Concentration level detection for left/right brain dominance using electroencephalogram signal

Swati CHOWDHURI[1], Dibyendu MAL[2]

[1] Department of EEE, Institute of Engineering & Management, Kolkata, India

[2] Department of PHYSICS, Heritage Institute of Technology, Kolkata, India

swati.chowdhuri@iemcal.com, dibyendu.mal@heritageit.edu

Abstract: Some features of left and right brained people can be determined using the left and right brain dominance theories. It can assist in the development of training syllabus for brain-balancing education topics. When performing any action, human focus or concentration is essential. This paper will examine the concentration levels of patients with left and right brain dominance using electroencephalogram (EEG) data. Brain activity may be tracked and recorded using EEG waves. The human brain's thinking and attention cause brain waves to alter in distinct frequency bands. A frequency-based EEG signal can be cleaned up and characteristics can be extracted using the baseline correction method. As a result, the EEG Topographical Power Spectral Density Value is created. The main objective of this paper is to compare the concentration levels of people with different brain dominance. Inversely, EEG signal can be used to predict whether a person has a left or a right brain dominance.

Keywords: Brain dominance, concentration, electroencephalogram, power spectral density, topographical value.

1. Introduction

Human brain is the most complex organ of the body, which controls human body and memory. Left and right hemispheres of the human brain are separated by corpus callosum (Sim et al., 2016; Cherry, 2020). Corpus callosum controls the exchange of information from the left hemisphere to the right hemisphere and vice versa. The movements of the right side of the body are controlled by the left hemisphere and vice versa (Trafton, 2014). Left and right hemispheres of human brain carry different functions. The left hemisphere is responsible for sequential and logical thinking, solving mathematical problems, while the right hemisphere is responsible for creative thinking and imagination, including music, art etc. (Alady, 2019; Oflaz, 2020). Most people use one side of the brain predominantly, so, based on this reality, people are divided into two categories: people with left brain dominance and people with right brain dominance (Daud et al., 2015; Wang et al., 2015). Left-brained people have a greater ability in mathematics and science that involve analytical and logical thinking, whereas, a right-brained person has a better talent in art and music that involve a higher level of imagination and creativity (Sim et al., 2016; Sudha et al., 2017). A few of the greatest minds (Albert Einstein, Leonardo DaVinci, Samuel Morse, and others) were whole-brain thinkers who achieved great things in all fields, such as inventions in scientific research as well as art or music (Ali et al., 2017).

EGG signal recognizes not only the human brain dominance, but also the concentration level of the human brain. The brain activity information can be acquired by different techniques like: magnetic resonance imaging (MRI), functional magnetic resonance imaging (FMRI), positron emission tomography (PET) and electroencephalogram (EEG) (Sim et al., 2019, Ashraf et al., 2017). EEG has now become a scientific field as by using EEG signal researchers can examine and estimate the fluctuation of human brainwaves. In human brain, the ionic current flows in neurons and generate the voltage (in a range from 10 to 100 microvolts) in the scalp (measurable electromagnetic waves). These waves are named EEG signals and need to be amplified by a computer system in order to be analyzed. EEG is a method which has high sampling frequency and it can measure the voltage emitted in the scalp (Sim et al., 2016). The raw EEG waveform is interfered by different sources of noise. Noise minimization can be done by means of the baseline removal method (Sim et al., 2019; Fawaz et al., 2020). Electroencephalography (EEG) is a process

https://doi.org/10.33436/v32i3y202209

which produces electrophysiological data and signals generated by brain using applied electrodes. Generally, electroencephalography (EEG) sensors use wet electrodes; they are multichannel and transmit data through a set of wires (Weka.Sourceforge, 2018). The recent development of single channel dry electrode sensor, by EEG sensor technology, is of great interest for researchers. This sensor has significantly low cost with higher usability as the studies conducted in school, homes or informal environments demonstrate.

