Determination of patterns in the EEG signals during relaxation through music using Bayesian Networks

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Abstract—*Today it is known that the brain waves behave during relaxation through music, however, it is not yet known whether there is a pattern of dependencies between different EEG frequencies during those processes. Brain oscillations are often underestimated as compared to slower oscillations. Mean power spectra of scalp EEG signals exhibit distinct peaks emerging from the general decrease in power with increasing frequency, suggesting the existence of characteristic dependence oscillatory modes in cortical field potentials. The interactions between peaks in different frequency bands, within and between cortical EEG sources, are not well understood. The reviewed evidence supports the theory that relaxation through music can lead to behavioral and neuron chemical changes with benefic effects. This study was to address this concept by focusing on Bayesian Networks (BN) to describe the relationship between the EEG frequencies during relaxation through music. It was obtained a model with 97.7% to accuracy, in which shows the relations between each EEG signals. The dependency probability distribution was calculated, according to the signal amplitude behavior. Music changes the behavior of the low frequency signals, synchronizing them inversely proportional. Delta and theta interactions over Alpha promote increase Alpha 1 powers in relaxation through music. This event is accompanied by synchronized interaction of low-sequence signals, from Beta 1 to Gamma. Alpha 2 remains an independent variable. Further studies are needed to understand the differences between music and their subsequent effects on behavior. However, Bayesian Networks has been show to an excellent tool of EEG signal Analysis.*

Key word: Bayesian Networks, Brain, Machine learning, Data mining.

I. INTRODUCTION

There are a lot of experimental efforts to understand musical processing in the brain using electroencephalogram (EEG). Music induces emotion in the brain. EEG signal is applied to measure electrical activity of the brain. These EEG signal contain precious information of the different moods of subject. It is accepted that listening to music increases the theta and alpha bands power that is associated to increase relaxation.

Deore and Mehrotra[1] determine the alpha rhythms in the left hemisphere are more predominant over the right hemisphere for emotions. Thus they conclude that the left region of the brain gives more response to the emotions rather than the right region. This study also shows that alpha power frequency carries useful information related to mood recognition. These features are separated using Linear Discriminate Analysis.

In other study, Deore[2] show that it is possible to recognize the different moods of person using EEG signal. They observe the different brain locations as Left Hemisphere and Right Hemisphere to recognize the significance according to different moods. The alpha powers are more alert during

National, Happy, Romantic mood as compared to Sad mood. So it is possible to distinguish these different moods using alpha power values.

An investigate using a 2-channel frontal EEG signal, Pan[3] classify two music preferences: like and dislike. The experimental results show evidence that frontal EEG signal contains sufficient information to discriminate preference of music. Furthermore, the frequency band optimization results indicate that gamma band is essential for EEG-based music preference identification.

Mitsukura *et al.* proposed a method for detecting the mood much music for prefrontal cortex electroencephalogram (EEG) activity.[4]

Marzukia[5] find the type of music that can produce such state of mind by analyzing the EEG power spectrum in those frequency bands. From the finding, it can be concluded that sound of instrumental piano and sound of nature increase relaxation as indicated by the increase of power in the theta/alpha frequency bands compared to the sound of wave and sound of bird.

An important aspect of music perception that gained much research interest is the music evoked emotion.[6–8] Greater frontal EEG activity during the mood inductions versus baseline was associated with more effective emotion regulation: less post-induction sadness and anxiety, and reduced mood-congruent attention interference effects. Effects did not differ between the left and right hemispheres. Results support the hypothesis that frontal EEG activity reflects both emotional context and emotion-regulatory capabilities.[9]

Today it is known that the brain waves behave abnormally significantly in episodes of anxiety and depression; Attention Deficit Hyperactivity Disorder can be determined and measured by calculating the Theta / Beta ratio, which has allowed developing protocols used as therapy. However, it is not yet known whether there is a pattern of dependencies between different EEG frequencies during the relaxation through music.

Although quantitative EEG is a very powerful tool for the detection and treatment of mental disorders, today is still impossible to understand the mechanism of the relationship between the different frequencies, due to the complex anatomy and function of the brain.[10] Moreover, with classical statistical tools, it is not possible to analyze several variables simultaneously.

Therefore, it is necessary to use new analysis techniques to incorporate a greater number of frequencies at once. Bayesian networks are techniques that enable analysis of many variables immediately.[11] The aim of this study is to determine and deduct the dependencies between EEG signals during relaxation through music using Bayesian networks.

II. METHODOLOGY

An before and after interventional study was conducted in Institute of Research and Developed Technologies GARMAN A.C. Andamaxei Av. #64 – 40, Paseos del Bosque, Corregidora, Querétaro, Mexico, C.P. 76990 to determine and deduct the dependencies between EEG signals during relaxation through music using Bayesian networks.

