Low Frequency EEG Analysis of Argentine Tango Dancers and Non-Dancers

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During moments of relaxation we have particular electric activities occurring in the brain, known as alpha waves. These alpha waves appear in moments prior to sleep, but also in times of meditation. Particularly in meditation, alpha wave activity is shown to occupy a larger area of the brain and soon concentrated in the frontal area, shifting to lower frequency waves such as theta and delta as more meditation training is received (Buzsaki, 2006). Theta and delta waves have also been observed during sleep, where theta waves will occur during stage 2 sleep and delta waves will occur during stage 3 and 4 (Gazzaniga & Heatherton, 2003). These alpha, theta, and delta waves (they are collectively referred to as low frequency waves) are measured by recording electroencephalogram (EEG), through electrodes placed over various locations on the scalp. Alpha waves generally have the range of 8 to 12 Hz; theta 4 to 8 Hz; delta 1 to 4 Hz (Gazzaniga & Heatherton, 2003).

In this study, we are investigating whether these low frequency wave activities are present in experienced dancers, primarily Argentine Tango dancers, and to contrast these findings against ballroom dancers and non-dancers. Tango dancers, much like meditators, rely on an internal focus and attention when performing their dance. Buzsaki (2006) discusses potential association between the low frequency activities with the decrease of anxiety and stress, and the increase of attention mechanisms. This suggests that by meditating, we may be able to improve our physio-psychological state and cognitive ability. Performing tango dance also uses an increase in attention mechanisms and can also be viewed as an anxiety and stress reducer.

Other studies have shown that subjects who have increased experience in tasks not related to meditation can show greater alpha power when performing their task, as opposed to subjects who have little or no experience. This has been shown in various groups of people including chess players (Grabner, Stern & Neubauer, 2003), taxi drivers (Grabner, Neubauer & Stern, 2006) and elite athletes (Del Percio et al, 2009). Grabner, Stern & Neubauer (2003) had experienced and novice chess players

perform a memory task that used chess pieces on a chessboard. They found that greater experience led

to better performance on the memory task as well as less alpha event-related desynchronization (ERD).

Grabner, Neubauer & Stern (2006) also compared taxi drivers of varying years of experience where

they performed a memory task. One task implemented had subjects memorize a route within a familiar

map of the local. They found less alpha ERD for experienced taxi drivers as opposed to novice taxi

drivers when performing the familiar map task. Del Percio and his colleagues (2009) compared elite

athletes to amateur and nonathletes in a simple balancing task. They found that greater experience yet

again showed less alpha ERD when performing this task. This greater power of alpha shown in

experienced as opposed to non-experienced people may share the same underling neural organization

mechanisms across all experts. These previous studies relate a decrease in alpha ERD to less neural

activity needed to perform a given task. This is because a decrease in alpha ERD means more alpha

power during a task. Since alpha waves are most common during moments of rest, and more

experience for a given discipline shows a decrease in alpha ERD, then the current hypothesis is that a

decrease in alpha ERD is related to more neurons at a resting state, or less neural activity. Using less

neural activity to perform a task has been coined as the neural efficiency hypothesis. The neural

efficiency hypothesis is not specific to alpha power, but this study measures neural efficiency using

alpha ERD.

    Buzsaki briefly states widespread theta rhythms can be seen in expert meditators. Through

decades of meditation practice and training, expert meditators shift their mean alpha peaks towards

lower frequencies of alpha, and inevitably becomes a mean theta peak. During a theta ERD, an alpha

ERD can be observed (Klimesch, 1999b). Klimesch first had subjects perform a semantics task, where

he related two words on a screen and subjects had to recall which words were related together. He

found that subjects during the memory task performance who performed exceptionally well exhibited a

theta ERD. Both groups, expert meditators and semantic task performers who performed exceptionally

well, exhibited a decrease in theta ERD possibly due to their expertise or experience with their respective tasks. Dancers who have also many years of training may also show this decrease in alpha frequency, potentially becoming a theta frequency, as well as an accompanying decrease in theta ERD. This would support the idea that people who are experts in a discipline or perform exceptionally well in a given discipline will exhibit more theta power than non-experts or those who perform not exceptionally well.

