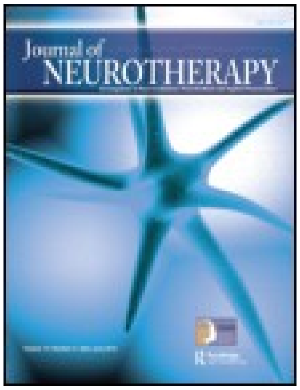

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Investigation of EEG Alpha Rhythm of Artists and Nonartists During Visual Perception, Mental Imagery, and Rest

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INVESTIGATION OF EEG ALPHA RHYTHM OF ARTISTS AND NONARTISTS DURING VISUAL PERCEPTION, MENTAL IMAGERY, AND REST

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In this article, differences in alpha power between multichannel EEG signals of artists and nonartists were investigated. The two groups were compared during visual perception, mental imagery, and at-rest conditions. We found no significant differences between the two groups in absolute alpha power at rest. Both absolute and relative alpha power were found to be significantly lower in artists during the visual perception and the mental imagery tasks for some of the channels, suggesting that the cerebral efforts of artists were higher during these conditions. These results indicate that artists considered more features of a painting compared to nonartists. The two groups differed in relative alpha power during the visual perception task compared to the at-rest condition. Relative alpha power values decreased during the visual perception for both groups; however, their variation patterns were different. More significant decreases in relative upper alpha power (10-12Hz) during the visual perception task for nonartists were observed, whereas more significant decreases in relative lower alpha power (8-10Hz) for artists during the visual perception task. These differences may be employed to measure progress in novice artists. In addition, it was found that upper phasic alpha power values were higher in artists compared to nonartists during the visual perception task. In the mental imagery task, lower phasic alpha power values were found to be higher in nonartists. However, the differences between the two groups were not significant in all of the channels indicating that EEG signals do not need to recorded in all channels when determining artistic expertise by absolute, relative, or phasic alpha power.

INTRODUCTION

Human beings attempt to attain different expertise depending on their requirements and interests during their lifetime (Shourie, Firoozabadi, & Badie, 2011). Expertise and long-term training correspond to changes in cortical activity and EEG signals (Panga, Nadalb, Müllerc, Rosenbergd, & Kleine, 2012); therefore, the patterns of brain activation differ between experts and nonexperts or novices in various fields (Vernon, 2005). Differences between the EEG signals of experts and nonexperts may be observed while they are performing expertise-related tasks or processing expertise-related stimuli (Bhattacharyaa & Petsche, 2002; Collins, Powell, & Davies, 1990; Crews & Landers, 1993; Fink, Graif, & Neubauer, 2009; Fink, Schwa, & Papousek, 2011; Hatfield, Landers, & Ray, 1984; Haufler, Spalding, Maria, & Hatfield, 2000; Karkare, Saha, & Bhattacharya, 2009; Panga et al., 2012; Salazar et al., 1990; Shourie et al., 2011; Vernon, 2005; Wagner, 1975; Yokochi & Okada, 2005). However, the cortical activity of experts and nonexperts may be different at rest, too (Shourie et al., 2011). EEG signal processing could help determine the proficiency-related differences in brain activation

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patterns. Previous research investigated cognitive factors and the cortical activity of artists and sportsmen (Bhattacharyaa & Petsche, 2002; Collins et al., 1990; Crews & Landers, 1993; Fink et al., 2009; Fink et al., 2011; Hatfield et al., 1984; Haufler et al., 2000; Karkare et al., 2009; Panga et al., 2012; Salazar et al., 1990; Shourie et al., 2011; Vernon, 2005; Wagner, 1975; Yokochi & Okada, 2005). Psychologists have shown that ordinary cognitive processes underlie the emergence of ideas and images in the minds of artists (Yokochi & Okada, 2005). Cognitive performance has been found to relate to alpha wave activity (Doppelmayr, Klimesch, Stadler, Pollhuber, & Heine, 2002), leading some previous researchers to focus on investigating the relationship between expertise and alpha wave activity.

For instance, it has been demonstrated that left-hemisphere alpha power increased significantly during the preparatory aiming period of expert shooters (Hatfield et al., 1984). In addition, the cortical activation of expert shooters was observed to be less than novice shooters at all sites, with the skilled shooters showing significantly more alpha wave activity in left temporal, parietal, and occipital regions (Haufler et al., 2000). A similar result was found between the best and the worst shots of expert archers (Salazar et al., 1990). Karate experts exhibited an overall increase in alpha power while breaking wooden boards (Collins et al., 1990). It has been observed that an increase in right-hemisphere alpha power was related to decreased errors for expert golfers (Crews & Landers, 1993). Professional dancers exhibit more right-hemispheric alpha synchronization than do novices during mental imagery of an improvisational dance (Fink et al., 2009). It has been reported that musicians produce more alpha power than nonmusicians when listening to music (Wagner, 1975). Therefore, the results of this research review confirm that expertise is related to alpha wave activities.