For this propose, Intel Core-i7 equipment is used with 8 GB of RAM and Windows 8 operating systems. The data is discretized in two intervals by Elvira software v 0.162, to be used in the development of the Bayesian network model that describes the relationships between all signal frequencies.

A set of 10 experimental data, which comprised of 16,384 records EEG applied to different people in the same basal conditions in the State Center for Mental Health (CESAM) of Queretaro, Mexico; which provided the data through the file format was obtained the text (txt). Each file became the space delimited text format (CSV) using MS Excel program, organized in 11 columns named as frequencies of the EEG signals in the range of Delta to Gamma signals, which were defined as random variables. Each column was 16,384 measured data value in microvolt (μV) corresponding to the source signal EEG electrode location in Fp2 International 10-20 system.

BN Elvira's analysis using software version 0.162 in three stages suggested by García-Manzo (2016) was performed: a) Pre-processing, b) Processing, and c) Post-processing. After obtaining the parametric learning network, the calculation of the conditional probabilities for the variables that show relationship or dependence was performed.

BN models are knowledge representation used in the field of Artificial Intelligence for approximate reasoning.[12] According to Correa,[13] the nodes of a BN acyclic graph correspond to concepts or variables and its links correspond to relationships or functions. Functional relationships describe causal inferences expressed in terms of conditional probabilities in which variables are defined in a discrete or qualitative domain.

$$P(x1,\ldots,xn) = \prod_{i=1}^{n} P(xi \mid parents\ (xi)) \qquad (1)$$

Hruschka et al.[14] found that a BN could be used to identify previously undetermined relationships among variables. They describe and quantify these relationships even with an incomplete data set. The solution algorithm of BN allows the computation of the expected probability distribution of output variables. The result of this calculation is dependent on the probabilities distribution of input variables. Globally, BN can be perceived as a joint probabilities distribution of a collection of discrete random variables.

$$P(cj \mid xi) = P(xi \mid cj)\, P(cj) \;/\; \sum_{k} P(xi \mid ck)\, P(ck) \qquad (2)$$

The most representative method of Machine learning in artificial intelligence approach is the K2 algorithm. This method is widely use even if it has the drawback to need the specification of an enumeration order on variables. The idea is to maximize the probability of the structure given the data in the search space of directed acyclic graph respecting this enumeration order.[15]

III. RESULTS

In present study a set of 10 experimental data, which comprised of 16,384 records EEG applied to different people in the same basal conditions were analysed.

A BN model with 97.7% accuracy, calculated in the post-learning step by Elvira system, which shows the relations between the variables obtained. For each EEG signal, the ratio of the frequencies' different ECG is determined. BN showed the dependency relations between some frequencies, according to the signal binary amplitude behavior. The relations for the entire signal frequency are inversely proportional.

The main difference between the relaxations through music comparing it with the normal condition in the EEG signals, as shown in Figure 1, in which signal amplitude is greater, especially in signals lower frequencies such as Delta and Theta. Other difference between the signals studied is that the synchronization between the frequency changes, which is most evident between the Delta and Theta frequencies.