Experienced dancers will have practiced a specific set of skills over time, relating to music and how to physically move in synchrony with that music. Although these dancers may not be formally trained musicians, more experienced dancers would be more experienced with their preferred genre of music (e.g. Argentine tango music for an Argentine tango dancer). This gives rise to the question: do Argentine tango dancers process music differently than non-dancers?

Fink, Graif & Neubauer (2009) showed that experienced dancers showed an increase in alpha power as opposed to non-dancers when performing tasks related to dance but not physically dancing, such as visualizing a dance. For their dance visualization task, they had all subjects imagine an improvised dance. For the experienced dancers, there was less alpha ERD for this task. Non-dancers showed a greater increase in alpha ERD. Since Argentine tango dancing is fundamentally creative because of its improvisational nature, would this translate to neurophysiological differences between tango dancers and non-dancers in other areas, such as music processing?

This study investigates whether music processing differs between tango dancers and non-dancers. We hypothesize that experienced dancers would have an increase in power for alpha, theta, and delta when compared to non-experienced dancers.

Method

Participants

24 participants (ages 20 to 60) took part in this study. All participants were screened for their experience in dance, and two groups (tango, non-dancers) were identified. 12 people (6 females) were assigned to the tango group and 12 people (6 females) to the non-dancer group. All participants were right-handed and had no neurological abnormalities.

All dancers in tango groups 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 different 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. 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.

<div align="center">

Results

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EEG Preprocessing

EEG data was preprocessed and analyzed 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 was to be rejected, the trial was excluded from further analysis. However, a trial was kept if artifacts that remained were eye-related or systematic (stereotyped) enough for independent component analysis (ICA) to detect. This stage of manual rejection 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, each trial in the concatenated dataset was fit into epoch windows of 108 s.

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. Non-dancers had mean rating scores of 5.4 for tango music, 5.9 for foxtrot music, and 8.8 for jazz/classical music.

When comparing rating scores within groups, tango dancers listening to tango music showed a significant difference from foxtrot [$F(2,44) = 43.52$, $p < 0.05$] and from jazz/classical [$F(2,44) = 32.24$, $p < 0.05$]. No significance was found when comparing tango dancers listening to foxtrot versus listening to jazz/classical. Non-dancers listening to jazz/classical showed a significant difference from foxtrot [$F(2,44) = 25.75$, $p < 0.05$] and from tango [$F(2,44) = 36.01$, $p < 0.05$]. No significance was found for non-dancers listening to foxtrot music versus tango music. Both groups showed a significantly higher score for their respective preferred music.

When comparing rating scores for preferred music between tango dancers and non-dancers, no significance was found.

EEG Results

The analysis of low-frequency waves were divided into four (4) separate and different narrow-band frequency lengths: delta ($0 - 4$ Hz), theta ($4 - 8$ Hz), low alpha ($8 - 10$ Hz) and high alpha ($10 - 12$ Hz). EEG data were analyzed using repeated measures analyses of variance (ANOVAs) performed on the percent change of effect (e.g. a difference in power) for each frequency band. ANOVAs were performed to test potential differences amongst group (tango dancers X non-dancers). Separate ANOVAs were performed for different factors, such as region (anterior electrodes [FP1, FP2, F7, F3, FZ, F4, F8, FT7, FC3, FCZ, FC4, FT8] X posterior electrodes [TP7, CP3, CPZ, CP4, TP8, P7, P3, PZ, P4, P8, O1, O2]) and sites (anterior left electrodes [FP1, F7, F3, FT7, FC3] X anterior right electrodes [FP2, F4, F8, FC4, FT8] X posterior left [TP7, CP3, P7, P3, O1] X posterior right [CP4, TP8, P4, P8, O2]). Greenhouse-Geisser method was used to correct degrees of freedom. Post-hoc analyses were

performed using the Scheffe test. In some cases, the use of LSD-t test was implemented if the amount

of subjects was unequal. Furthermore, the Bonferroni correction was performed for LSD-t test results.

