A Cognitive Approach Towards Measuring Effectiveness Of Meditation Using Enobio-8 EEG Device

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Abstract
In recent times, Mind-Body awareness training (MBAT) through yoga and meditation has harvested interest because of raise in the attentiveness of the potential health benefits and enhancement in concentration level this training can offer to practitioners [1]. In our work using Brain to Computer Interface(BCI), cognitive analysis of yoga with meditation on health of individual being based on Electro Encephalo Graphy (EEG) is achieved by using Enobio-8 by acquiring EEG data at four defined stages. In the first stage, subjects were informed to relax and then data is recorded for 3-minute duration called as "Before Meditation". In the second stage, subjects were intimated to perform meditation for 10-minutes and later data is recorded for 3-minute duration called as "After Meditation". In the third stage, subject's EEG data is recorded before pranayama for 3-minute duration called as "Before Pranayama and meditation". In the fourth stage, subjects perform prescribed Pranayama and meditation for 10-minute, later EEG data is recorded called as "After Pranayama and meditation". Acquired EEG data is preprocessed and features are extracted using MATLAB for comparative analysis. In time domain, mean, standard deviation, variance, minimum, maximum, skewness and median is calculated for all the four stages. Similarly, in frequency domain power, energy and entropy is calculated for delta, theta, alpha, beta, gamma bands.

Keywords: Brain to Computer Interface(BCI), ElectroEncephaloGraphy (EEG), Mind-Body awareness training (MBAT),Meditation,Enobio-8

1. INTRODUCTION

Nowadays, human life is moving towards machinery with increased mental strain. Yoga meditation overcomes this stress and ensures mental harmony when accomplished habitually as it elevates physical, mental, and spiritual health. Experimental investigations on the effect of yoga meditation are considered by analyzing Electroencephalogram (EEG) using brain–computer interface (BCI). The brain waves of the human who is under meditation will be recorded using Enobio-8 BCI kit[2][3][4]. To measure brain activity, the EEG is usually used. EEG signals are classified into wave bands as shown in figure 1 to specify various states or activity levels.

The 10-20 system of electrode positioning is a method to represent the location of scalp electrodes. These electrodes are availed to record the electroencephalogram using a machine called an electroencephalograph. In the EEG signal analysis, the electrode positioning using 10-20 system is shown in the below figure 2.

Brain Computer Interface or Man machine interface has been one of the emerging fields of research and has improved in recent years. Yoga meditation focuses on peace and health in one's personal and social life. When it is practiced regularly, brings stability of mind to balanced state

in the difficult situations and to reach the premier level of emotional stability [6]. The latest researches on brain wave monitoring have demonstrated that long-term meditations have intense impact on the brain wave activity [7][8][9].

2. Implementation

In the implementation, we were able to (a) Develop protocol for acquiring EEG data from brain using 8-channel Enobio-8 device from C3,C4, CZ, F3,F4, FZ,T7 and T8 position as per 10-20 system (b) Using MATLAB tool, developed algorithm for preprocessing the acquired EEG signal by band pass filtering to remove artifacts and decomposed the signal using 4th level Discrete wavelet transform DB4 to extract the features in time domain and frequency domain.

Mind Body Awareness Training (MBAT) for Subjects:

In our work, subjects were trained meditators as well as untrained meditators of different ages, gender and profession. Also following methods were asked to the subjects to perform for the data acquisition at the "Department of Inner Science and Engineering, SJCIT" which is dedicated center for Meditation.

SESSION-1: Below protocol is followed for the EEG recording and it's called "Meditation without Pranayama".

Step 1: Subjects were asked to sit comfortably on chair or yoga mat. Process of data acquisition has been explained to the subjects and after their concert, process of setting up the EEG Enobio-8 cap on the scalp, connecting BP and heart beat rate monitor is commenced.

Step 2: EEG data is recorded for 3-minutes using EEG device after taking health parameters like BP and Heart beat rate. During recording of EEG, subjects were asked to read VTU Sports Magzine-2019 to normalize the situation. This recording is considered as "Before Meditation".

Step 3: After recording of EEG data "Before Meditation", subjects were asked to perform Meditation for the duration of 10 minutes. Necessary instructions are provided to those who do not know the meditation process.