Creativity and memory are cognitive domains that affect mental performance (Lanni et al., 2008; Yokochi & Okada, 2005). Creative cognition is indicated by stronger prefrontal alpha power in the upper alpha band (Fink et al., 2011). Memory performance is associated with alpha power, too. Good memory performance is related to an increase in tonic (absolute power measured during a resting condition) alpha power and a decrease in phasic (event-related power, which is calculated as the percentage of change in power with respect to the resting condition) alpha wave activity. Tonic and phasic power are associated with cognitive performance quality in different ways (Doppelmayr et al., 2002; Klimesch, 1999). Alpha power decreases during encoding and retrieval of a spatial memory task. In addition, it has been found that encoding required more cerebral effort than retrieval (Jaiswala, Ray, & Slobounov, 2010).

Creativity and memory are essential cognitive domains for performing some tasks such as artistic endeavors. It is likely that artists are more capable in mental imagery tasks compared to nonartists. This difference could be related to their memory performance. In addition, it is probable that artists are more capable of creativity compared to nonartists, suggesting that the two groups could differ with respect to alpha wave activity. Previous researchers have investigated differences between the EEG signals of artists and nonartists. For instance, it has been found that phase synchrony was significantly higher in artists compared to nonartists in the high-frequency bands during visual perception (Bhattacharyaa & Petsche, 2002). In another study, artists and nonartists were classified by scaling exponents, and an artificial, neural network-based classifier differentiated the two groups with an average classification accuracy of 81.6% (Karkare et al., 2009). Other researchers have investigated differences between artists and nonartists in scaling exponents as well. They found that the two groups were differentiable at rest by scaling exponents; however, the discrimination between the two groups decreased when performing the same cognitive tasks (Shourie et al., 2011). In addition, it has been observed that artistic expertise is related to reduced ERP responses to visual stimuli (Panga et al., 2012). However, there were no broad studies that investigated differences between the two groups in alpha wave activity.

This review of research prompted the current study, which investigates differences between artists and nonartists in the alpha wave bandwidth of EEG signals. This study examines whether alpha power differences reflect artistic expertise by looking at the differences between multichannel EEG signals of artists and nonartists during visual perception and mental imagery of selected paintings. The EEG power spectrum densities were calculated in the alpha frequency band (8–13 Hz) and its two subbands (8–10 Hz and 10–12 Hz) for the two groups. The two groups were then compared in tonic, relative and phasic alpha power. Although differences between the two groups could be observed only in some channels, the comparisons were performed for each channel separately. Results of this study suggest that these methods can be employed for measuring progress in novice artists. In addition, it may be possible to use the obtained results to design a neurotherapy training protocol to enhance artistic abilities in novice artists.

METHODS

Data Set

In this article, EEG signals related to the research of Karkare et al. were studied. The EEG signals were recorded in 19 electrode sites while participants performed four tasks of visual perception, four tasks of mental imagery, and while at rest. The electrodes were located according to the International 10–20 system (Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, and O2). Twenty women were equally divided into two groups, artists and nonartists. The average age of each group was 44.3 years and 37.5 years, respectively. In the visual perception task, each participant looked at a painting that was projected onto a white wall for 2 min. In the mental imagery task, the participants mentally imagined the painting that was previously shown for 2 min. For the at rest condition, the participants looked at a white wall for 2 min. All artists graduated from the Viennese Academy of Fine Arts with a Master of Arts degree. Nonartists, on the other hand, had no specific interest or training in visual art (Karkare et al., 2009).

Spectral Analysis

Welch's method is used for estimating the power spectral density of a signal at different frequencies. The method is based on the periodogram spectrum estimating method. In this method, the signal is divided into L overlapping segments of length M. A data window is applied to each data segment. Therefore, the periodogram is calculated for each segment as shown next:

$$\hat{p}_d(f) = \frac{1}{MU}\left|\sum_{n=0}^{M-1} x_d(n)w(n)e^{-j2\pi fn}\right|^2 \qquad (1)$$

Where U is a normalized factor for the power in the window function obtained as:

$$U = \frac{1}{M}\sum_{n=0}^{M-1} |w(n)|^2 \qquad (2)$$

where *w(n)* is the windowed data. The individual periodograms are then time-averaged and Welch's power spectrum is obtained:

$$\hat{p}_{welch}(f) = \frac{1}{L}\sum_{i=0}^{L-1} \hat{p}_d(f) \qquad (3)$$

Finally, an array of power measurements versus frequency ''bin'' is obtained (Welch, 1967). Therefore, relative power was calculated as shown next:

$$\Pr(f) = \frac{Pa(f)}{\sum_{f=0.3}^{45} Pa(f)} \qquad (4)$$

where *Pr(f)* is a relative EEG power at a frequency band and *Pa(f)* is an absolute EEG power at the same frequency band. In this article, power spectral densities were calculated in the alpha frequency band (8–13 Hz) and its two subbands (8–10 Hz and 10–12 Hz).