MindWave Mobile from NeuroSky is widely used for this type of studies (Gruzelier, 2009). The research related to Brain-Computer Interface (BCI) and Human-Computer Interaction (HCI) was based on NeuroSky sensor. An e-learning system is proposed to capture the meditation and attention signals to customize educational experience via the NeuroSky sensor (Tanaka et al., 2021). The same type of signals is used to distinguish between relaxing states at different places (Bird et al., 2018). In similar way, an Nuero Wander is developed which is a Brain-Computer Interface (BCI) game using sensor' attention and meditation signal as game controller (Leske et al., 2019). Mental state classification (relaxed, neutral, and concentrating) is done by using time-windowing technique with feature selection (Wang et al., 2016). Here the authors observed classification accuracy of 87% by using Random Forest method which was preprocessed with OneR classifier as a feature selection. But best cutting-edge solution for classification gives an accuracy level of 95% for emotional EEG data from low-cost, low resolution EEG setup (Bird et al., 2018). Using EEG headbands is very effective to categorize the high performance of valence through different levels of satisfaction during a definite mission (Li et al., 2009). Artificial Neural Network (ANN), Deep Belief Network (DBN) and Support Vector Machine (SVM), are very effective to categorize the state of feelings from EEG data when allowing for binary classification: positive and negative classes (Abujelal et al., 2016).

Lots of research work has been done to determine the concentration level using different machine learning algorithms. This paper analyses the EEG data as a comparative basis for left- and right-brained people and implements the complicated time-based waveform EEG Topographical Power Spectral Density Value (EEGTPSDV) method in order to detect the human concentration level considering the brain dominance level. The paper is organized as follows. Section 2 presents the acquisition of EEG data, section 3 discusses about left and right brain dominance instrument HBDI, while section 4 shows the preprocessing of the data. Section 5 deals with the extraction of signal features and section 6 presents the results of the present analysis. Finally, section 7 offers the conclusions of the paper.

2. Electroencephalogram (EEG) signal acquisition

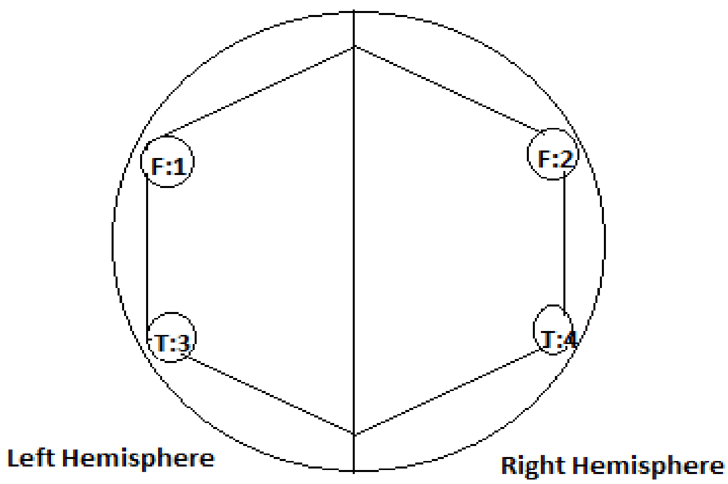

Figure 1. Grid points to acquire EEG signal (Redrawn based on figure in page 140 of "Electroencephalography: Basic Principles, Clinical Applications, and Related Fields", (Niedermeyer & Silva, 2004))

The acquired EEG signal collected from the frontal lobe and temporal lobe from both hemispheres (left and right) is shown in Figure 1. The odd numbers of channels (1, 3) represent the frontal and temporal lobes of the left hemisphere, and the even numbers of channels (2, 4) represent the frontal and temporal lobes of the right hemisphere.

To minimize the signal imbalance, the positions of the electrodes for the left and right hemispheres of the brain should be symmetrical and equal. Channel 1 and 3 collect EEG signals from the frontal and temporal lobes of the left hemisphere, while channels 2 and 4 collect EEG signals from the frontal and temporal lobes of the right hemisphere. Signal acquisition from both hemispheres is done in this way.

3. Left and right brain dominance instrument (HBDI)

Willian Hermann modified the Hermann Brain Dominance Instrument, a psychometric evaluation that determines the power of each cognitive style in the left and right hemisphere of the brain (Think Hermann, 2020). Using this instrument, several companies can be able to determine the cognitive skills and personalities of their employees. The concept of HBDI can be specified in four modes; they are: analytical thinking, interpersonal thinking, sequential thinking, and imaginative thinking (Open BCI., 2020). Figure 2 shows the entire brain model idea of HBDI.

