers differed marginally at the anterior left [*t*(120) = 2.93, *p* = 0.0041] and anterior right sites [*t*(120) = 2.80, *p* = 0.0060]. In musicians listening to jazz/classical music, dancers and non-dancers displayed significant differences in all four sites [anterior left: *t*(120) = 4.64, *p* = 0.0000091; anterior right: *t*(120) = 4.37, *p* = 0.000027; posterior left: *t*(120) = 5.38, *p* = 0.00000038; posterior right: *t*(120) = 4.31, *p* = 0.0000034]. Among dancers listening to jazz/classical music, nonmusicians and musicians differed marginally in the posterior left site [*t*(120) = 1.99, *p* = 0.049]. Within non-dancers listening to jazz/classical music, nonmusicians and musicians differed marginally in the posterior left [*t*(120) = 2.43, *p* = 0.016] and posterior right sites *t*(120) = 2.14, *p* = 0.034]. The effects of concern were those occurring between musicians and nonmusicians within each of the dance types. The non-dancer group displayed musicianship effects in more regions than did the dancers, albeit they were marginally significant.

Low Beta (12-22 Hz).

As in gamma and high beta, a significant Music × Dance Type interaction was obtained from the Dance Type × Electrode ANOVA (Figure 2). Post-hoc analyses using Scheffe demonstrated a preferred music effect within each group. In dancers, tango music elicited an increase in low beta power, whereas other music elicited a decrease. Differences were observed between tango music and foxtrot [*F*(2, 44) = 10.10, *p* = 0.0002] and between tango music and jazz/classical [marginal, *F*(2, 44) = 5.46, *p* = 0.0076]. Foxtrot and jazz/classical were not significantly different. In non-dancers, jazz/classical elicited an increase in low beta power, whereas other music brought out a decrease. Jazz/classical was not different from tango music (*p*

= 0.13), but was significantly different from foxtrot music [*F*(2, 44) = 8.60, *p* = 0.0007]. Tango and foxtrot music were not significantly different. Similarly demonstrated in gamma and high beta, the preferred music effect was observed within each group, yet was not significant between the groups (*p* = 0.6232).

ANOVAs performed to examine possible effects of sex did not yield significant interactions with sex, so further analysis for sex was not pursued. Sex did not seem to contribute to the observed music effects within each dance.

To examine musicianship, a Musicianship/Dance Type × Site ANOVA was performed, and yielded a marginally significant Musicianship/Dance Type × Site interaction [*F*(9, 60) = 2.10, *p* = 0.044]. Post-hoc LSD-*t* (for unequal *n*) tests were calculated with a Bonferroni adjusted alpha level of 0.000044 (0.05/120) per test, and revealed marginal differences. In dancers, nonmusicians and musicians were marginally different at the anterior right site [*t*(60) = 2.75, *p* = 0.0079]. Other marginal differences accounting for the interaction were between the posterior right site in dancer nonmusicians and anterior right site in dancer musicians [*t*(60) = 3.18, *p* = 0.0023], as well as between the anterior left site in dancer nonmusicians and the anterior right site in dancer-musicians [*t*(60) = 2.44, *p* = 0.018]. No significant differences were obtained in the tests; musicianship did not seem to affect the observed music and dance type effects.

Correlation Analyses

Regression analyses were performed to investigate possible relations between frequency power measures and music enjoyment. Music enjoyment was measured on a Likert scale ranging from 1 to 10 (1 = *least enjoyable*, 10 = *most enjoyable*; see *Method* above), and averaged across the trials for each music condition (tango, foxtrot, jazz/classical). Music enjoyment ratings were correlated with percent change increase in power in each of the frequency bands. Separate correlations were made for ratings of all music, and for ratings of only tango and jazz/classical music. Only in gamma was there a significant or marginally significant correlation. Gamma power percent change had a moderate positive correlation with enjoyment ratings for all music, $r(70) = 0.335$, $p = 0.004$. Without ratings for foxtrot music, the correlation was marginally significant, $r(46) = 3.99$, $p = 0.0049$ (Figure 5). Gamma power appeared to be sensitive to preference, with percent change in power increasing as preference for music increased.

Discussion

The purpose of the current study was to explore how dance experience modulates the power of high-frequency activity; specifically, alpha and high-frequency (beta and gamma) waves. It was hypothesized that non-dancers would elicit more power in the right hemisphere than in the left, and that dancers would show more power in the left relative to the right, or no asymmetry at all. The results did not directly support the given hypotheses regarding differences between the two groups. The hypotheses regarding alpha were not supported (non-dancers did not show a right hemisphere-dominant increase in alpha power, and dancers did not show predominantly left hemisphere power increase nor display remarkable symmetry), thus warranting no further discussion about alpha power. However, the results indicated differences in other respects, especially in beta and gamma, as well as a few unexpected outcomes.

