Annals of Clinical Cases

ISSN: 2692-7993

Research Article

Effect of the Marijuana Binaural Beats on the Brain

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Abstract

In this work, we study the effect of Marijuana binaural beats on the brain. For this aim three groups are allocated: before, during, and after 10 min from hearing binaural beats. The Electroencephalogram (EEG) signal was detected using Bitalino sensor and analyzed using Matlab software. The synchronization degree parameter is calculated using bispectrale analysis. The obtained results are compared to six others parameters which are also extracted from the same analysis, such as entropies, the average of bispectrale amplitude, and weighted center of the bi-spectral. The obtained results are very satisfactory and show that the synchronization is high in normal cases, low after hearing to Marijuana binaural beats, and zero during hearing to digital drugs.

Keywords: Electroencephalogram signal; Marijuana drug; Binaural beat; Bispectral analysis; Degree

Introduction

The binaural beats or digital drugs; are sounds that are thought to be capable of changing brainwave patterns and inducing an altered state of consciousness similar to that effect by taking drugs or achieving a deep state of meditation, this effect was discovered in 1839 by Heinrich Wilhem Dove.

Hearing two sounds of slightly different frequency in each ear would produce an effect on the brainwaves and thus trigger a kid of sound; which equal to difference between both frequencies (Figure 1). This new frequency can change the brainwaves rhythm. It can be used in medical field as a legal drug. It can be also dangerous for users; it causes hallucinogenic sensation, heart problems (tachycardia) and in most times it causes addiction. Many studies have tried to analyze and to determine the effect of binaural beats on the brain, such as: Nantawachara J et al. [1]. They investigated the effect of a 3 Hz binaural beats on sleep stages. Jakub K et al. [2] explored the effect of binaural beats on Working Memory Capacity (WMC). In their study, participants were divided into two groups. One group underwent a binaural beat stimulation while listening to the sound of the sea. The other group was listening solely to the sound of the sea without binaural beat stimulation. They found that only participants from the binaural beat group showed an improvement in WMC.

The study of Singh y et al. [3], was based on the physiological markers of psychological stress were assessed using Galvanic Skin Response (GSR), Heart Rate (HR), and Electroencephalography (EEG). They conclude that The EEG correlates of mental stress. Christine B et al. [4] determined the effects of different acoustic stimulation conditions on participant response accuracy and cortical network topology, as measured by EEG recordings, during a visuospatial working memory task. Three acoustic stimulation control conditions and three binaural beat stimulation conditions were used: None, Pure Tone, Classical Music, 5 Hz binaural beats, 10 Hz binaural beats, and 15 Hz binaural beats. They found that listening to 15 Hz binaural beats during a visuospatial working memory task not only increased the response accuracy, but also modified the strengths of the cortical networks during the task. The three auditory control conditions and the 5 Hz and 10 Hz binaural beats all decreased accuracy. Based on graphical network analyses, the cortical activity during 15 Hz binaural beats produced networks characteristic of high information transfer with consistent connection strengths throughout the visuospatial working memory task. Kennerly R et al. [5] utilized Beta frequency binaural-beat audio signals to investigate facilitation of human performance on two memory tasks and two memory related tasks. The results indicate that beta frequency binaural-beat audio signals are an effective method for facilitating simple free recall memory, ability to attend, and the ability to persevere at routine motor tasks.

This work is part of the neurological diagnosis aid; in which we studied the effect of the Marijuana binaural beats on the brainwaves. The study was conducted on 23 healthy students volunteer and the Electroencephalogram (EEG) signal was detected before, during, and after 10 min from hearing Marijuana binaural beats sound using Bitalono sensor and Matlab software. The EEG signal was analyzed using bispectral analysis; it is not only a power estimator like Fast Fourier Transform (FFT) or Autoregressive models (AR), but it preserves and takes into account the information on the phase. This method permits us also to extract some others parameters such as: synchronization degree, entropy, square entropy, cubic entropy, the entropy of phase, mean of bispectral amplitude, and the weighted center of the bi-spectrum. The obtained results for the different sets is illustrated and discussed in detail in the following sections, then an evaluation of the proposed method is made using a statistical classifier that corresponds to the ANOVA test (Figure 1).