The probability of a type I error was maintained at 0.05.

No results were reported for theta band because no significant results were obtained.

Delta band.

The main effect of region showed an increase in power for anterior electrodes, which was

significantly different from posterior electrodes [$F(1,22) = 10.26$, $p = 0.0041$]. This finding shows that

regardless of whether you are a dancer or a non-dancer, there is an anterior region increase significantly

greater than the change in posterior region when listening to any type of music.

Low alpha band.

When ANOVA for sites were performed, a marginally significance result was shown for the

interaction of music type x group type x sites [$F(6,132) = 2.06$, p = 0.0625]. However, follow-up

analyses showed that tango dancers listening to tango music was significantly different from tango

dancers listening to all other types of music [anterior left tango music versus anterior left foxtrot music:

$F(6,132) > 46$, $p < 0.0001$; anterior right tango music versus anterior right foxtrot music: $F(6,132) =$

46.19, $p < 0.0001$; posterior left tango music versus posterior left foxtrot music: $F(6,132) = 13.52$, $p <$

0.0001; posterior right tango music versus posterior right foxtrot music: $F(6,132) > 46$, $p < 0.0001$;

anterior left tango music versus anterior left classical/jazz music: $F(6,132) = 16.72$, $p < 0.0001$;

posterior right tango music versus posterior right classical/jazz music: $F(6,132) = 14.69$, $p < 0.0001$].

This was observed for all sites except for anterior right and posterior left sites when listening to

classic/jazz music [anterior right tango music versus anterior right classical/jazz music: $F(6,132) =$

9.46, $p > 0.05$; posterior left tango music versus posterior left classical/jazz music: $F(6,132) = 2.78$, $p >$

0.05].

In contrast, non-dancers showed no site differences when listening to classical/jazz music in comparison with other types of music with the exception of the posterior left when listening to foxtrot music [posterior left foxtrot music versus posterior left classical/jazz: $F(6,132) = 27.26$, $p<0.0001$].

With these above two findings, the difference between preferred music and other music for tango dancers was larger than the difference between preferred music and other music for non-dancers.

To examine further differences between tango dancers and non-dancers listening to their respective preferred music, a post-hoc analysis was performed comparing tango dancers listening to tango music and non-dancers listening to classical/jazz music. Tango dancers showed a significant difference from non-dancers when listening to preferred music in three of the four sites [anterior left: $F(6,132) = 41.33$, $p < 0.0001$; anterior right: $F(6,132) = 58.01$, $p < 0.0001$; posterior right: $F(6,132) = 28.03$, $p < 0.0001$]. There were no differences observed in the posterior left site. These finding indicate that there is a preferred music effect for both groups, however tango dancers showed significantly less change when compared to the non-dancers for their preferred music.

High alpha band.

Correlational analysis was performed on percent change in high alpha with respect to years of experience with Ss preferred music. Experience was defined for dancers as the amount of time in years they have been dancing tango whereas non-dancer's experience was defined as the amount of time in years they have described themselves as "avid lovers" of classical/jazz music. Tango dancers showed a positive correlation with experience and high alpha percent change ($r = 0.63$). In contrast, non-dancers showed a negative-trending correlation with experience and high alpha percent change, but this finding was not significant ($r = -0.39$).