Figure 1
EEG in normal conditions

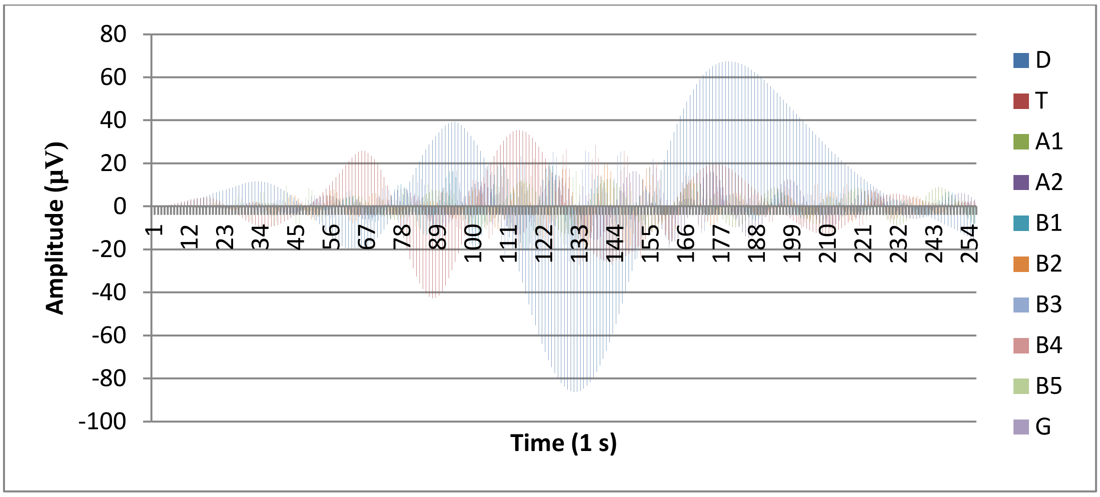
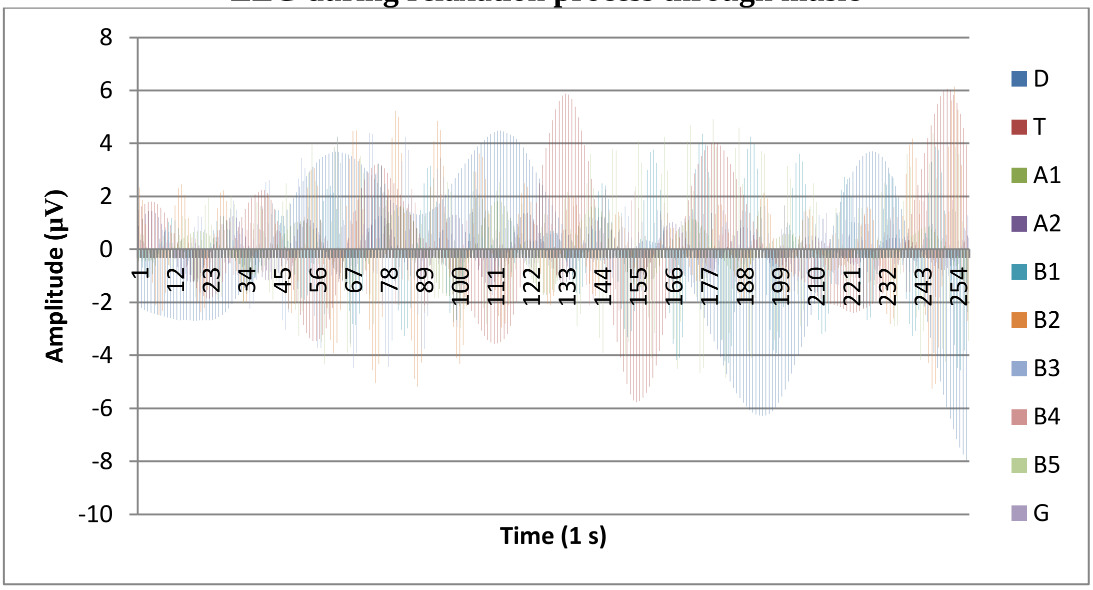


Figure 2 shows the amplitude signals for each frequency. Here Relaxation by music decreases significantly amplitude of the signals at all frequencies at its tenth Delta and Theta approximately; in relaxed state, high frequency signals remain constant in amplitude.

Figure 2
EEG during relaxation process through music



By employing the K2 algorithm (Figure 3), main relationships between the frequencies during relaxation through music and the normal condition was found (Figure 4), when Theta frequency presents the maximum amplitude and influences the increase of the signal Alpha 1.

Under normal conditions, the signals remain independent are Delta, Alpha 2 and Beta 1, while relations observed are inversely proportional between the following signals: Theta with Alpha 1, Beta 2 Beta 3, Beta 4 with Beta 5 and Gamma Beta 5.

Figure 3
Relationship over normal conditions

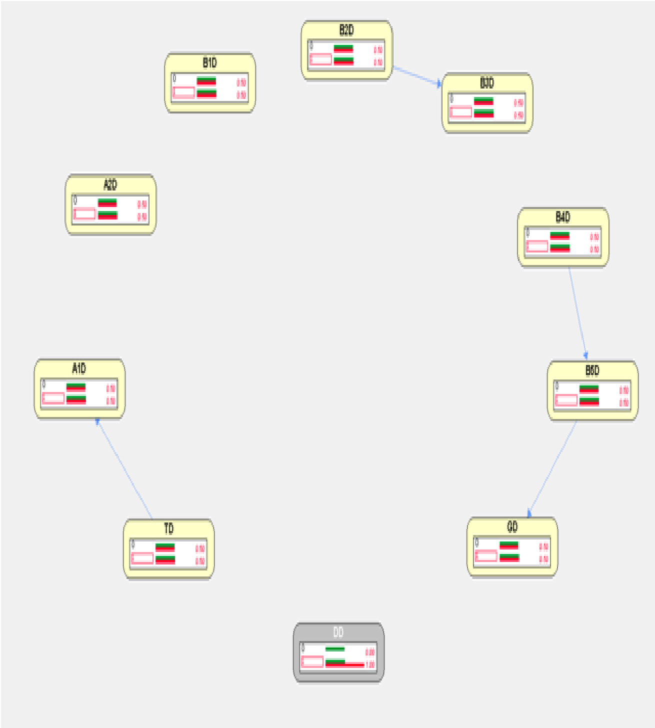
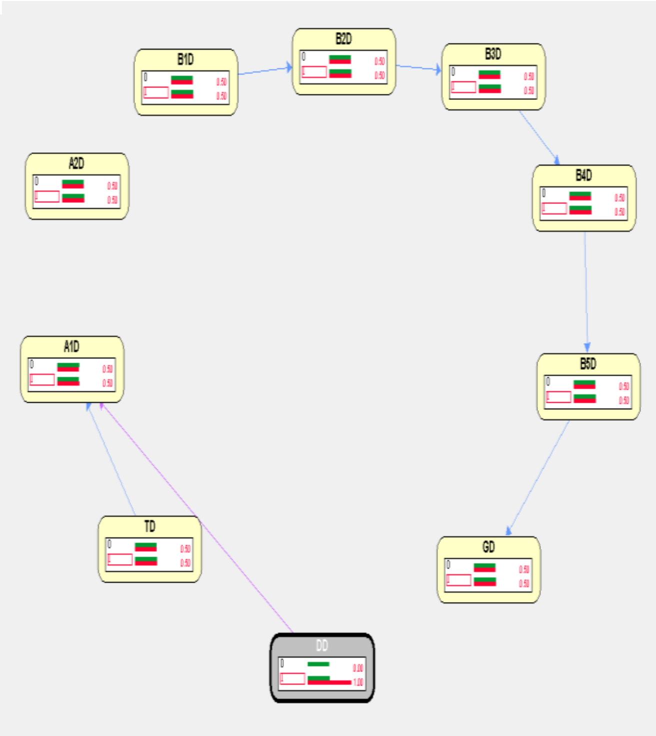