Statistical Analysis

A Kolmogorov–Smirnov test was used to compare values of the extracted features to a standard normal distribution. This test was performed for the features of each channel separately. Accordingly, none of the obtained features had normal distribution. Therefore, a Mann–Whitney U-test was used to determine the significant differences between the two groups in the different conditions.

RESULTS

Power spectrum densities in the alpha frequency band (8–13 Hz) and its two subbands (8–10 Hz and 10–12 Hz) were calculated for the EEG signals of the two groups during the visual perception task, the mental imagery task, and at rest. The Mann–Whitney statistical test was used to find significant differences between the studied EEG signals.

The two groups were compared in tonic alpha power. Therefore, the absolute alpha power spectrum density was calculated in all of the channels for each group in the at rest condition. No significant differences were found between the two groups in tonic alpha power values. The obtained results are shown in Figure 1.

Next, differences between the two groups in absolute alpha power during the visual perception and the mental imagery tasks were investigated. For each task, the power spectrum densities of the four trials were averaged. Figure 2 represents the obtained results.

It was observed that the two groups were different in absolute alpha power during the visual perception and the mental imagery tasks; however, the significant differences were not observed in all of the channels. The patterns of significant differences in absolute alpha power for the visual perception and the mental imagery were similar. Alpha absolute power values were found to be lower in artists compared to nonartists for all of the channels and alpha subbands (8.44 ± 3.16 vs. 13.07 ± 6.67 for the visual perception task and 12.49 ± 6.32 vs. 23.34 ± 15.09 for the mental imagery task). The most significant differences between the two groups were found in the C4, C3, and P4 channels during the visual perception task. Both upper and lower alpha power were effective for discriminating the groups. The absolute power averages for the four trials and all of the channels are shown in Figure 3 and Figure 4.

In addition, the relative alpha power values of the two groups were considered. First differences in relative alpha power for each of the groups during the visual perception task as compared to the at rest condition were investigated. The comparisons were performed using the power spectrum averages of the four trials. A Mann–Whitney test was used to determine significant differences. Figure 5 shows the obtained results.

We observed that the two groups differed significantly in relative alpha power values for the at-rest condition. However, their variation patterns were different. More significant decreases in relative upper alpha power during the visual perception task for nonartists were observed, whereas more significant decreases in relative lower alpha power for artists during the visual perception task. Relative alpha power values were higher at rest compared to the visual perception task for both groups in

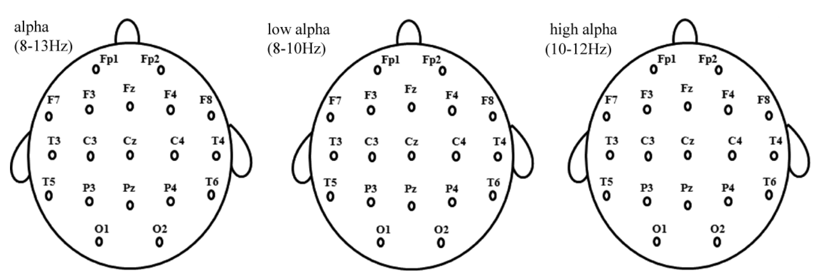


FIGURE 1. Statistically significant differences in tonic alpha power values (absolute alpha power of the EEG signals) between the two groups at rest. *Note.* Light gray circles, $p < .05$. Dark gray circles, $p < .01$. Black circles, $p < .001$.

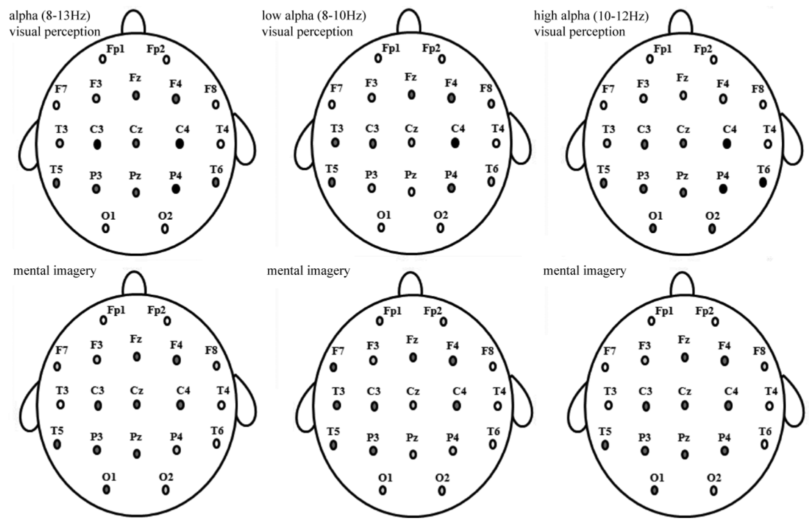


FIGURE 2. Statistically significant absolute alpha power value differences between the two groups during the visual perception and the mental imagery tasks. *Note.* Light gray circles, $p < .05$. Dark gray circles, $p < .01$. Black circles, $p < .001$.