Discussion

This study investigates the hypothesis that Argentine tango dancers would elicit higher levels of power in alpha (8 – 12 Hz), theta (4 – 8 Hz), and delta (0 – 4 Hz) power than non-dancers when

listening to their preferred music because of Argentine tango dancers experience with dancing to their preferred music

High alpha (10 – 12 Hz) frequency percent change from baseline showed a positive correlation for tango dancers and years of experience in dancing when they listened to tango music (Figure 1). High alpha frequency has been show to occur when intelligent participants or participants with specific areas of expertise are performing an active task, such as a memory task or intelligence task (Grabner, Neubauer & Stern, 2006). Increases in high alpha percent change can also be attributed to experience, where the more experience you have in a task the more high alpha power you will elicit (Grabner, Stern & Neubauer, 2003). Ideally, more experience a subject had with their preferred music should show a larger increase in percent change for high alpha, regardless of group and regarding only experience. However, these data indicate only tango dancers showed a positive correlation. It is possible that this sort of result is due to tango dancers being trained in tango dance, whereas experience in loving jazz/classical music is only attributed to listening to jazz/classical music. Subjects who trained in tango dance could accurately determine when they began their dance training, the type of training they received, and the amount of time they spend dancing. However, non-dancers did not show this increase in alpha even though some of the lovers of jazz/classical music commonly stated they have loved their particular music "all their life".

Low alpha (8 – 10 Hz) frequency showed that when tango dancers were listening to their preferred music of tango, they showed a significantly smaller reduction, or less desynchornization, in percent change when compared to foxtrot music and in the anterior left and posterior right for jazz/classical music (Figure 2). Non-dancers showed no differences when listening to their preferred music of jazz/classical when compared to listening to tango music and only significantly less desynchronization for the posterior left when compared to foxtrot music. When tango dancers listening to tango music and non-dancers listening to jazz/classical music are compared, tango dancers listening

to tango music show significantly less desynchronization in all regions except for the posterior left. Low alpha waves are related to general attention during a task (Klimesch, Schimke & Pfurtscheller, 1993) or general alertness (Grabner, Neubauer & Stern, 2006). Tango dancers listening to tango music show less alpha desynchronization, or more alpha synchrony, when compared to all other conditions within and between groups. Since only tango dancers show this difference, this can be attributed to tango dancers training in tango dance – named "dance effect". As both groups listen to music, general attention resources are being recruited from different areas of the brain. Due to the familiarity and experience with tango music that tango dancers possess due to the physical nature of dancing, they may not have to use as many resources to pay attention to tango music, which is reflected by less alpha desynchonization. Compared to non-dancers listening to jazz/classical music, tango dancers had less alpha desynchornization in all areas except for the posterior left. Also, tango dancers showed significantly less desynchronization when listening to tango music versus foxtrot or jazz/classical. In contrast, non-dancers showed drastically fewer differences when listening to any type of music, which may reflect the lack of experience in dance. The difference in the bilateral anterior area for tango dancers may be due to the cognitive processes that are also involved with dancing. The differences in the right side of the brain for tango dancers may be due to the ability to put tango music into a specific context of dance whereas non-dancers listening to jazz/classical may have varying, weak or no contextual thoughts. This leaves us with posterior left, however it is very possible that an increase in power would lead to a significant result like all the other areas of the brain.

Delta (0 – 4 Hz) frequency showed a significant difference between the anterior and posterior areas, where the anterior area has a significant increase in percent change relative to the posterior area (Figure 3). This was the same for both groups. The implications of delta and theta may be related an internal focus or concentration, similar to meditation (Harmony et al, 1996). Harmony had subjects perform arithmetic problems mentally. She found that during the task, subjects had an increase in delta

power from baseline. This gives rise to the idea of internal concentration, or the attention to internal processing, increasing delta power. Since both dancers and non-dancers showed no differences between each other, the process of listening to music, or internally concentrating on the music, is the same for everyone.