Step 4: After meditation, health parameters are recoded and EEG data is recorded for 3-minutes duration. This recording is considered as "After Meditation".
Below figure 3 depicts the protocol followed for "Meditation without Pranayama".

SESSION 2: Subjects were asked to take break for 4 to 5 hours and informed to continue their daily activities.

SESSION 3: Below protocol is followed for the EEG recording for session 3 and it's called "Meditation with Pranayama".

Step 1: EEG data is recorded for 3-minutes using EEG device after recording health parameters. This recording is considered as "Before Pranayama and Meditation".

Step 2: Subjects were asked to perform Pranayama which involves breathing exercise.

Step 3: Health parameters are recorded called as "After Pranayama".

Step 4: After Pranayama, now subjects are informed to perform meditation for 10 minutes with making subjects to listen to specific recorded chanting which helps in avoiding external noise and increasing the effectiveness of mediation.

Step 5: After meditation, Health parameters and EEG data is recorded for 3-minutes duration. This recording is considered as "After Pranayama and Meditation".

Below figure 4 depicts the protocol followed for "Meditation with Pranayama"

Environment Setup for Data Acquisition at BCI Site:
All the work related to MBAT and data acquisition is conducted in yoga center at "School of Inner Science and Engineering, SJCIT". Below figure 5 depicting environment setup for quality data acquisition of EEG data.

NIC-2 tool, Enobio-8 device and Heart Rate Monitor Tool:
NIC-2 Tool: NIC (Neuroelectrics Instrument Controller) is the software toolwhich enables workstations to communicate with Neuroelectrics devices. NIC functions both on wired and wireless medium to control the devices. NIC permits EEG data to be received and analyzed in real-time for both Enobio and Starstim devices. Below figure 6 depicts NIC 2 tool displaying EEG data.

Enobio-8: Features of Enobio-8 device are it is mobile, comfortable, precise and robust wireless EEG which is ideal for out-of-the-lab and BCI applications. It has high dynamic resolution (24 bits, 0.05 uV) and sampling rate. It offers a bandwidth of 0 to 125 Hz. Below figure 7 shows the Enobio-8 device.

Heart Rate Monitor: Heart rate monitor used here is Gibson Model number sjdbp 1011 from Nikkei ElectromedicalCo.Ltd. Japan. It is upper arm BP Monitor device which is battery operated. Below figure 8 shows the heart rate monitor system.

NIC-2 Protocol Design:
Enobio-8 uses 10-20 system for placement of electrodes to capture EEG data. In the protocol design for our research work, data is recorded from the electrodes placed at position C3,C4,CZ,F3,F4,FZ,T7 and T8 position as shown in below figure 9 and figure 10. Also flowchart represents the protocol for the data acquisition using NIC 2 tool is shown in figure 11.

Sampling Rate of Data Acquisition:
For recording the EEG data, the ENOBIO-8 device along with NIC V2 is used at four sessions as given below

- Before Meditation
- After Meditation
- Before Pranayama and Meditation
- After Pranayama and Meditation
  Communication type used here is WiFi and interfaced windows based Laptop/Computer. Total number of channels used is 8 and EEG sampling rate is 500 samples/second for duration of 180 minutes. Total number of samples recorded is 90000.

Easy File Format:

The data recorded from EEG device is stored in easy file type. The data from each channel are stored in the form of columns. Below table 1 is channel montage for recoding purpose. Along with the channel data recorded, accelerometer data from 3 channels is recorded with accelerometer sampling rate of 100 Samples/second. It is stored as 3 columns in the easy file. The sample of recorded EEG data in the form of .easy file as given in below figure 12.

Easy File Format:
Along with EEG data, heart beat rate and blood pressure are monitored at the following session shown in table 2 to monitor the physical health of a subject as additional data.

EEG Signal Analysis at BCI Site:
EEG signal can be analyzed and ascertainedin the time domain, as voltage plotted with respect to time or in the frequency domain as voltage or power plotted with respect to frequency. Both time and frequency analysis is used for EEG based applications. The noises in the EEG signal can be filtered by pre-processing for improving the performance EEG analysis as shown in below block diagram.