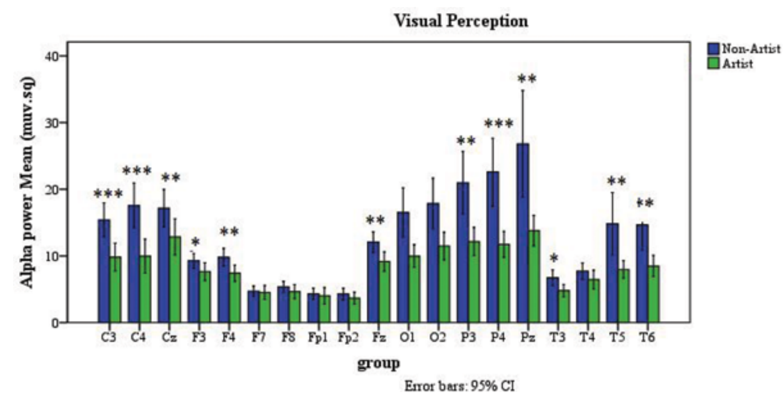


FIGURE 3. Comparisons of absolute alpha power values between the two groups during the visual perception task. *Note.* The comparisons were performed using the average of the absolute power values across the four trials. $^*p < .05$. $^{**}p < .01$. $^{***}p < .001$. (Color figure available online.)

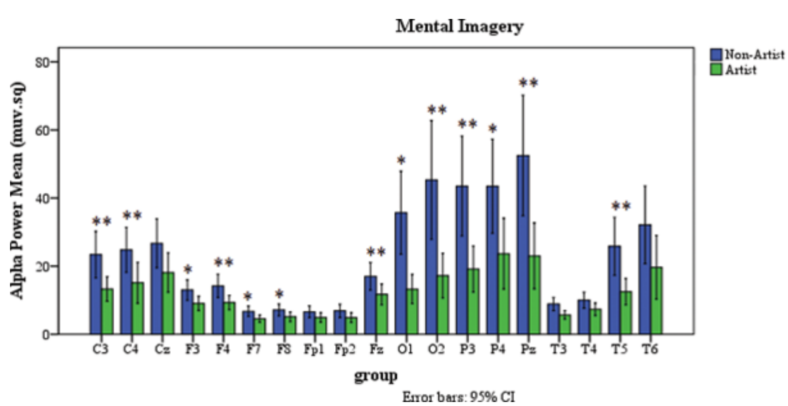


FIGURE 4. Comparisons of absolute alpha power values between the two groups during the mental imagery task. *Note.* The comparisons were performed using the average of the absolute power values across the four trials. $^*p < .05$. $^{**}p < .01$. (Color figure available online.)

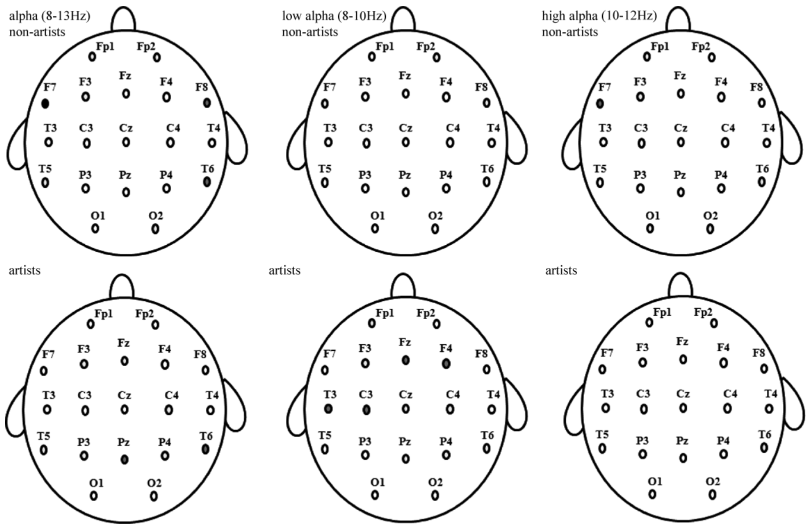


FIGURE 5. Statistically significant differences in relative alpha power values for the two groups during the visual perception task compared to the at-rest condition. *Note.* Light gray circles, $p < .05$. Dark gray circles, $p < .01$. Black circles, $p < .001$.

all of the channels (0.17 ± 0.02 vs. 0.13 ± 0.01 for artists and 0.23 ± 0.05 vs. 0.18 ± 0.03 for nonartists). The relative alpha power averages of the two groups during the visual perception and at-rest conditions are shown for some of the channels in Figure 6.