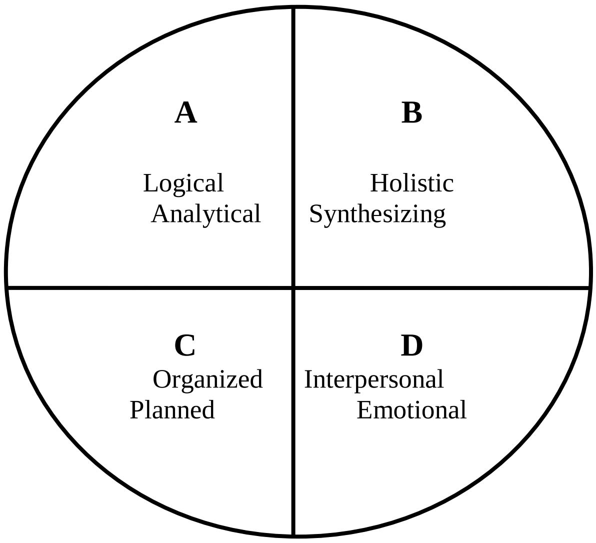

Figure 2. Hermann Brain Dominance Instrument

The outcomes of the test presented in the four quadrants demonstrate the complexity of this topic. Quadrant A characterizes the front left side of the brain that points out the user's ability in analytical thinking, which includes logical thinking, mathematics, and fact-based decision making. Quadrant B characterizes the back left side of the brain that points out the user's ability in continuous thinking, which includes thorough planning, timing, and registering. Quadrant C characterizes the back right side of the brain, emphasizing the user's ability in emotional and interpersonal thinking, which conveys information and feelings. Quadrant D characterizes the front right side of the brain and highlights the user's ability in creative thinking.

The outcome of the HBDI test shows the percentage of each quadrant based on which it can be concluded if the user is a left-brained or a right-brained person or a whole-brain thinker. The result also shows the stability between the left and right brain hemisphere.

4. EEG signal processing

The amplification of EEG signal is very essential as the original signal voltage is very low. The raw EEG data is sometimes affected by electrical line noise so it's equally important to eliminate unwanted artifacts from the acquired raw signal (Al-Fahoum et al., 2014). In this research we analyze the EEG signal to analyze the concentration level of human being using sample data. The EEG signal processing technique is shown in Figure 3.

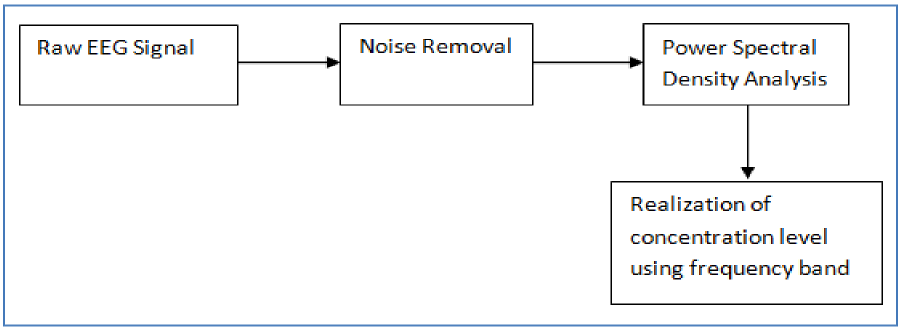

Figure 3. EEG signal preprocessing techniques

5. Extraction of features of EEG signal

In this research the spectrum of EEG signal is used to determine the concentration level. The power spectrum of the EEG data has been calculated by using Fast Fourier Transformation (FFT). Equation (1) for FFT (Subramaniyam, 2018) and equation (2) for power spectral density are as follow:

$$X(k) = \sum_{k=1}^{N-1} X(n) W_N^{kn}; k = 0, \ldots\ldots, N-1 \tag{1}$$

where, $W_N = e^{-j\frac{2\pi}{N}}$

$$PSD = |X(k)|^2 = \left| \sum_{n=0}^{N-1} x(nTs) e^{-j\frac{2\pi nk}{N}} \right|^2 \tag{2}$$

The value of ‘k’ has N complex multiplications, since’k’=0,1…N-1. The multiplication of x(n) and W^{kn} will be completed for N times, since $n = 0$ to $N-1$. The Spectral Centroids are calculated by using formula in equation (3).

$$C = \frac{\int xg(x)dx}{\int g(x)dx} \tag{3}$$

Equation (3) represents the Spectral Centroids that are engaged to identify the center value of each EEG frequency band (Leske et al., 2019). The entropy can analyse the amount of randomness is in the signal.