Method

The proposed approach is illustrated in the block diagram below (Figure 2) which includes four steps: Database, Bi-spectral analysis, Extraction of bi-spectral parameters (synchronization degree, entropy, square entropy, cubic entropy, the entropy of phase, mean of bispectral amplitude, the weighted center of the bi - spectrum), and ANOVA test (Figure 2).

Citation: El Houda BYN, El Amine DSM. Effect of the Marijuana Binaural Beats on the Brain. Ann Clin Cases. 2020;1(5):1022.

Publisher Name: Medtext Publications LLC

Manuscript compiled: Dec 11th, 2020

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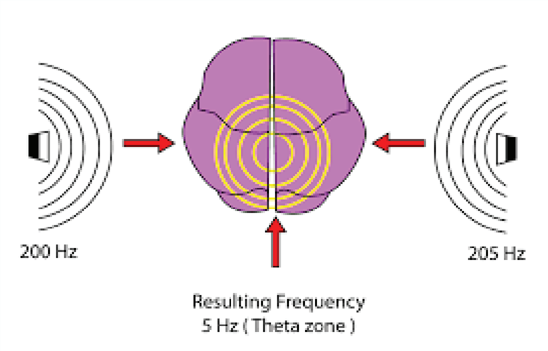

Figure 1: How binaural beats work.

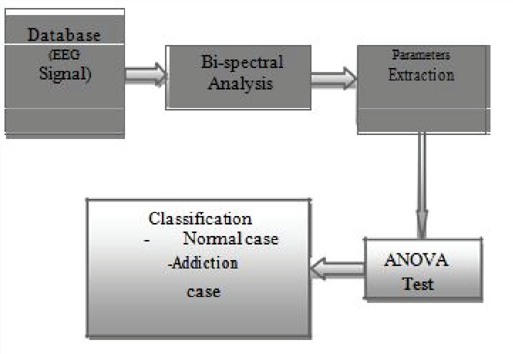

Figure 2: Block diagram of the proposed method.

Database

EEG signals (Figure 3) were detected using the Bitalino sensor (Figure 4). It is a purpose-built sensor for physiologic signals detection. The data was visualized and recorded continuously in real time using MATLAB Bitalino Toolbox, with a sampling frequency of 200 Hz. The signals were filtered by low pass filter with cutoff frequency of 100 Hz.

The study was conducted on 23 healthy students volunteer. The EEG signal was detected before, during, and after 20 min from hearing Marijuana binaural beats sound.

The volunteers were relaxed in an awake state with open eyes. We used three electrodes. One electrode is placed on the forehead, the second is placed on the lobe of the ear, and the third one is placed on parietal part of the head. Our database groups together three sets (denoted A, B, and C). Each set contains 23 EEG signal. Group A represents the acquired EEG signals of 23 healthy volunteers before hearing Marijuana binaural beats. Group B represents the acquired EEG signals of the same volunteers during hearing the Marijuana binaural beats, however group C represents the acquired EEG signals of the same volunteers after 10 min from hearing the Marijuana binaural beats.

Figure 3: Bitalino sensor.

Bi-spectral analysis of the EEG signal

Bi-spectral analysis is the study of nonlinear interactions [6,7]. It is defined as the Fourier transform of the third cumulant. Considering that the Fourier transform of the second-order cumulant (the auto-correlation function) is known by the Power Spectral Density (PSD). The bi-spectral is defined by equation (1).

$$B(f_1,f_2)=E[X(f_1)X(f_2)X^*(f_1+f_2)] \quad (1)$$

Where X (f) is the discrete Fourier transform (DFT) of x (nT).

X^* (nT) is the conjugate of x (nT)

E [.]: is the operator of mathematical expectation.

Since the correlation function is an even function, and its FT gives a symmetry spectrum (i.e., the spectrum repeats twice "mirror effect"), we find that the bi-spectrum which represents the FT of the tri-correlation function, repeats itself four times. It is therefore sufficient to calculate the spectrum for the frequencies that lies in the non-redundant region Ω as it is illustrated in Figure 5 [8-10].