First, in all high frequency bands—gamma (32-59 Hz), high beta (22-32 Hz), and low beta (12-22 Hz)—a preferred music effect was observed: there was an increase in power from baseline or less of a decrease relative to baseline, compared to other music when tango dancers listened to tango music and when non-dancers listened to jazz/classical music. (Preferred music was corroborated with the help of rating scores; dancers rated tango music highest relative to other music, and non-dancers rated jazz/classical highest.) The preferred music effect, however, seemed to be the strongest or most clearly shown in the gamma band, less so in high beta, and the least in low beta. The correlations between band power and enjoyment ratings help explain this gradual weakening—only in gamma was there a significant correlation between enjoyment and percent change. Nevertheless, a preferred music was present and did not interact with dancer type. Thus, listening to preferred music generally elicited higher power in everybody at the high-frequency bands than did other music.

Listening to favorite or preferred music is perhaps a product of attention to and cognitive effort on the music, of which high-frequency activity is an indicator. The current results are consistent with the findings of the exploratory EEG study by Petsche, Richter, Von Stein, Etlinger, and Filz (1993), in which coherence in beta was associated with listening to familiar or favorite music. A combined PET-EEG study by Nakamura et al. (1999) showed increased beta power relative to rest when healthy volunteers listened to traditional Indonesian music. Beta power was positively correlated to regional cerebral blood flow (rCBF) in the bilateral posterior precuneus, a region they explain is possibly involved in music processing. These help to explain the music effects found in the low and high beta bands.

As for the preferred music effect in gamma, past research has implicated the high-frequency band in attention. Fries, Reynolds, Rorie, and Desimone (2001) recorded local field potentials of neurons in the visual cortex of macaque monkeys who attended to a stimulus inside or outside their receptive fields. They found that gamma power and synchrony of the potentials recorded from these neurons increased with attention (i.e. when the monkeys attended to the stimulus inside their receptive field). Lutz, Greischar, Rawlings, Ricard, and Davidson (2004) measured EEG gamma activity in long-term meditation practitioners and in non-practitioners. Their results showed that gamma power increased for both groups when both practitioners and non-practitioners moved from rest to a meditative state (the increase, however, was greater for the practitioners). Lutz et al. explained that especially in meditation, increased gamma power may indicate that diffuse neural networks become highly-synchronized in high-frequency bands. The current findings showing increased power at high-frequency bands during preferred music conditions suggest that listening to favorite music is different from listening to non-preferred music. Because it is highly engaging and stimulates attention, preferred music can increase power in the high frequencies which are indicative of wakeful, alert states. Listening to preferred music may even be comparable to other intensely engaging states, such as meditation, since both tasks seem to produce amplified activity in the high frequencies.

A second major observation in the current study was the presence of a significant hemisphere effect only in the gamma band: there was a higher power change in the left than in the right hemisphere in all subjects. This result contradicts this study's hypotheses. An fMRI study by Ohnishi et al. (2001) demonstrated right-dominant activation in non-musicians, and left-dominant activation in musicians while they passively listened to music, suggesting that specialized training in music may shift lateralization from right to left. The current results do not seem to agree with the Ohnishi et al.'s fMRI results which were consistent with what is generally known about the left hemispheric specialization. Given that the left hemisphere is involved in analytical thinking, perhaps both groups processed music analytically, activating the left regions in similar ways. A possible explanation is that due to the cautionary instructions and the setting, all the subjects may have attended to the music intensely, thereby increasing concentration on the music and making a conscious effort to analyze it. It is difficult to listen to music calmly when one is sitting in a closed chamber and told not to make eye, head, or body movements.

A third key observation is the contrast between anterior and posterior regions when subjects listen to preferred music. In dancers listening to tango, the posterior region had increased power in high-beta whereas the anterior region showed a decrease in high-beta. The non-dancers who listened to jazz/classical did not demonstrate such a contrast, since both their anterior and posterior regions showed similar increases in high-beta power. A study by Orgs, Dombrowski, Heil, and Jansen-Osmann (2008) examined alpha and beta event-related desynchronization (ERD), defined as a power decrease from a control time-frame relative to an event or task. Non-dancers and dancers were instructed to watch dance movements and everyday movements on a video, as their EEG activity was recorded. The experimenters found that dancers had a more robust ERD than non-dancers, especially when watching dance movements. The difference in ERD or power decrease in alpha and beta bands was modulated by dance experience. Orgs et al. propose that the reason for the greater power decrease in dancers was that dancers' mirror neurons suppressed motor cortex activity in the central cortical areas to a greater extent than the non-dancers, due to the dancers' better ability to match dance movement to the right motor representation. The current study's results seem to agree with the findings of Orgs et al. (2008). Both non-dancers and dancers listened to their preferred music, but only dancers displayed a high-beta decrease, which was seen in the anterior area, which contains the motor cortex. Dancers, familiar with their music as pieces for dancing to tango, might have employed motor systems in the brain that non-dancers did not, thus the decrease in high-beta power in dancers. Beta ERD has been implicated in motor action in other studies, such as one by Doyle, Yarrow, and Brown (2005), who showed that beta ERD was lateralized before a motor action was performed. It seems that beta power decrease has something to do with motor planning or selection.