The entropy of discrete random variable, X= [x (0) x (1) …… x(N-1)] with Probability Density Function (PDF) denoted by p(x) is given by:

$$H(x) = -\sum_{i=0}^{N-1} P_i(x) \log_2(P_i(x)) \tag{4}$$

where *i* represent the discrete states.

To analyze the EEGTPSV, collect the EEG signal for the grid point mentioned in Figure 1.

EEG Topological Power Spectral Value **(EEGTPSV**) is used to find out the human concentration level. A processing technique (Fourier transform) is used to convert EEG signal to frequency-based waveform and the concentration level is decided based on the Power Spectral Density (PSD) of the frequency domain representation of the signal.

6. Results and discussion

The Power Spectral Densities (PSD) vs Normalized Frequencies (Hz) of the EEG signal for all four channels are represented here in Figures 4(a-d).

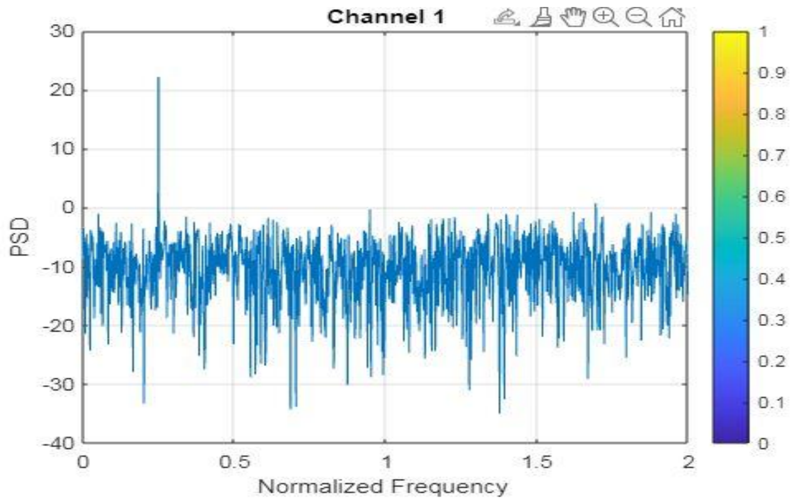

Figure 4(a). PSD analysis of EEG signal for channel 1(F:1)

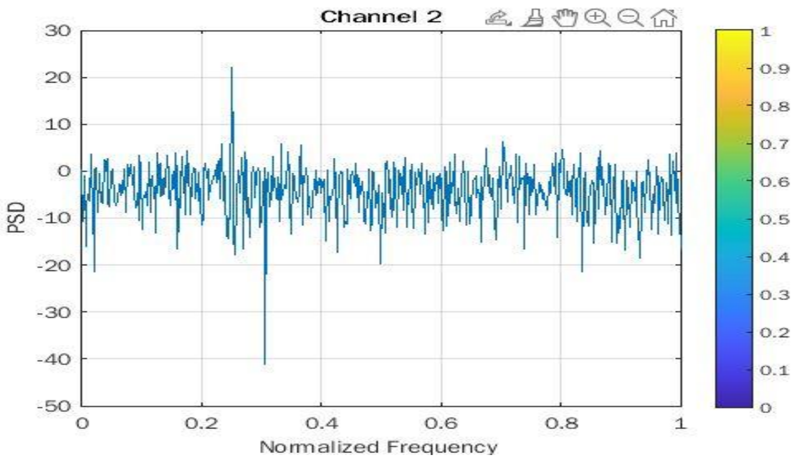

Figure 4(b). PSD analysis of EEG signal for channel 2(F:2)

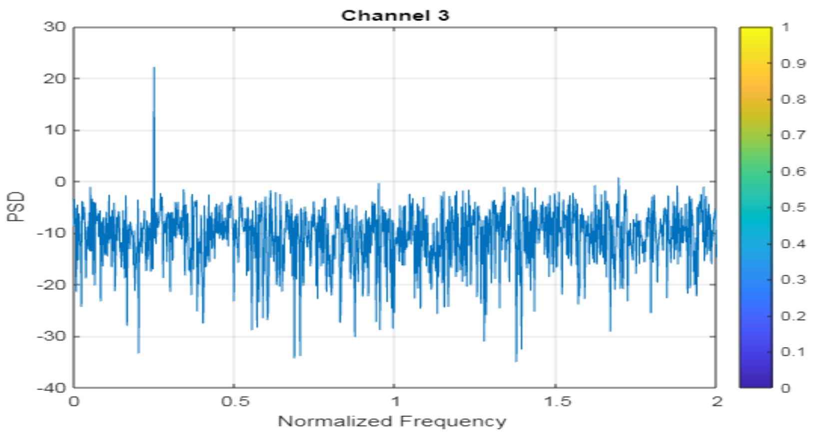

Figure 4(c). PSD analysis of EEG signal for channel 3(T:3)