Extraction of characteristics

The bi-spectral analysis allows us to extract certain parameters, such as synchronization degree, the average amplitude, the standard bi-spectral entropy, the standard bi-spectral square entropy, the

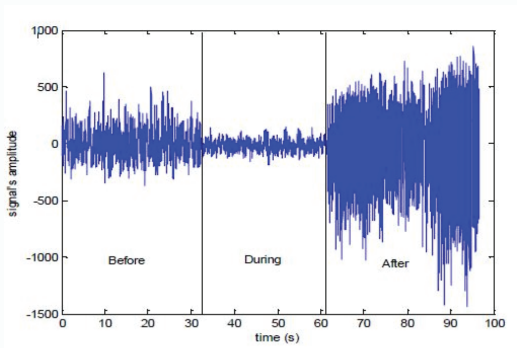

Figure 4: EEG signal in three phases: before, during, and after hearing to the Marijuana binaural beats.

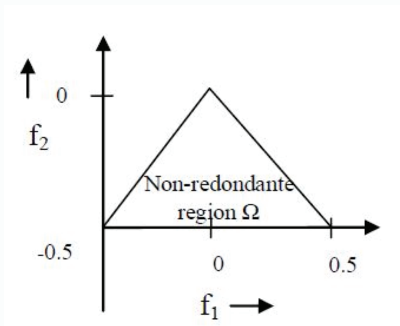

Figure 5: The non-redundant region for the calculation of bi-spectral frequencies.

standard bi-spectral cubic entropy, the entropy of phase, and the weighted center of the bi-spectrum, which give us information on the distribution and dispersion of the signal.

Synchronization degree: The synchronization degree (Synch) is defined as the ratio between the number of harmonics and all the sinusoids number of the bispectrum. We must indicate here that the number of harmonic and the sinusoids must be calculating n times if it is generated by n ways.

The synchronization is close to 100% in awake subject, i.e., the sinusoids components are all synchronous between them. It decreases with the deepening of unconsciousness.

The average amplitude: The average amplitude of the bi-spectral can be used for discrimination between similar power spectra. It is defined by:

$$M_{ave} = \frac{1}{L} \Sigma_{\Omega} \left| B(f_1, f_2) \right| \qquad (2)$$

Where L: is the number of peaks.

The standard bi-spectral entropy: There are a number of concepts and analytical techniques directed to measuring the irregularity of the frequency spectrum of a stochastic signal, such as EEG. Entropy describes the irregularity, complexity, or unpredictability characteristics of a signal. It is defined by equation (3) [11].

$$p1 = -\Sigma_n p_n \log p_n \qquad (3)$$

Where: $wc_2 = \dfrac{\Sigma_{\Omega}\, jB(i,j)}{\Sigma_{\Omega}\, B(i,j)}$

The standard bi-spectral square entropy: The bi-spectral square entropy P2 is given by equation (4).

$$p_2 = -\Sigma_{\Omega} p_n \log p_n \qquad (4)$$

Where: $p_n = \dfrac{\left| B(f_1, f_2) \right|^2}{\Sigma_{\Omega} \left| B(f_1, f_2) \right|^2}$

The standard bi-spectral cubic entropy

$$p_3 = -\Sigma_{\Omega} p_n \log p_n \qquad (5)$$

Where: $p_n = \dfrac{\left| B(f_1, f_2) \right|^3}{\Sigma_{\Omega} \left| B(f_1, f_2) \right|^3}$

The normalization in the equations above, shows that the entropy is calculated for a parameter which is between 0 and 1 and therefore the entropies (P1, P2 and P3) are also calculated between 0 and 1. P2 and P3 give information on the degree of variability.

The entropy of phase:

$$p_e = \Sigma_n p(\Psi_n) \log p(\Psi_n) \qquad (6)$$

Where: $\grave{U} = \{(f_1, f_2) | f_1, f_2, \text{dans la region de la figure 2}\}$

$$\Psi_{\Omega} = \{\phi \,|\, -\pi + \frac{2\pi n}{N} \le \phi < -\pi + \frac{2\pi (n+1)}{N}, n = 0, 1, .., N-1\}$$

$$p(\Psi_n) = \frac{1}{L} \Sigma_{\Omega} 1(\varphi(B(f1, f2)) \in \Psi_n) \qquad (7)$$

L: is the number of samples in the Ω region shown in Figure 2.