These comparisons were also performed for each of the two groups during the mental imagery task and the at-rest condition. The obtained results were shown in Figure 7.

We observed no significant differences in relative alpha power values during the mental imagery task when compared to the at-rest condition for nonartists. However, significant differences were noted in relative lower alpha power values in F3, Fz, F4, and T3 channels for artists when comparing the mental imagery task to the at-rest condition.

Next, the relative alpha power values of the two groups were compared (see Figure 8). The comparisons were performed using the relative alpha power averages of the four trials.

No significant differences between the two groups were observed for the at-rest condition. However, it was found that the two groups were significantly different in some of the channels for each of the cognitive tasks. It was found more significant differences in relative upper alpha power compared to relative lower alpha power between the two groups during the visual perception. Specifically, the relative alpha power was higher in nonartists compared to artists for all of the channels (0.18 ± 0.03 vs. 0.13 ± 0.01 for the visual perception task and 0.24 ± 0.05 vs. 0.17 ± 0.02 for the mental imagery task).

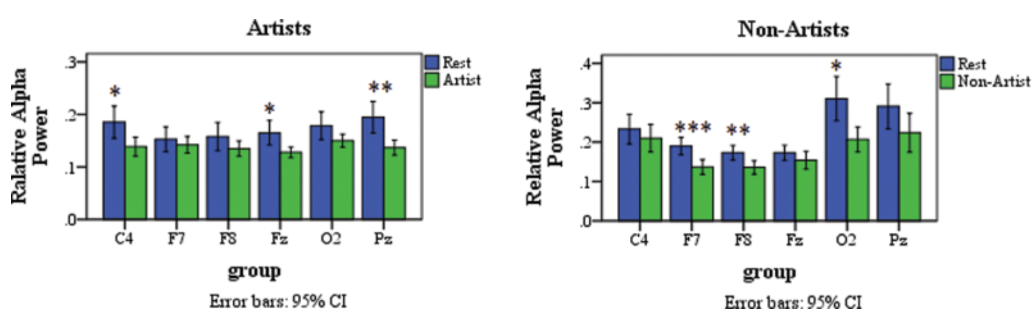


FIGURE 6. Comparisons of the relative alpha power averages in six channels (C4, F7, F8, Fz, O2, and Pz) between the two groups during the visual perception task. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. (Color figure available online.)

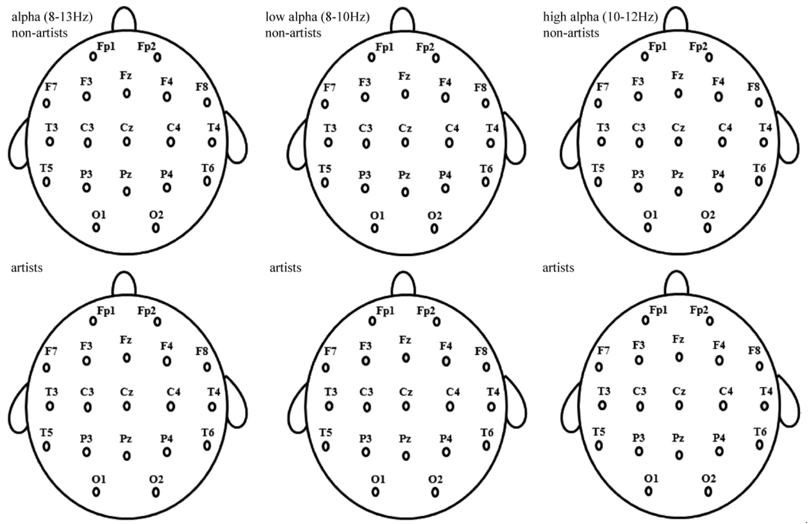


FIGURE 7. Statistically significant differences in relative alpha power values for the two groups during the mental imagery task compared to the at-rest condition. Light gray circles, $p < .05$. Dark gray circles, $p < .01$. Black circles, $p < .001$.

The relative alpha power averages of the two groups are shown in Figures 9 and 10.

Finally, the two groups were compared in phasic alpha power. The comparisons were performed using the phasic alpha power averages of the four trials. The obtained results are represented in Figure 11.