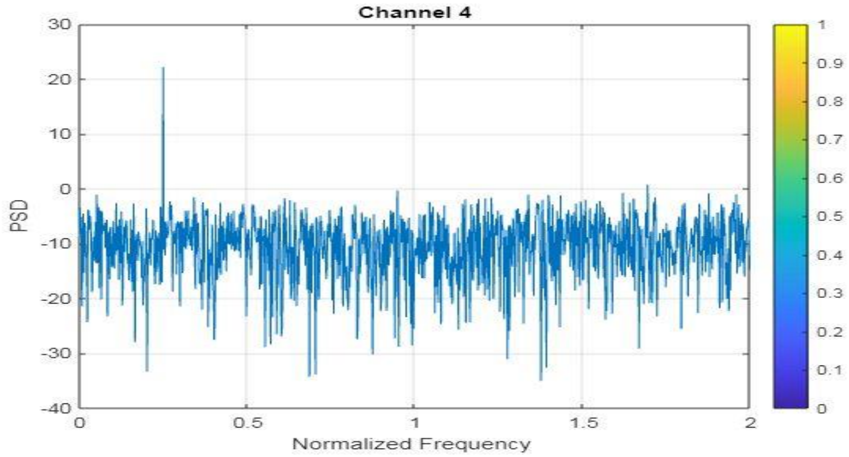

Figure 4(d). PSD analysis of EEG signal for channel 4(T:4)

The PSD values of EEG signal are analyzed in different frequency bands, in order to determine the human concentration level: Delta (0.5Hz to 4Hz), Theta (4-8 Hz), Alpha (8-13 Hz), Beta (13-30 Hz) and Gamma (above 30 Hz). The EEG frequency bands corresponding to different brain states are shown in Figure 5. In Delta band human brain is in a sleep/unconscious state and in Theta band it is in a deep physical relaxation state. The calm conscious state shows in Alpha band, whereas busy and alert states are reflected in Beta band, for human brain. Gamma band is the band with the highest performance, where human brain is in its full concentrated state.

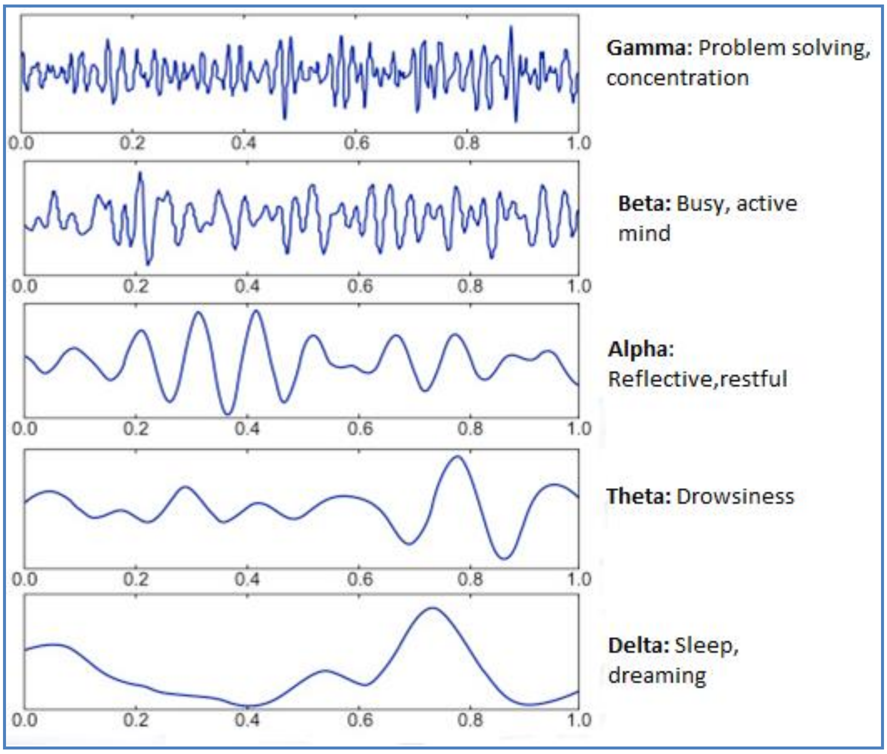

Figure 5. EEG frequency band comparisons

The representation of PSD signal in different frequency bands does not only determine the human concentration level, but is also varies in different hemispheres of the brain, based on dominant method. PSD signal variations in different frequency bands for each channel are shown in Figures 6(a-d).