Ǿ: is the phase of the bi-spectrum.

1(.): An indicator function.

The phase entropy would be zero if the process was harmonic and perfectly periodic and predictable. As the process becomes more random, entropy increases. In contrary to Fourier phase, the bi-spectral phase does not change with a time lag [12].

Weighted center of the bi-spectral (WCOB):

The weighted center of bispectrum definition [7] is given by equation (8):

$$wc_1 = \frac{\Sigma_{\Omega}\, iB(i,j)}{\Sigma_{\Omega}\, B(i,j)} \qquad wc_2 = \frac{\Sigma_{\Omega}\, jB(i,j)}{\Sigma_{\Omega}\, B(i,j)} \qquad (8)$$

Where i, j are the frequency indexes in the non-redundant region Ω in the abscissa and ordinate axes respectively. It gives us information on the distribution and the number of peaks in the i^{th} line or in the j^{th} column.

Results and Discussion

The algorithm of the bi-spectral analysis is implemented and applied on the different sets of EEG records. The obtained results for the three cases are illustrated in Figures 6 up 11. The color represents the relative variation of the amplitude of the bi-spectrum; the red color indicating the strongest increase and the blue color indicating the greatest decrease.

The bi-spectrum was estimated on the different frequency bands. The beta wave corresponding to the frequency [13- 40] Hz; results from the state of an attentive subject, with open eyes. The alpha wave corresponding to the frequency [7-13] Hz; which results from a state of relaxed awakening. The theta wave corresponding to [4-7] Hz, results from a light sleep state, while, the delta wave corresponding to [0-4] Hz, results from a state of deep sleep.

We must mention here that the spectrum of the Marijuana binaural beats signal shows three carrier frequencies: 58, 43, and 360 Hz, and two binaural beats frequencies: 2.5, and 9 Hz.

Group A

The bi-spectrum of the EEG signal which represents healthy case, before hearing the binaural beat is shown in Figure 6 (record A6). It shows distributed peaks over the interval [0 - 40] Hz, with a predominance of the five peaks: a1 around (7.112, 19.558) Hz, a2 around (7.112, 7.112), a3 around (5.33, 16.002) Hz, and a4 around (16.002, 21.336) Hz.

The frequencies 7.112 and 10.668 Hz are interpreted by the presence of α wave. While the frequency 16.002, 19.588, and 21.336 Hz are interpreted by the presence of the β wave. In this case a β wave has the great amplitude as it is shown in Figure 6; thus we can confirm that this person is in waking state.

We clearly notice that the frequencies 16.002, 19.558, and 21.336 Hz are the nonlinear interactions of the frequencies (5.334*3) Hz, (7.112*2 and 5.334) Hz, and (16.002 and 5.334) Hz respectively (Figures 6 and 7).

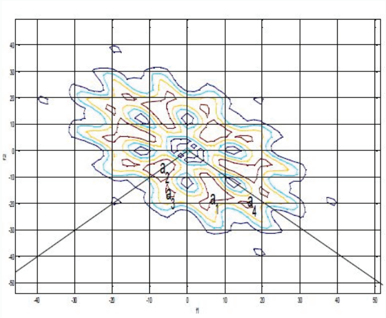

Figure 6: Bi-spectrum of EEG signal before hearing to Marijuana binaural beats (record A6).

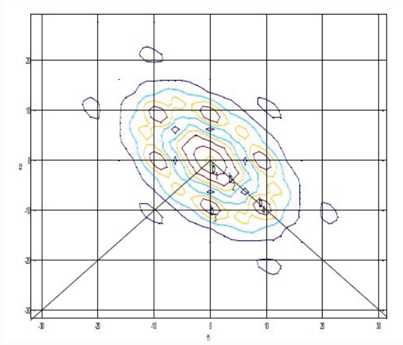

Figure 8: Bi-spectrum of EEG signal during hearing to Marijuana binaural beats (record B6).