The fourth observation of interest is the significant sex difference within dancers. In dancers, who listened to tango music, females and males differed in gamma power change, specifically in the posterior right region. No sex differences occurred in the non-dancer group. This is interesting because of a possible effect of role in the dancers. In tango, the dance role is usually gender-specific: males are usually leaders, and females are followers. The presence of a sex difference in the dancer group and an absence thereof within the non-dancers, might mean an effect of roles on the way the dancers processed tango music. Perhaps leaders listened to tango music differently from followers.

Significant interactions involving musicianship were found in the high beta band. Of concern were the significant differences between musicians and non-musicians in dancers and in non-dancers at the four sites (anterior left, anterior right, posterior left, posterior right). The non-dancers showed marginally significant effects of musicianship in more regions that interacted with music type (posterior right when listening to tango music; posterior left when listening to jazz/classical; and posterior right when listening to jazz/classical). It is possible that some musicians from the non-dancer group contributed to the interaction. Musicianship was a difficult factor to control for; thus, there may be no definite explanation for any differences involving musicianship.

Future research might look at time development in each band, such as gamma, which showed greater activation in the left hemisphere, a region related to temporal processing. Another possible study might observe dancers when they are engaged in more dance-relevant tasks, such as watching or performing simple movements, instead of passive listening to music.

The current study's results did not support the proposed hypotheses. No clear differences in hemispheric specialization between dancers and non-dancers were observed. Instead, differences were found between the groups in which anterior and posterior regions varied in high-beta power for dancers, but not for non-dancers. Another result found only within dancers was the sex difference, in which female dancers differed from male dancers in gamma power at the posterior right region of the brain when they listened to tango music. In these respects, dancers and non-dancers were different in the way they listened to their preferred music. It seems that expertise or training in dance can change cortical organization. The overall differences, such as the preferred music effect and left hemisphere gamma increase irrespective of dance experience, indicate that the brain’s electrical activity can be altered by listening to music, which is a relatively passive task.

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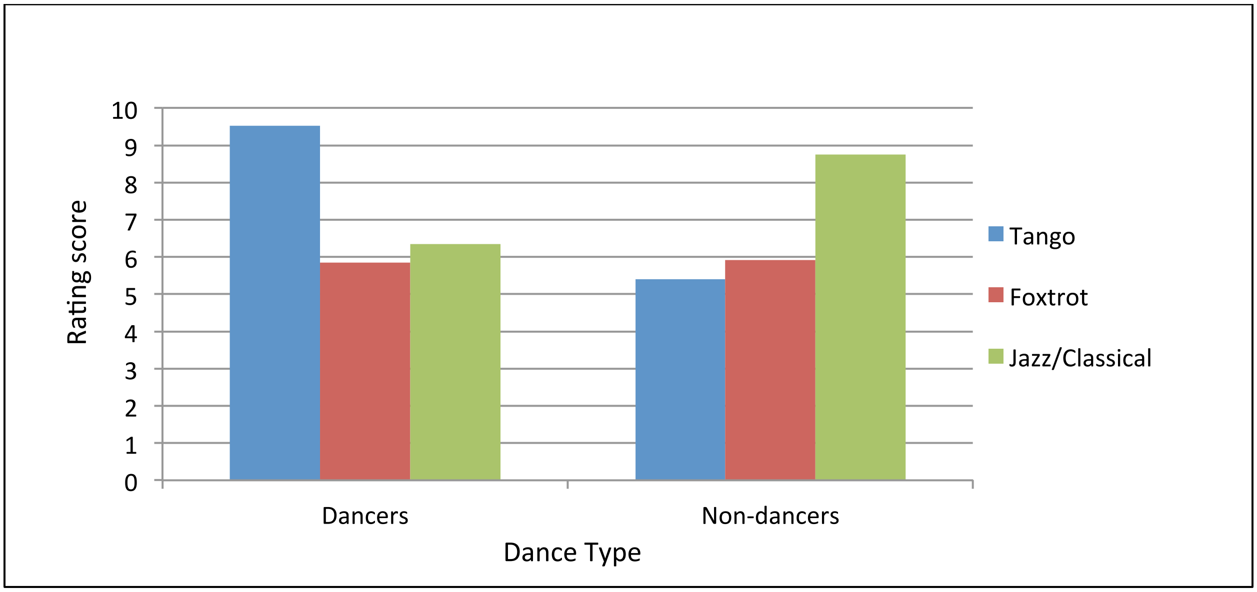

Figure 1. Subjects' mean rating of enjoyment of tango, foxtrot, and jazz/classical music (1 = *least enjoyable*, 10 = *most enjoyable*).