In summary, the dancer effect is most prominent in the low alpha region, where tango dancers listening to tango music show less desynchronization in percent change when compared to all other conditions within and between groups. This may suggest that tango dancers will elicit less alpha desynchronization because of their experiences with tango music through dance. Alpha waves are generally associated with a resting state, or periods of relaxation (Gazzaniga & Heatherton, 2003). However, previous studies suggest that people with experience related to a specific task will exhibit more alpha than people without experience. Grabner, Stern & Neubauer (2003) showed that chess experts performing a memory task involving chess pieces would have more alpha than chess novices performing the same task. Grabner, Neubauer & Stern (2006) showed this finding again, this time using taxi drivers with decades of experience versus new taxi drivers in a memory task involving a familiar local map and a specified route. Del Percio and his colleagues (2003) showed that expert athletes performing a simple physical task had more alpha than amateur athletes and non-athletes. All of these studies measure neural efficiency by the increase in alpha power due to the generally associated idea of alpha activity as a sign of neurons at rest, or the use of fewer mental resources. The findings from this study also support the neural efficiency hypothesis, where more experiences (i.e. dance) with a music genre can lead to fewer mental resources needing to be activated when listening to that same genre.

Future studies should observe two different dance types, such as tango dance and foxtrot, and whether other dance types exhibit similar results.

References

Babiloni, C., Marzano, N., Iacoboni, M., Infarinato, F., Aschieri, P., Buffo, P., Cibelli, G., Soricelli, A.,

    Eusebi, F., Del Percio, C. (2010). Resting state cortical rhythms in athletes: A high-resolution

    EEG study. *Brain Research Bulletin, 81*, 149-156.

Buzsaki, G. (2006). CYCLE 8: Perturbation of the Default Patterns by Experience. In *Rhythms of the*

    Brain (pp. 214-217). Oxford University Press, Inc.

Del Percio, C., Babiloni, C., Marzano, N., Iacoboni, M., Infarinato, F., Vecchio, F., Lizio, R., Aschieri,

    P., Fiore, A., Toràn, G., Gallamini, M., Baratto, M., Eusebi, F. (2009). "Neural efficiency" of

    athletes' brain for upright standing: A high-resolution EEG study. *Brain Research Bulletin, 79*,

    193-200.

Fink, A., Graif, B., & Neubauer, A. C. (2009). Brain correlates underlying creative thinking: EEG

    alpha activity in professional vs. novice dancers. *NeuroImage*, *46*(3), 854-62.

Gazzaniga, M. S., & Heatherton, T. F. (2003). Patterns of electrical brain activity during different

    stages of sleep. In *Psychological Science* (pp. 301) Norton.

Grabner, R. H., Stern, E., & Neubauer, A. C. (2003). When intelligence loses its impact: Neural

    efficiency during reasoning in a familiar area. *International Journal of Psychophysiology*,

    49(2), 89–98.

Grabner, R. H., Neubauer, A. C., & Stern, E. (2006). Superior performance and neural efficiency: the

    impact of intelligence and expertise. *Brain research bulletin*, *69*(4), 422-39.

Harmony, T., Fernández, T., Silva, J., Bernal, J., Díaz-Comas, L., Reyes, a, et al. (1996). EEG delta

    activity: an indicator of attention to internal processing during performance of mental tasks.

    International journal of psychophysiology : official journal of the International Organization of

    Psychophysiology, *24*(1-2), 161-71.

Klimesch, W. (1999). Auditorily elicited EEG desynchronization and synchronization: A review of

Christina M. Krause's doctoral thesis. *Scandinavian Journal of Psychology*, *40*(4), 329-331.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: a