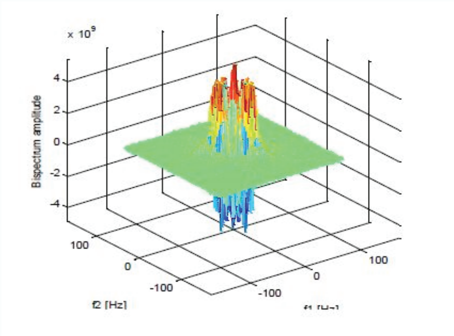

Figure 7: Bi-spectrum in 3D of EEG signal before hearing to Marijuana binaural beats (record A6).

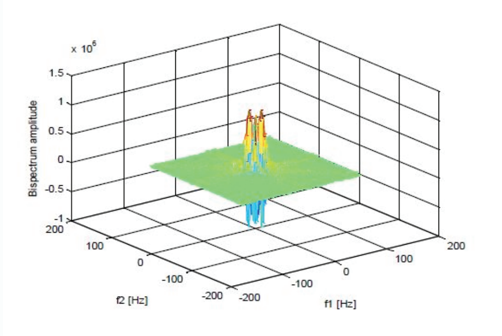

Figure 9: Bi-spectrum in 3D of EEG signal during hearing to Marijuana binaural beats (record B6).

This result leads us to conclude that the EEG signal is non-linear, non-stationary, and has a random appearance.

In the other hand, the synchronization degree indicates 60%, because we have three harmonic components (16.002, 19.558, and 21.336 Hz) between five frequencies (5.334, 7.112, 16.002, 19.558, and 21.336 Hz). Thus, we suggest that the both hemispheres of the brain manage to work together in a perfect harmony.

Similar results have been obtained after the implementation of the proposed algorithm on the other signals (A1 up A23) where we found that the degree of synchronization varies between 52.1% to 83.4%.

Group B

The bi-spectrum of the record B6 which represents the EEG signal recorded during hearing to the binaural beats, is illustrated in Figures 8 and 9.

The Figure 8 shows a predominance of three peaks: b1 around (0, 2.5) Hz, b2 around (0, 3.75) Hz, and b3 around (0, 9) Hz, and b4 around (9, 9) Hz. These result shows that there is no interaction between these frequencies i.e., they are independent and there is no synchronization between the both hemispheres (Synch=0). In the other hand, we note that the frequencies 2.5 and 9 Hz are the frequencies of the binaural beats, however the frequency 3.75 Hz belong to the delta rhythm (<4 Hz) which corresponds to loss of consciousness i.e., the brain can't focus on anything. We know also that the frequency 9 Hz associated with sacral Chakra, and it used to affect relationships, and enhance THC (or tetrahydrocannabinol, is the chemical responsible for most of marijuana's psychological effects.), however the frequency 2.5 Hz corresponds to stimulate the relationship energy [https://free-binaural-beats.com/frequency-list/] [http://www.lunarsight.com/biblio.htm].

Similar results were obtained for all the signals which are recorded during hearing binaural beats, except for the record B11, B18, and B20, where we found a predominance of the β waves. In the other hand the synchronization indicate zero degree in all cases.

Group C

The bi-spectrum of the record (C6) which represents the EEG signal after 10 min from hearing the binaural beat is illustrated in Figures 10 and 11. It shows a set of peaks distributed over the interval [0-30] Hz, with a predominance of three peaks: c1 around (2.5, 5) Hz, c2 around (0, 9) Hz, and c3 around (9, 9) Hz. As it is shown in Figures 10 and 11, we remark an increase in δ, θ, and α waves and a decrease in β waves. The frequency 5 Hz is the result of the quadratic interaction of the frequency 2.5 Hz. i.e. the synchronization degree equal (1/4=25%).

Similar results were obtained for the other records except for C11, C18, and C20; where we found a predominance of β waves. However, in the record C2 we found a predominance of α waves. In these cases the synchronization degree varies between (0 and 33%). The frequency 9 Hz and 2.5 Hz are present in all the records except for the signal C2 where we found only the frequency 9 Hz.