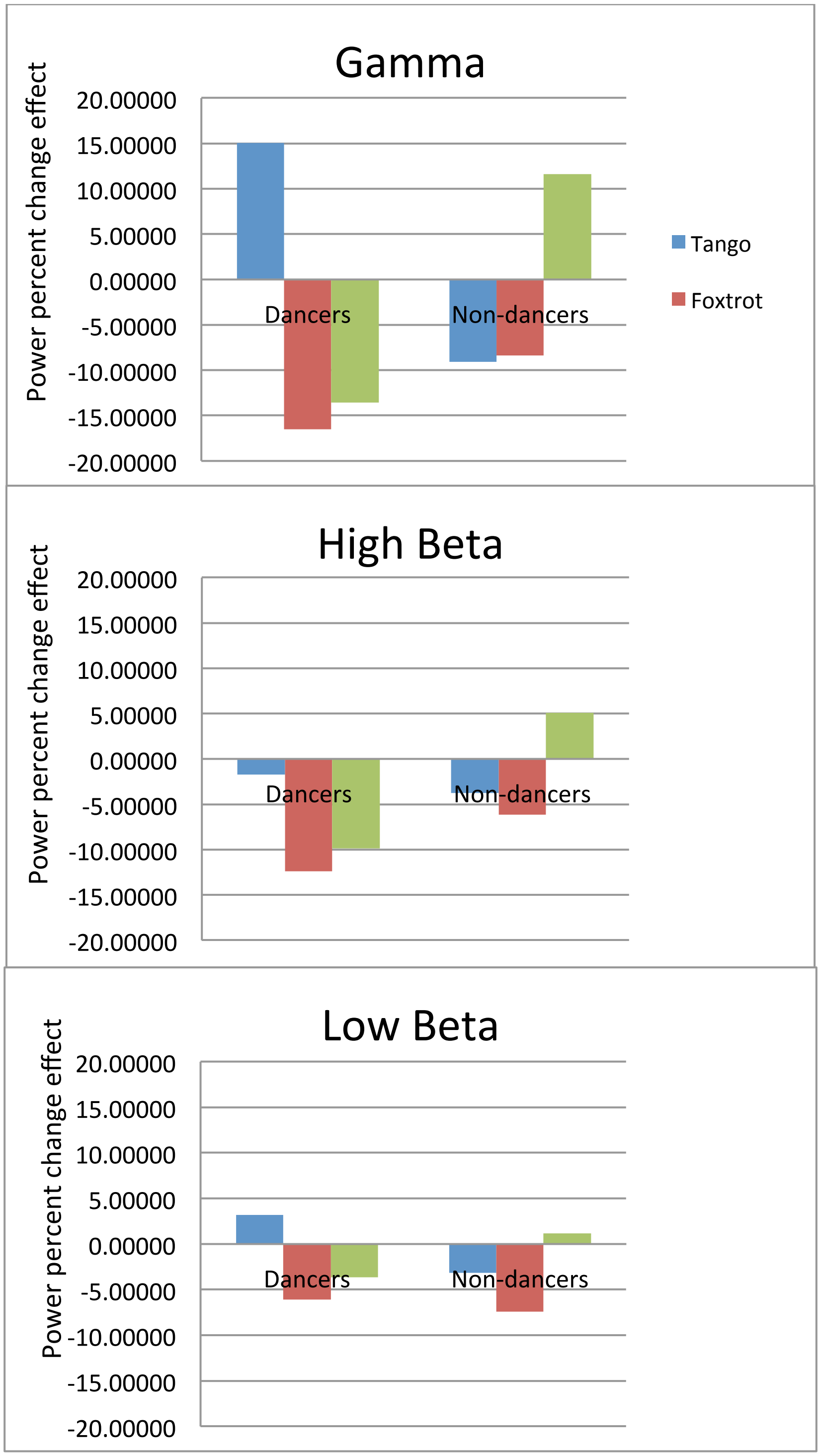

Figure 2. Percent change in power from baseline in the gamma, high beta, and low beta bands among dancers and non-dancers when listening to music. A preferred music effect is apparent within dancers and non-dancers. This effect is not significantly different across groups.