3. DATA ACQUISITION AND PREPROCESSING OF EEG DATA

Collection of Raw EEG Data:
Data acquisition using wearable Enobio-8 allows portable and effective monitoring of human cognitive signals. Below figure 14 shows the raw EEG signal acquired.

Detrending of EEG data- Normalization:
The detrend here is used to subtracts the average or a best-fit line (in the least-squares sense) from acquired raw data.

Band pass filtering of EEG data:
The detrended signal is passed through band pass filter between 2 to 64 Hz with 50Hz notch filter. The 50Hz line frequency can also be removed at data acquisition using NIC V2 tool. In our work, firpm-Parks-McClellan optimal FIR filter is used.

Band Extraction Using db4 Wavelet:
In our work, each signal is decomposed with 4th level Discrete Wavelet Transform (DWT) 'db4'as a mother wavelet and scaling function for DWT.

Feature Extraction in Time Domain:
Features are the meaning full information in the signal. Following features in time domain are extracted from the bands for analysis purpose.
* Mean
* Started Deviation
* Variance
* Minimum
* Maximum
* Skewness

Feature extraction in frequency domain:
Frequency domain features are extracted from the bands for analysis purpose. Following are the features extracted in frequency domain.
* Power
* Average Energy
* Differential Entropy

4. **Results and Discussions**

Using BCI, cognitive impact of yoga with meditation on physical and mental health of human being, based on EEG using Enobio-8 is analyzed. EEG data is acquired at four stages. Acquired EEG data is preprocessed and features are extracted using MATLAB for comparative analysis. In time domain mean, standard deviation, variance, minimum, maximum, skewness and median is calculated for all the four stages. Similarly, in frequency domain power, energy and entropy is calculated for delta, theta, alpha, beta, gamma bands.
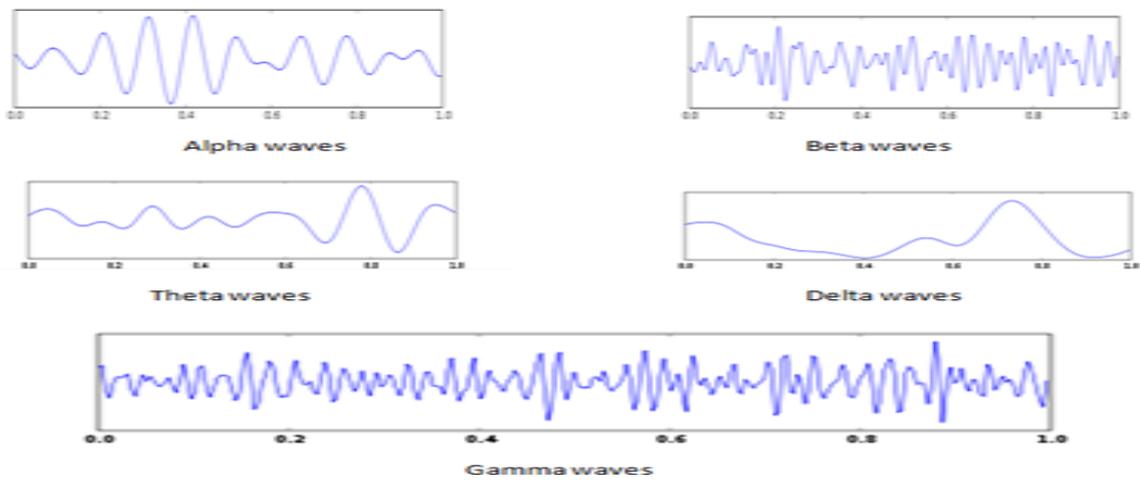
Figure 1: Types of Brain Waves
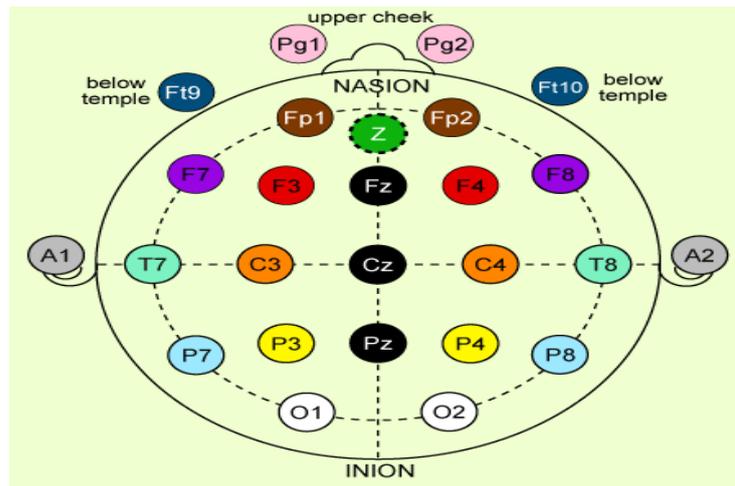
Figure 2: 10-20 EEG System[5]
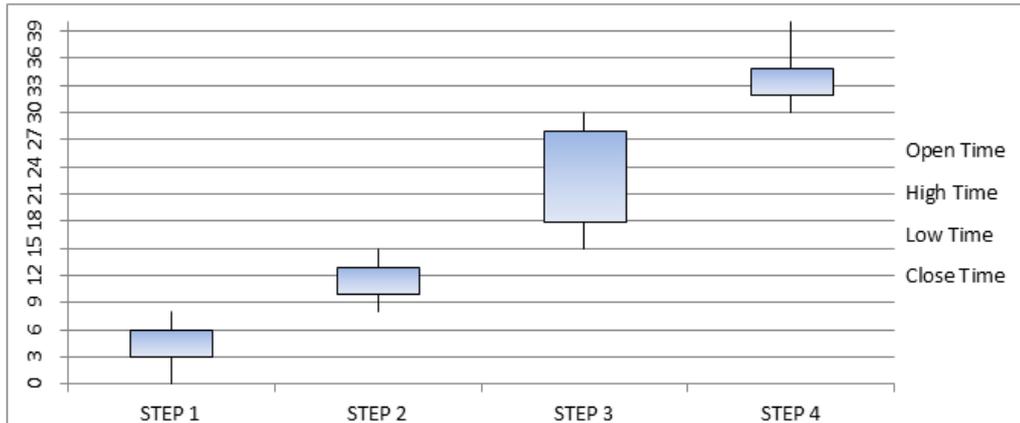
Figure 3: **Display of protocol "Meditation without Pranayama" of 40-minutes duration with**