Figure 4
Relationship during relaxation process through music



Under normal conditions, the signals remain independent are Delta, Alpha 2 and Beta 1, while relations observed are inversely proportional between the following signals: Theta with Alpha 1, Beta 2 Beta 3, Beta 4 with Beta 5 and Gamma Beta 5.

While in a state of stress, the Delta Theta signal influences, Beta 2 depends on Beta 1, Theta and Delta, Beta and Gamma depends 5. Alpha 1 and 2 signals as well as Beta 3 and 4 are independent.

IV. DISCUSSION

In present study BN showed the dependency relations between some frequencies, according to the signal binary amplitude behavior. The relations for the entire signal frequency are inversely proportional. Difference in EEG signals between normal condition and relaxations through music is there like signal amplitude is greater, especially in signals lower frequencies such as Delta and Theta. Other difference between the signals studied is that the synchronization between the frequency changes, which is most evident between the Delta and Theta frequencies. Relaxation by music significantly decreases amplitude of the signals at all frequencies at its tenth Delta and Theta approximately; in relaxed state, high frequency signals remain constant in amplitude. Main relationships between the frequencies during relaxation through music, and the normal condition where Theta frequency presents the maximum amplitude and influences the increase of the signal Alpha 1.

During relaxation by music more of relationships between different frequencies are observed: Music increases the Delta, theta, and alpha bands relationship that are associated to increase relaxation; Delta and theta interactions over Alpha promote increase Alpha 1 powers in relaxation through music which is consistent with the studies carried out by Deore[2] and Marzukia.[5] This event is accompanied by synchronized interaction of low-sequence signals, from Beta1 to Gamma.

Alpha 2 remains an independent variable. The music changes the behavior of the low frequency signals, synchronizing them inversely proportional; when one increases the subsequent decreases; we have found that there are no studies which are designed to analyze these relationships, and we consider being of importance; these frequencies are present in cognitive processes.

Under normal conditions, the signals remain independent are Delta, Alpha 2 and Beta 1, while relations observed are inversely proportional between the following signals: Theta with Alpha 1, Beta 2 Beta 3, Beta 4 with Beta 5 and Gamma Beta 5. While in a state of stress, the Delta Theta signal influences, Beta 2 depends on Beta 1, Theta and Delta, Beta and Gamma depends 5. Alpha 1 and 2 signals as well as Beta 3 and 4 are independent.

In all three cases, the inverse relationship between Gamma and Beta 5 is preserved; this relationship does not depend on the states of stress or relaxation through music, gamma band is essential for EEG-based music preference identification.[3]

V. CONCLUSION

An EEG signal is the result of the sum of distinct signals at different frequencies, which are serially interconnected and they dependent on each other signals during relaxation through music condition. Music increases the Delta, theta, and alpha bands relationship that are associated to increase relaxation; Delta and theta interactions over Alpha promote increase Alpha 1 powers in relaxation through music. This event is accompanied by synchronized interaction of low-sequence signals, from Beta1 to Gamma. Alpha 2 remains an independent variable. The music changes the behavior of the low frequency signals, synchronizing them inversely proportional; when one increases the subsequent decreases. We have found that there are no studies which are designed to analyze these relationships, and we consider being of importance. These results could be used to design therapeutic methods of relaxation through music. The BN is a good tool with which we were able to study the relationships between different EEG frequencies of a signal

CONFLICT

None declared till date.

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