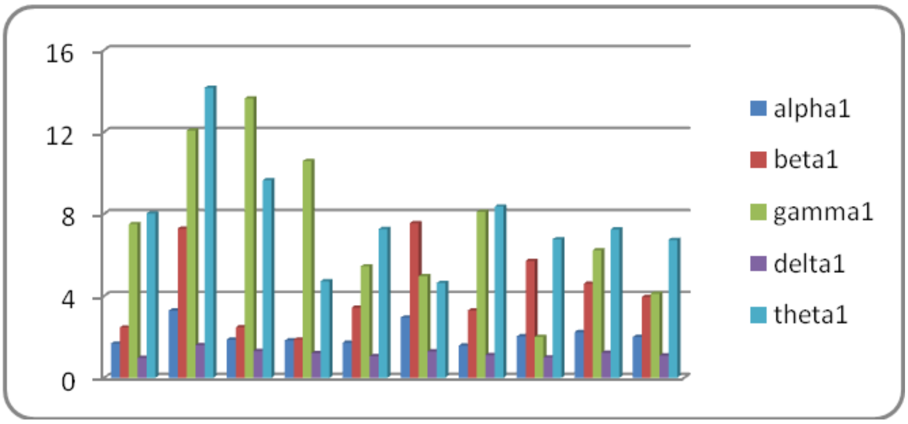

Figure 6(a). Frequency band channel 1 (Left Dominance)

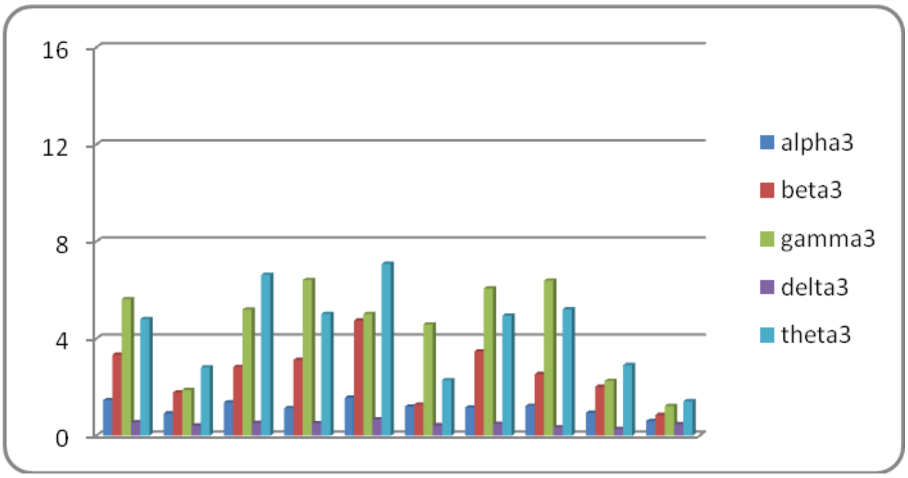

Figure 6(b). Frequency band channel 3 (Left Dominance)

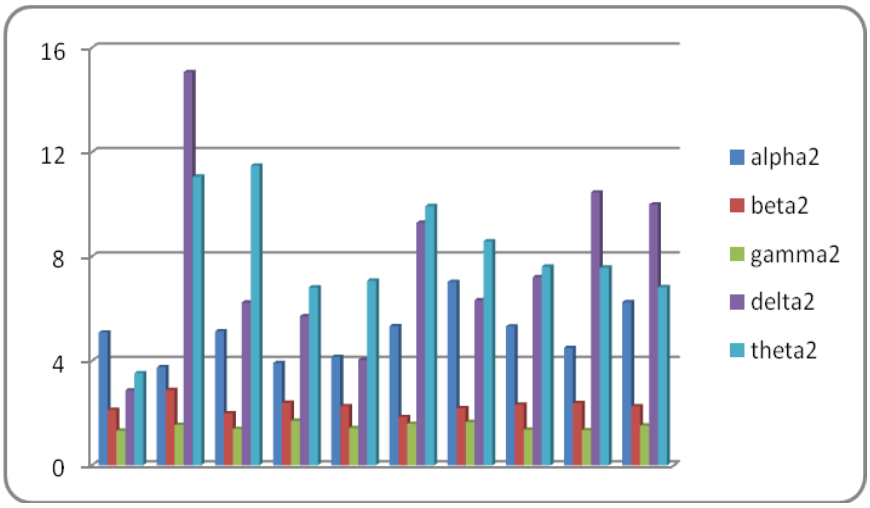

Figure 6(c). Frequency band channel 2 (Right Dominance)