Accordingly, the two groups were significantly different in upper phasic alpha power during the visual perception task in three channels. However, no significant differences were found between the two groups in lower phasic alpha power during the visual perception task. The upper phasic alpha power values were higher in artists compared to nonartists in all of the channels during the visual perception task (1.18 ± 0.18 vs. 0.93 ± 0.15). In the mental imagery task, lower phasic alpha power was higher in nonartists (1.27 ± 0.18 vs. 1.09 ± 0.14). The upper phasic alpha power values were higher in artists in channels P4 and T6. Conversely, the upper phasic alpha power was higher in nonartists in channel F7. The phasic alpha power averages for some of the channels are shown in

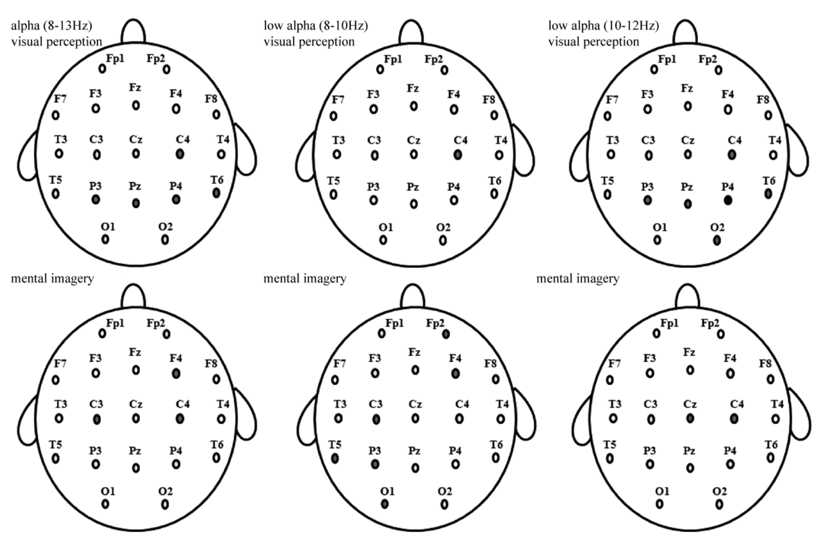


FIGURE 8. Statistically significant differences between the two groups in relative alpha power values during the visual perception and the mental imagery tasks. Light gray circles, $p < .05$. Dark gray circles, $p < .01$. Black circles, $p < .001$.

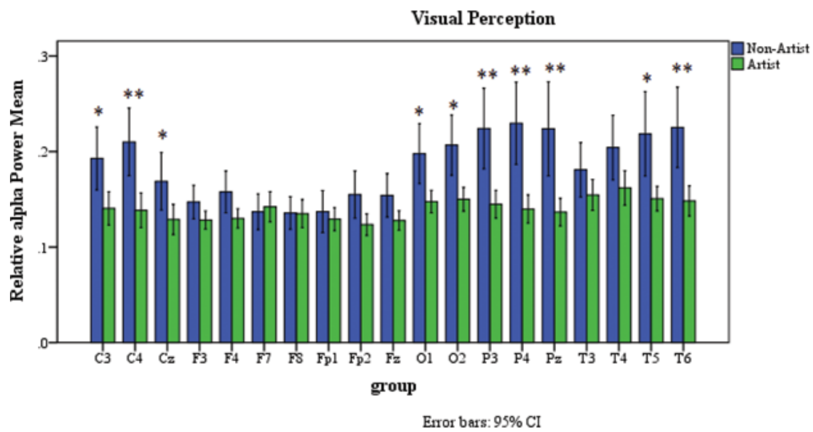


FIGURE 9. Comparisons between the relative alpha power averages in the two groups during the visual perception task. $^{*}p < .05$. $^{**}p < .01$. (Color figure available online.)

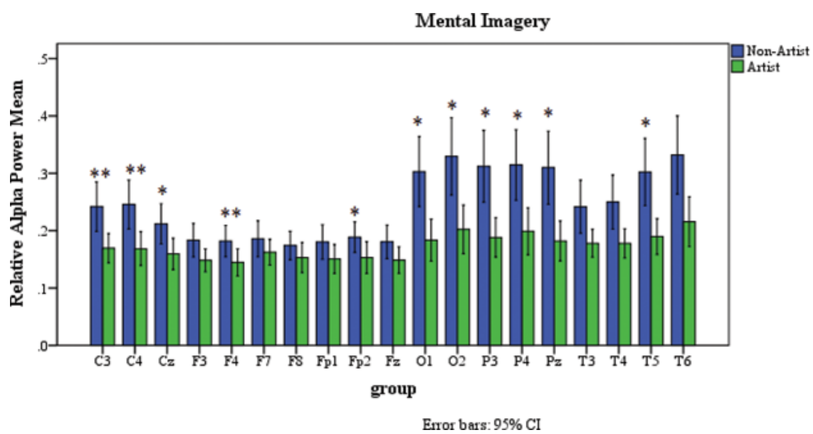


FIGURE 10. Comparisons between the relative alpha power averages in the two groups during the mental imagery task. $^{*}p < .05$. $^{**}p < .01$. (Color figure available online.)