steps in x-axis and time (minutes) in y-axis
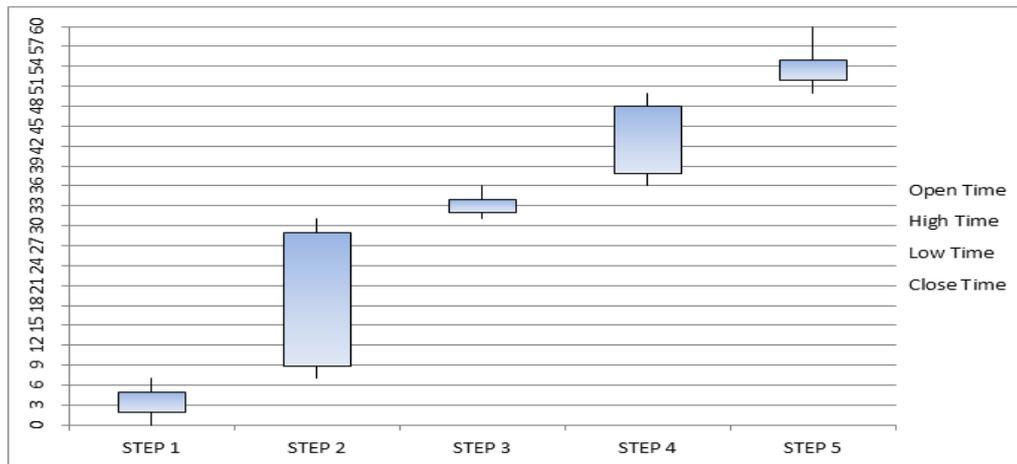
Figure 4: Display of protocol "Meditation with Pranayama" of 60 minutes duration with steps in x-axis and time (minutes) in y-axis

Figure 5: Environmental setup for data acquisition in yoga center at "School of Inner Science and Engineering, SJCIT".