Evaluation

The bi-spectral analysis also allows us to extract six parameters which are: bi -spectral entropy (Ent1), square bi-spectral entropy (Ent2), cubic bi-spectral entropy (Ent3), and the bi-spectral phase entropy (EntPh), the average bi-spectral amplitude (mAmp), and the weighted centers of the bi-spectrum (wc1, wc2). The obtained results are shown in Figure 12. In order to evaluate the obtained results, the

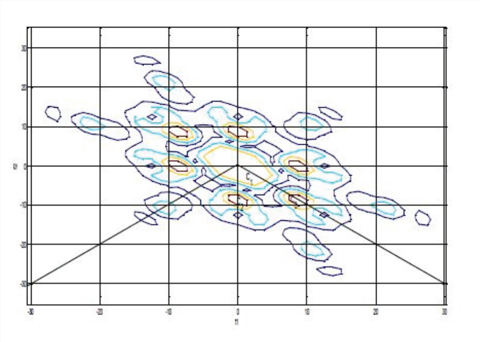

Figure 10: Bispectrum of the EEG signal after hearing to Marijuana binaural beats (record C6).

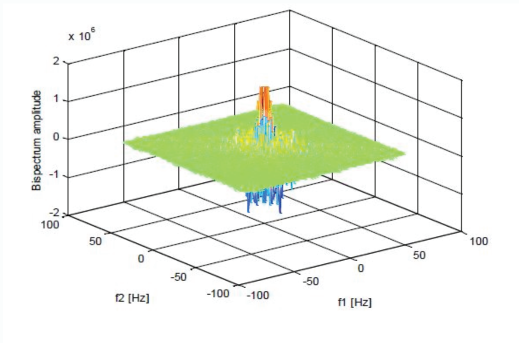

Figure 11: Bispectrum in 3D of the EEG signal after hearing to Marijuana binaural beats (record C6).

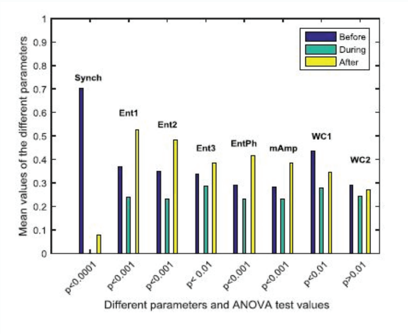

Figure 12: The mean values and the ANOVA test for different extracted parameters.

ANOVA test was used. The P value is the measure used to identify significant statistical differences between the mean values of different groups. p<0.01 are considered significant values, while values of p<0.001 are considered very significant values.

According to the diagram illustrated in Figure 12 the parameters: Synch, Ent1, Ent2, Ent3, EntPh, and mAmp show very significant values compared to Ent3, and WC1. We note also that the synchronization degree is more precise than the other parameters. Thus we can conclude that the both hemispheres work together in a perfect harmony. The entropies show a high values in the group C, and a low values in the group B i.e., the EEG signal is more random, non-stationary and more complicated in group A compared to the group B, and less complicated to the group C; because the biological systems become functionally deficient, due to effect of the binaural beats frequencies on the brain which cancels the brain function and replaces its waves with binaural waves. In the 3rd group (C), there is an incredible increase of the amplitude resulting from reaction of the brain with binaural frequencies, because it plays the THC (Tetrahydrocannabinol) role which gives the euphoria sensation, and there is a nerve strain.

Conclusion

In this work, the bi-spectral analysis is used in order to analyze the EEG signal in three cases (three groups): before, during, and after hearing the Marijuana binaural beats noted (A, B, and C respectively). The obtained results are very satisfactory and show a predominance of delta, theta, and alpha waves after 20 minutes from hearing the binaural beats, indicating that during this phase, beta waves decreases, and delta, theta, and alpha waves increase. The synchronization degree gives a satisfactory results compared to the entropies (Ent1, Ent2, Ent3, EntPh), average amplitude mAmp, and weighted center of the bi-spectrum (wc1), however no significant values were found in parameter WC2, i.e., the proposed algorithm is able to distinguish between the different cases; where a higher values of synchronization were found in group A compared to group C; while in group B the synchronization is nil. In fact during this phase, the EEG signals are more regular and less complex compared to the other groups; because the music (e-drug) controls the brain.

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