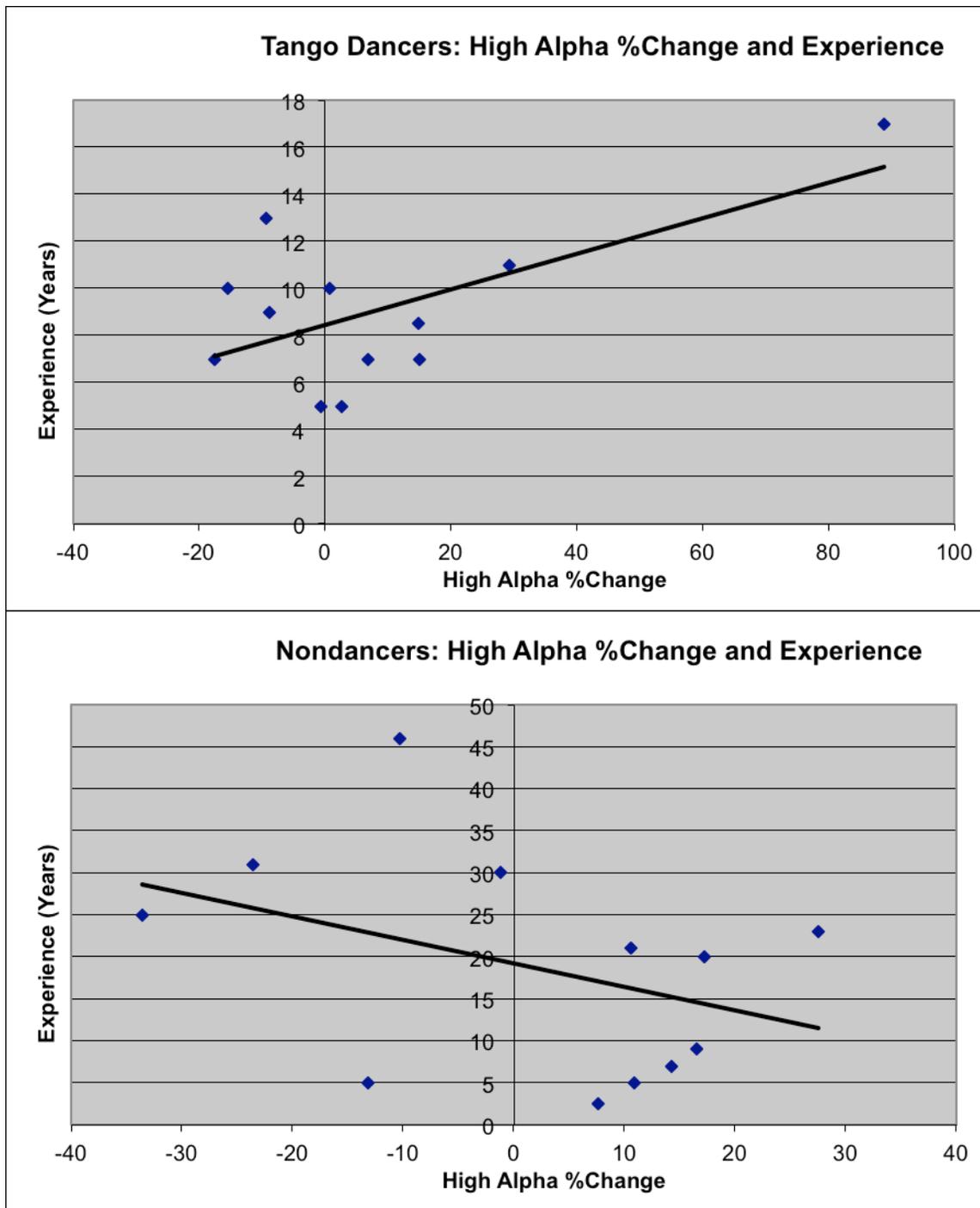review and analysis. *Brain research. Brain research reviews*, *29*(2-3), 169-95.