Figure 6: NIC-2 tool displaying EEG waveforms

Figure 7: NIC-2 tool displaying EEG waveforms

Figure 8: Heart Rate Monitor
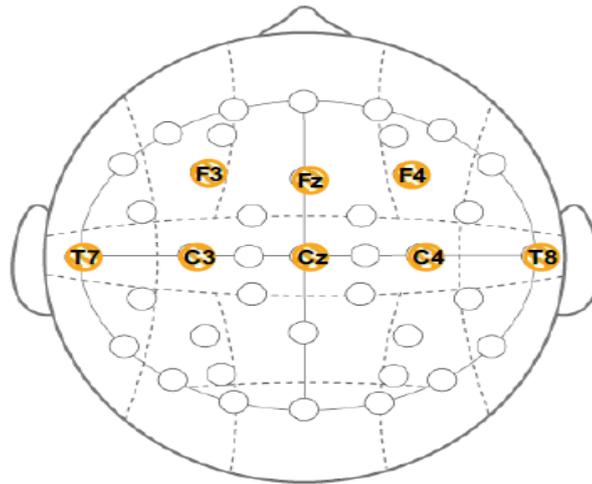
Figure 9: Placement of Electrode for ENOBIO-8
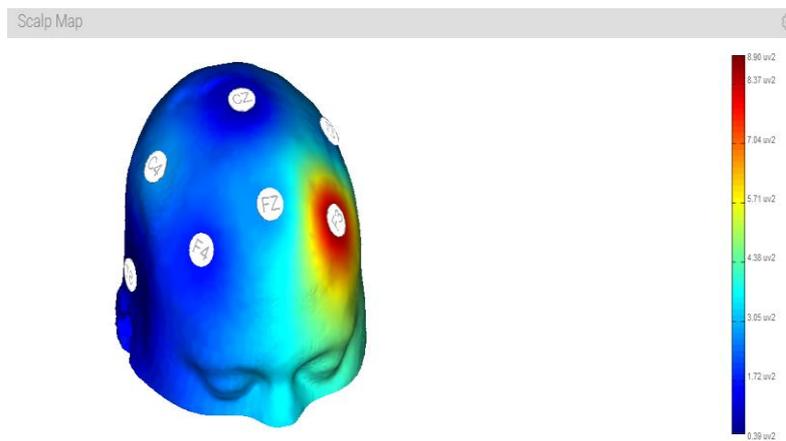

Figure 10: Scalp Map for ENOBIO-8
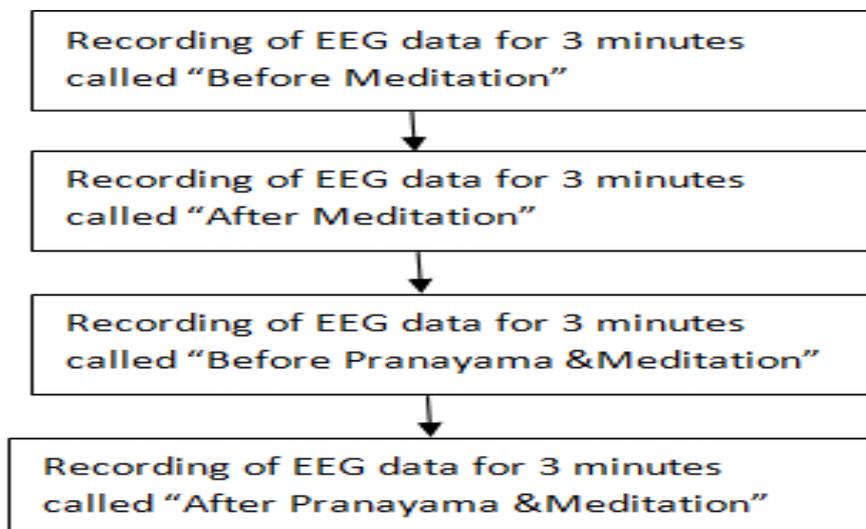
Figure 11: Flowchart for data acquisition protocol

Figure 12: Easy file format

Figure 13: Block Diagram of EEG signal analysis

Figure 14: Raw EEG Signal

Following are the features extracted both in timeas well as frequency domain.