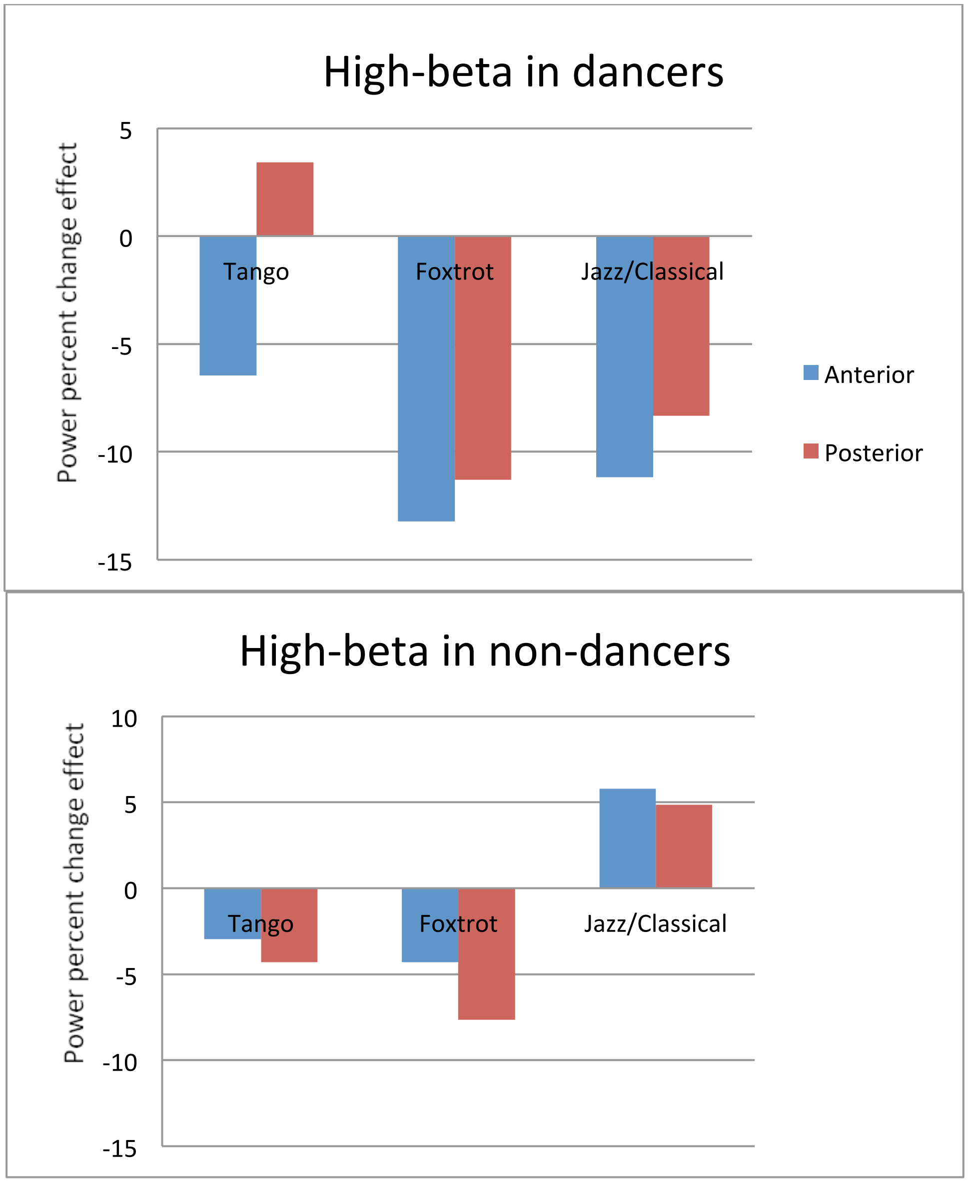

Figure 3. Percent change in high-beta power from baseline in anterior and posterior sites of the scalp of dancers and non-dancers listening to music. The difference between anterior and posterior sites is significant within dancers listening to their preferred music (tango), but not within non-dancers listening to their preferred music (jazz/classical).