Figure 1. (*above*) Tango dancers showed a significant positive correlation for percent change in high alpha and experience ($r = 0.63$, $p < 0.05$). (*below*) Non-dancers did not show any significance.
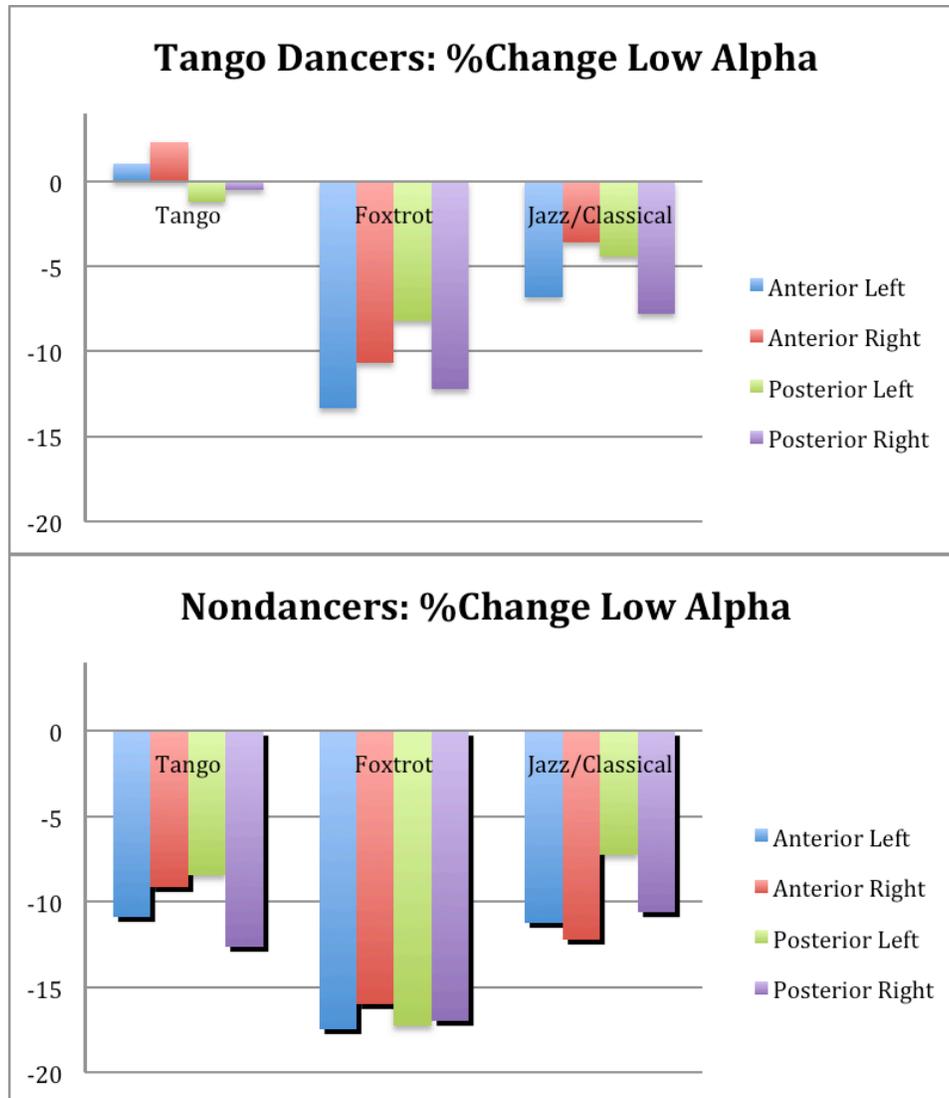
Figure 2. (*above*) Tango dancers percent change in low alpha when listening to tango music, foxtrot music, and jazz/classical music. There was a significant low alpha ERD for tango dancers listening to tango music when compared to tango dancers listening to any other combination of music ($p < 0.001$). (*below*) Non-dancers percent change in low alpha when listening to tango music, foxtrot music, and jazz/classical music. Non-dancers listening to jazz/classical music showed no differences when compared to non-dancers listening to tango music. There was only one significant difference