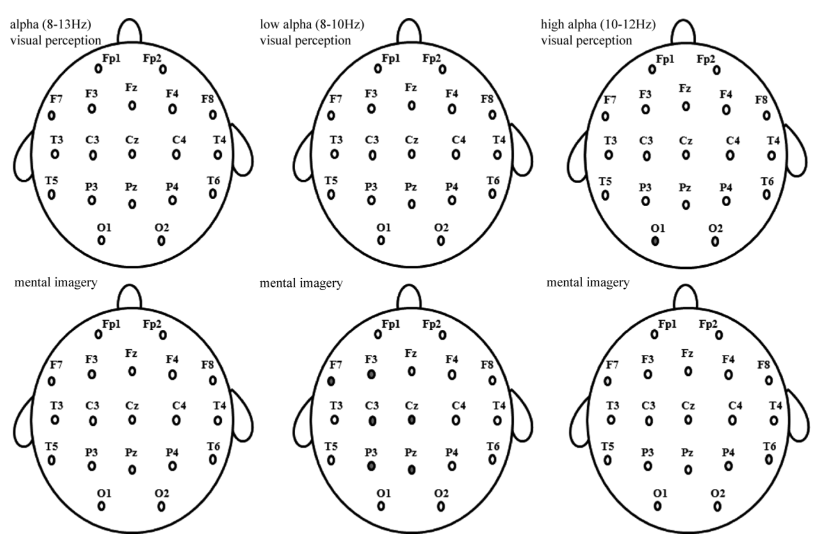
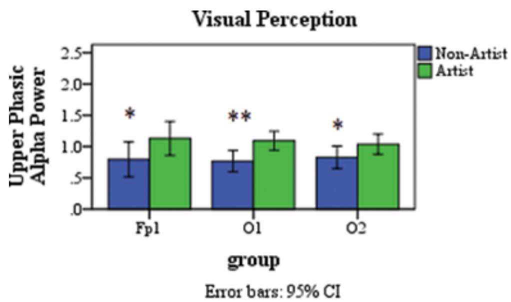


FIGURE 11. Statistically significant differences in phasic alpha power values for the two groups during the visual perception and the mental imagery tasks. Light gray circles, $p < .05$. Dark gray circles, $p < .01$. Black circles, $p < .001$.



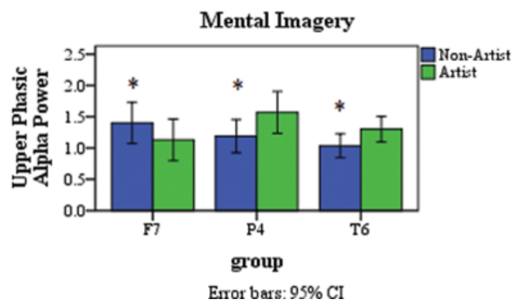


FIGURE 12. Comparisons between the upper phasic alpha power averages for some of the channels in the two groups during the visual perception and the mental imagery tasks. $^{*}p < .05$. $^{**}p < .01$. (Color figure available online.)

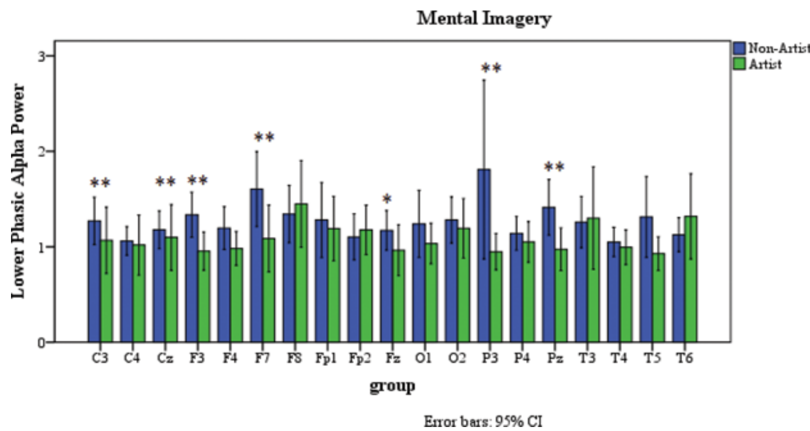


FIGURE 13. Comparisons between the lower phasic alpha power values in the two groups during the mental imagery task. $^{*}p < .05$. $^{**}p < .01$. (Color figure available online.)

Figures 12 and 13. The comparisons were performed using the phasic alpha power averages of the four trials.