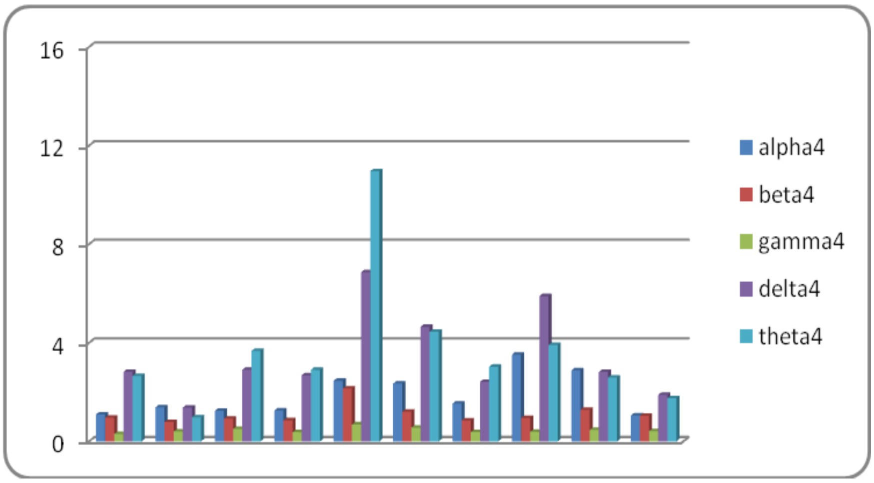

Figure 6(d). Frequency band channel 4 (Right Dominance)

Human brain activity changes in different frequency bands, as shown in Figure 5. The human brain is in a resting state in the Theta frequency band, and in the Beta frequency band, it is in an active state. Brain activity with information processing like thinking and consciousness occurs in the Gamma frequency band. The results show that the PSD value is higher in the Theta, Beta, and Gamma frequency bands for left-brained people than for right-brained dominant people. Similarly, for right-brained people, PSD values are high for the even numbers of the channels in the same frequency band.

7. Conclusion

In this research, an EEG signal preprocessing technique is implemented to eliminate the noise from the acquired signal. An efficient method is analyzed, i.e., the EEGTPSDV technique, which can detect the concentration level of different brain dominances of people. The EEG signal was taken from the frontal and temporal lobes of the left and right hemisphere and EEGTPSDV computed and concluded that the concentration level of EEG power spectral density is highly correlated with the brain dominance level contributed by the respective hemisphere. The acquired EEG signal, in conjunction with the EEGTPSDV method, demonstrates that PSD value is higher in the Theta, Beta and Gamma frequency bands on the left hemisphere than on the right hemisphere. From the concentration level of EEG signal it can be predicted the person's brain dominance level. This research, analyzing the EEG signal, proves that brain dominance is no longer a myth and, on this basis, a teacher can detect the concentration level of a student and design a training syllabus accordingly.

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Swati CHOWDHURI is an Associate Professor at Institute of Engineering and Management. She received her Ph.D. and M. Tech Degree at Jadavpur University and her B.E. Degree at Burdwan University with Honours. Her research interests are in the field of MIMO communication, Mobile communication, Mobile ad-hoc Network, Signal Processing and Robotics. She has more than 40 publications in international journals and conferences.

Dibyendu MAL is an Assistant Professor at Heritage Institute of Technology. He received his Ph.D. Degree from Jadavpur University, in 2009, his M.Sc. Degree from Jadavpur University, in 2003, and his B.Sc. Degree from Vidyasagar University, in 2001. He received the MHRD Scholarship Award, from the Government of India, at B.Sc. (H) level. His research interests are in the field of Condensed Matter Physics, Fractal Analysis, Signal Processing and Wireless Network. He has published more than 15 papers in international journals and conferences.