between non-dancers listening to jazz/classical in the posterior left and non-dancers listening to foxtrot in the posterior left ($p < 0.0001$). When preferred music for each group was compared, non-dancers showed a significantly larger low alpha ERD for all regions except for posterior left ($p < 0.0001$).
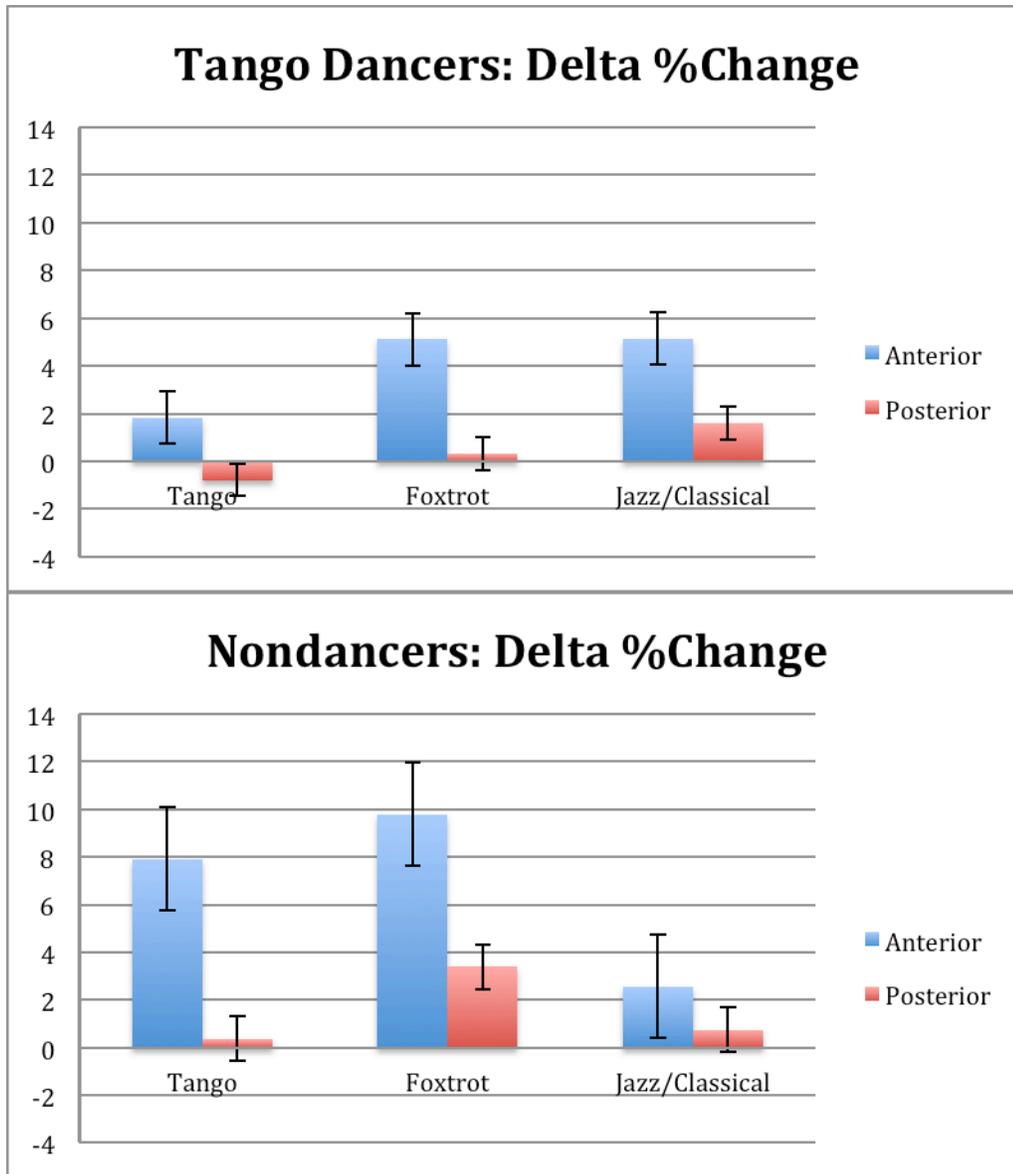
Figure 3. (*above*) Tango dancers percent delta change when listening to tango, foxtrot, or jazz/classical music. There was a significant increase in anterior delta power when compared to posterior delta power.(p = 0.0041). (*below*) Non-dancers percent delta change when lstening to tango, foxtrot, or jazz/classical music. There also was a significant increase in anterior delta power when compared to posterior delta power. No differences were found when compared between groups.