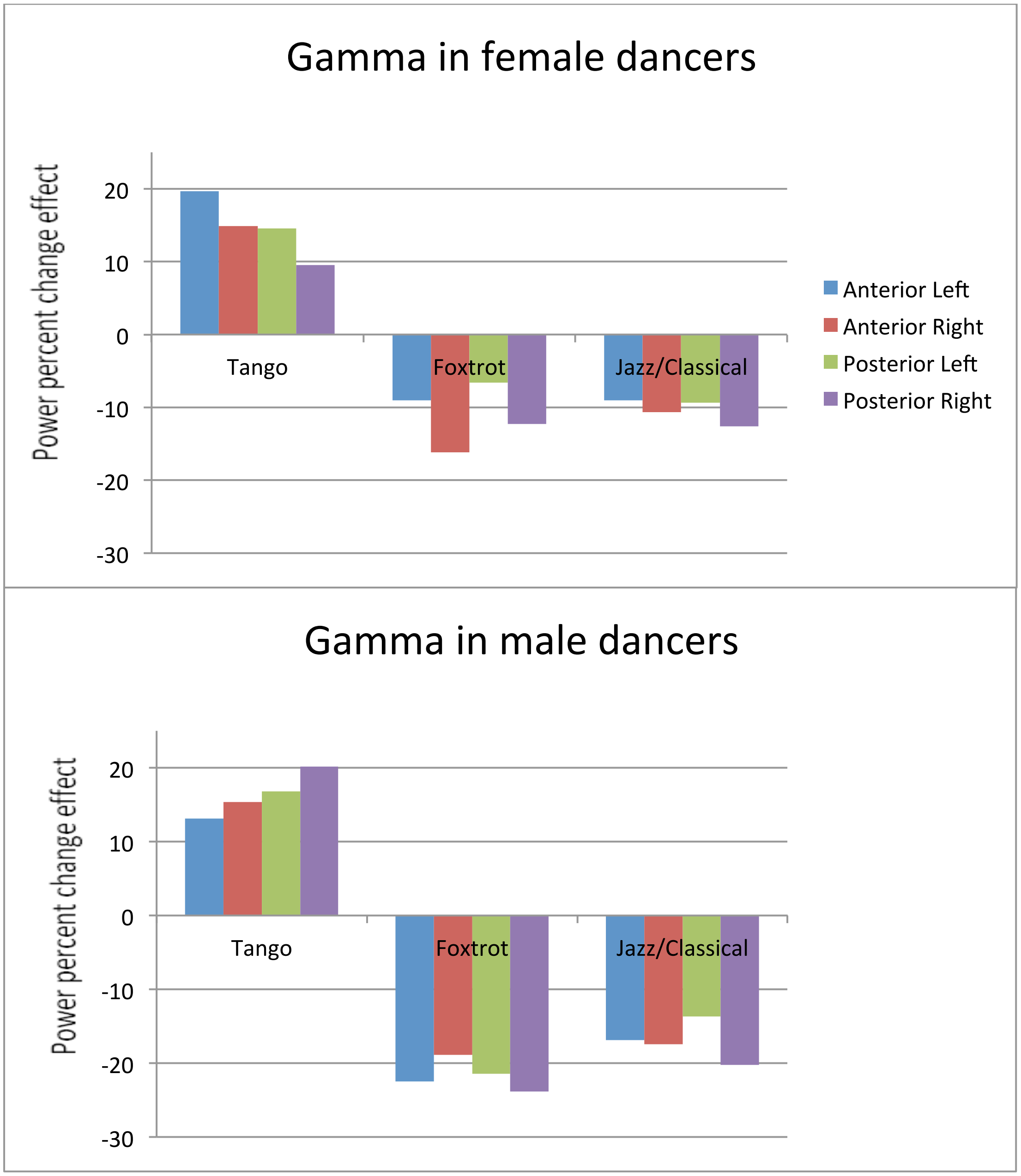

Figure 4. Percent change in gamma power among four scalp sites within female dancers and male dancers when listening to music. When listening to tango music, female dancers and male dancers differed significantly in the posterior right site.