DISCUSSION

In this article, differences between EEG signals of artists and nonartists in alpha power were investigated. The studied EEG signals were compared between the four groups during a visual perception task, four mental imagery tasks, and an at-rest condition. It was expected that artists were more capable in mental imagery compared to nonartists and that this capability could be related to their memory performance. It is probable that artistic expertise affects memory performance and that artists memorize pictures more capably. Therefore, they can retrieve the pictures more skilfully. It has been determined that good memory performance is related to an increase in tonic alpha power and a decrease in phasic alpha power (Klimesch, 1999). However, we observed no significant differences in absolute alpha power (tonic alpha) between the two groups at rest. In addition, the upper phasic alpha power values were found to be higher in artists in all of the channels during the visual perception task. Conversely, the lower phasic alpha power values were found to be lower in artists during the mental imagery task. Therefore, we cannot conclude artists were stronger in memory performance. Consequently, memory performance does not appear to be affected by artistic expertise.

We found that the two groups were significantly different in absolute alpha power values during performance of the two cognitive tasks for some of the channels. Absolute alpha power values were observed to be lower in artists. A similar result was obtained in relative alpha power as well. Decreased alpha power is related to high cortical activation (Jaiswala et al., 2010). Therefore, the cerebral efforts of artists were greater during memorization and retrieval of the paintings.

Relative alpha power variations of the two groups were measured for the two cognitive tasks and were compared to the at-rest condition. It was found that relative alpha power values were decreased with respect to the at-rest condition for both groups during the visual perception task. These results are consistent with the results reported by Jaiswala et al. It has been demonstrated that alpha power decreases during encoding of a memory task (Jaiswala et al., 2010). Nonartists exhibited no significant differences during the mental imagery tasks compared to the at-rest condition. Significant decreases were observed for artists in four channels during the mental imagery task. These results are consistent with reports of less cortical activation during retrieval as compared to encoding (Jaiswala et al., 2010).

Many researchers have found that experts exhibit less cortical activation during performance of an expertise-related task compared to nonexperts or novices (Abernethy & Russell, 1987; Allard, Graham, & Paarsalu, 1980). Experts in psychomotor domains were characterized by their effortless and highly focused performances (Starkes, 1987). Conversely, novices necessitated more cerebral effort to perform the same skill-dependent task. Previously, high levels of practice have been related to less mental involvement, especially in the psychomotor domains (Abernethy & Russell, 1987; Starkes, 1987). This means that experts process their skill-related information more efficiently and effectively (Haufler et al., 2000).

However, we cannot expect that the cortical activation of artists is less than nonartists. Nonartists may look at a painting indifferently, may focus solely on the details of the painting, or may perceive the picture as a whole when looking at the painting. The painting may be interesting or exciting for nonartists. Nevertheless, nonartists appear to look at the paintings more superficially compared to artists. Conversely, artists look at the painting technically and think about how they can draw it. They consider the style and the aim of the painting. Artists judge the painting more precisely, and they consider both the details and the painting as a whole. Artists attend to some characteristics that nonartists do not. Although both skilled artists and novices perform the same skill-dependent tasks, their performance quality is quite different.

Non-experts and novices differ substantially in training in a certain skill. For instance, novice artists are trained to attend some technical features in a painting. Conversely, nonartists may not know which features are important in the painting. Therefore, they look at the painting more superficially. Conversely, both novice artists and expert artists know and investigate the essential features of the painting. Nevertheless, their investigation rates are not the same. Expert artists judge the painting effortlessly and more efficiently compared to novice artists. Therefore, it is probable that the cortical activation of expert artists is less than novices. However, we cannot expect that cerebral efforts of artists are less than nonartists. Absolute and relative alpha power values were found to be lower in artists during the visual perception and the mental imagery tasks. Therefore, the cerebral efforts of artists were higher. This result confirms that artists considered more features compared to nonartists in the paintings.

We found that the capability of artists in mental imagery was not related to their memory performance. It may be that this arises from their visual perception performance. Artists look at a painting more technically. Therefore, they can mentally imagine the painting more capably. Their visual perception has been improved because they know art and its significant features.

Creative cognition is reflected by stronger prefrontal upper alpha power (Fink et al., 2011). It was observed that alpha power values were significantly lower for both groups compared to the at-rest condition. In addition, absolute and relative alpha power values were higher in nonartists. Both groups looked at a selected group of paintings, then they mentally imagined the painting just viewed. Therefore, they did not perform any creative task. Consequently, we did not observe any effect of creativity for both of the two groups.

It was found that the two groups significantly differed in relative alpha power values during the visual perception task compared to the at-rest condition. However, their variation patterns were different. More significant decreases in relative upper alpha power during the visual perception task for nonartists were found. This result was observed in relative lower alpha power for artists, too. These differences may be used for measuring progress in novice artists by measuring changes in relative alpha power during a visual perception task and at rest and then comparing these results to those obtained by expert artists while engaged in similar tasks.

Last, the obtained results may be used to design a neurotherapy training protocol to enhance the artistic abilities of novice artists. For instance, training to decrease alpha power in P4, C4, or C3 channels may be useful for empowering novice artists during visual perception.

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