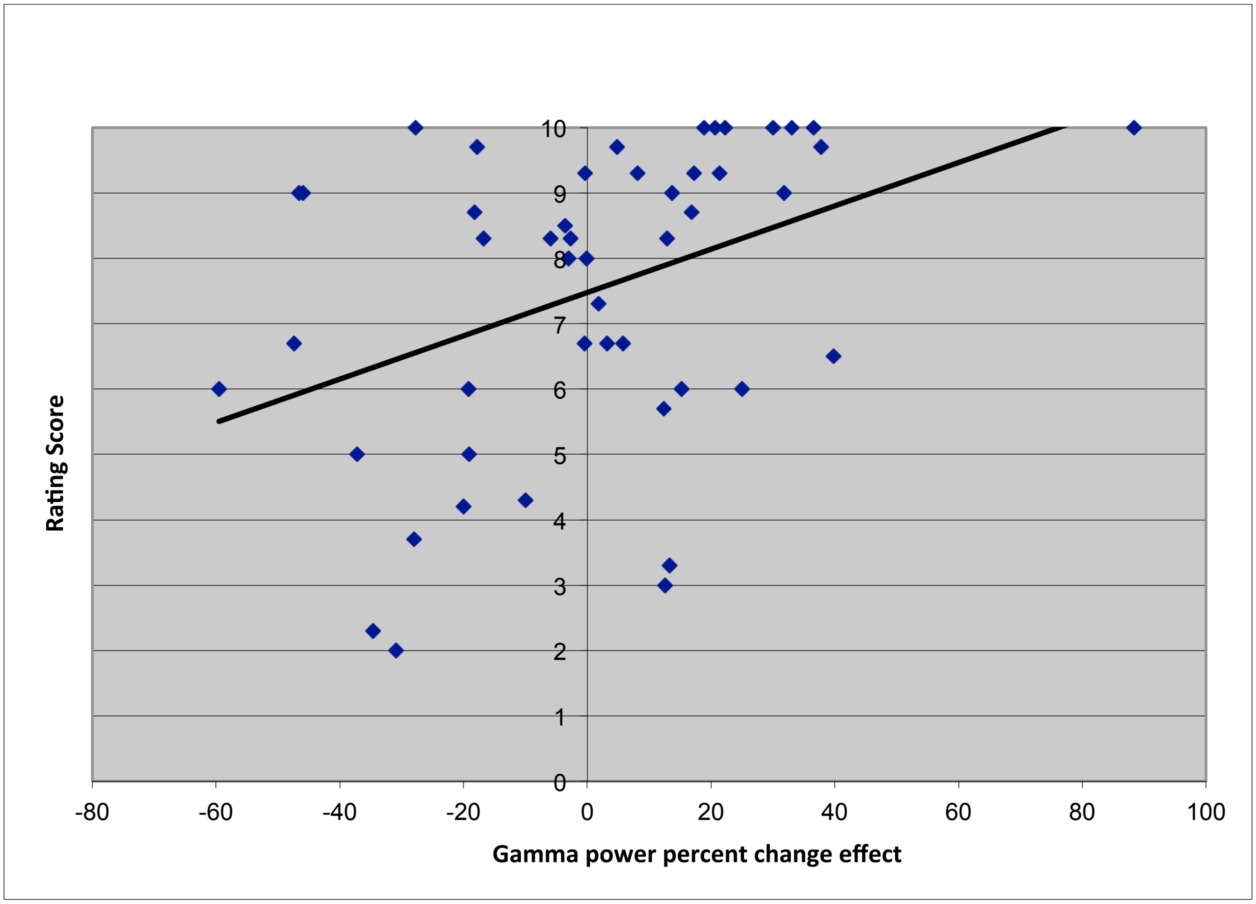

Figure 5. Scatterplot showing correlation between percent change in gamma power and music enjoyment ratings.

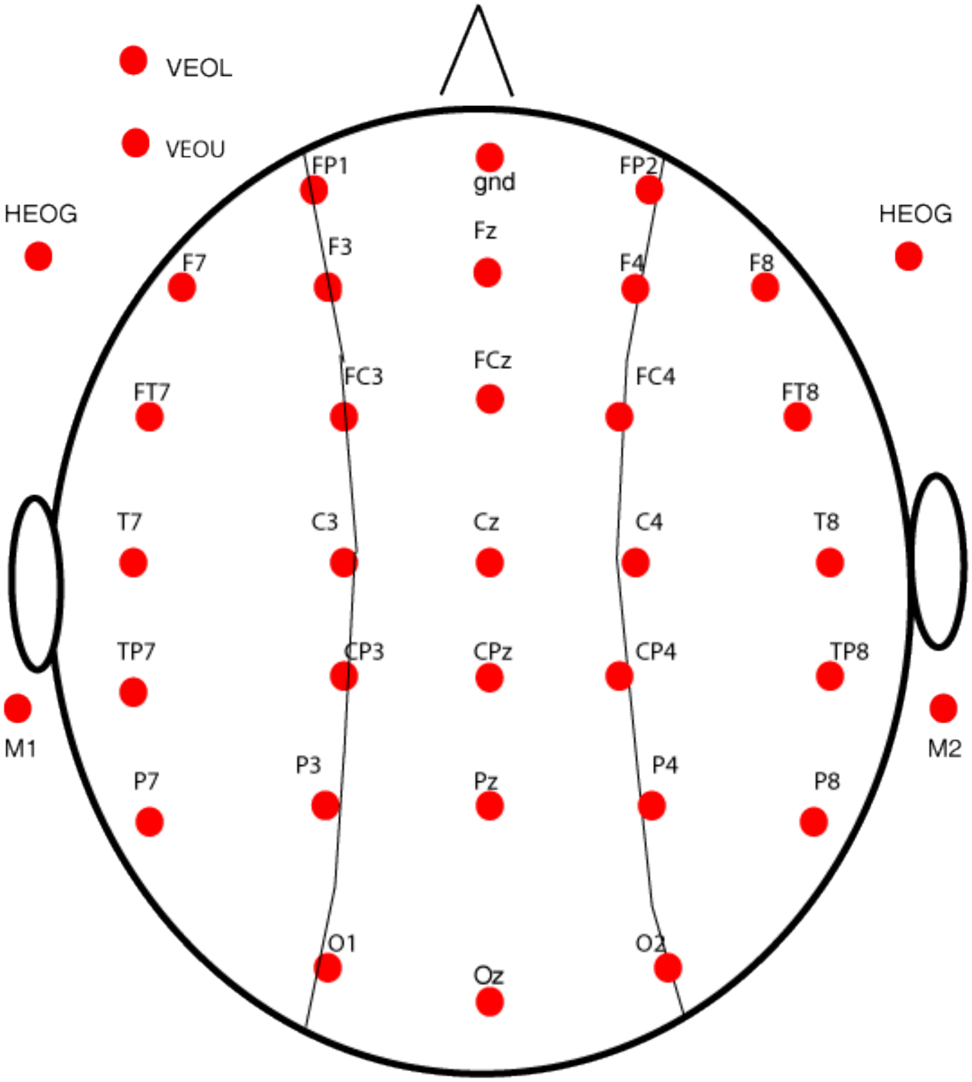

Figure 6. Electrode locations on the electrocap.

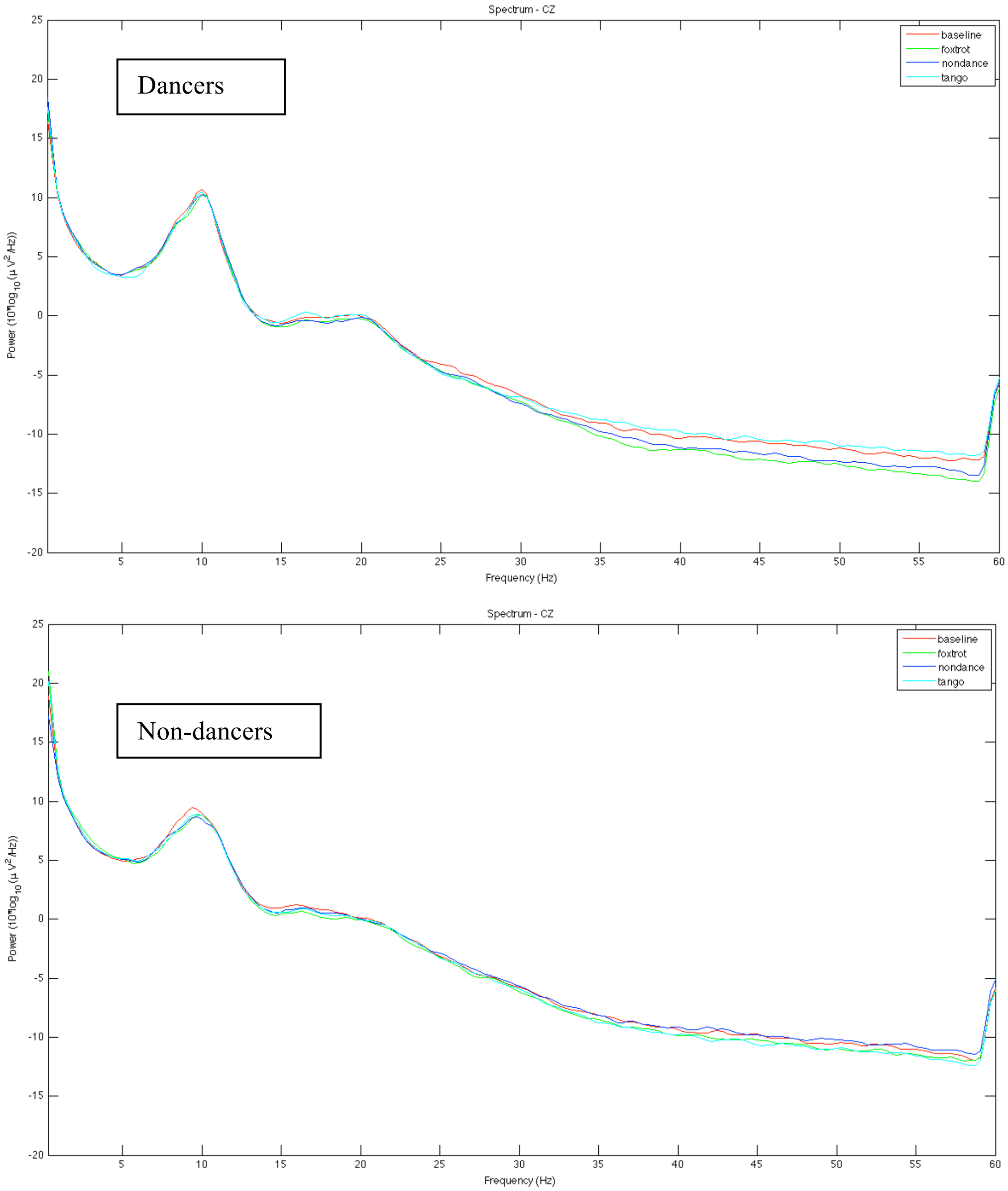

Figure 7. Frequency spectra at electrode Cz in dancers and non-dancers during baseline and the three music conditions. Power during their preferred music condition (tango, light blue line) in dancers in the higher end of the frequency spectrum (especially at gamma, 32-59 Hz) is more defined relative to baseline (red line). This appears different from the non-dancers' spectrum at gamma, where the difference between their preferred music condition (nondance music, dark blue line) and baseline (red line) do not seem distinct.