TIME DOMAIN FEATURES		
1	Mean	
2	SD	
3	Var	
4	Min	
5	Max	
6	Skewness	
7	Median	

FREQUENCY DOMAIN FEATURES		
1	Power	

|		
		power of delta
2	Energy	energy of alpha energy of delta
3	Entropy	differential entropy of alpha differential entropy of delta
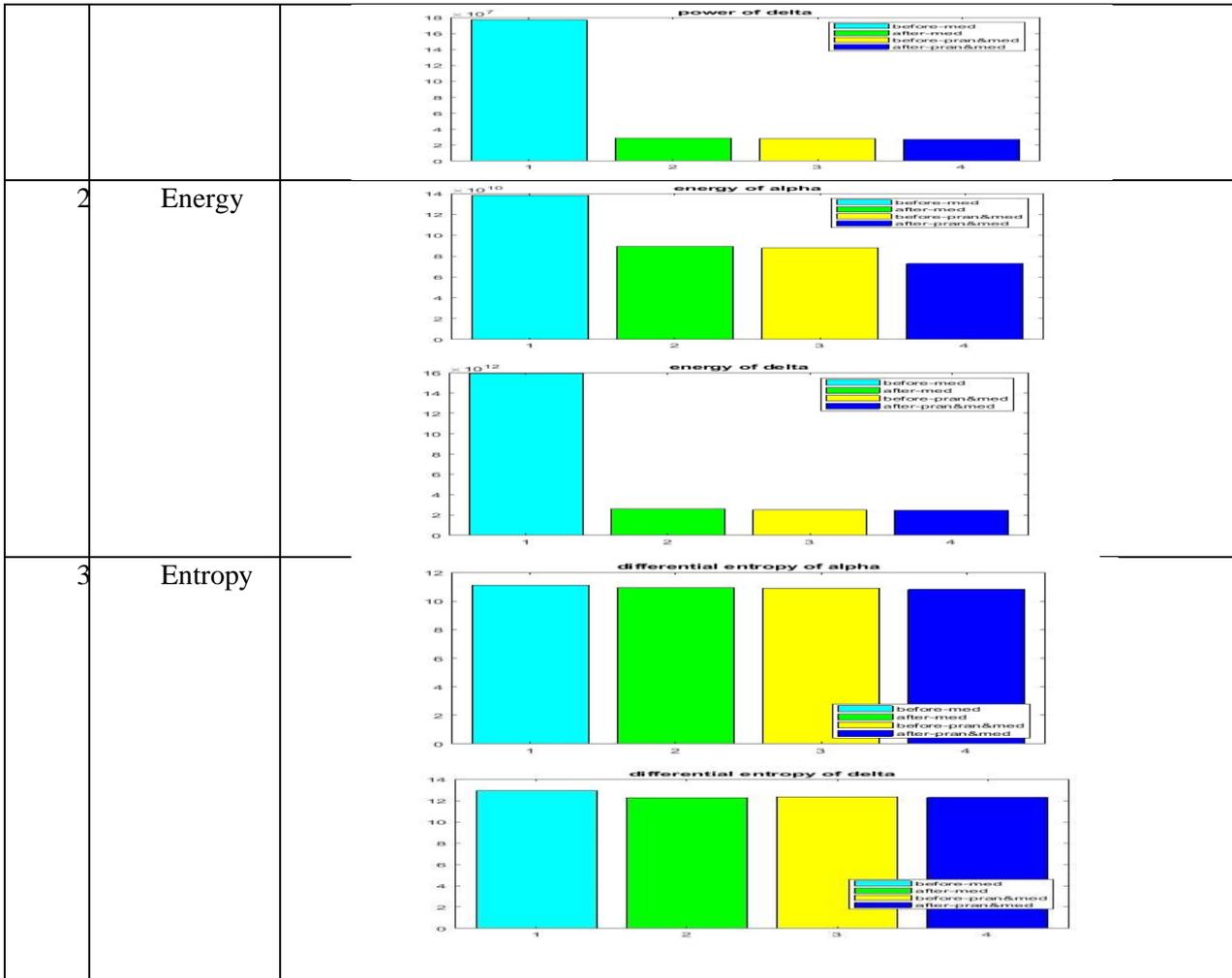
Table 1:Channel and its position

CHANNEL	POSITION
Channel 1	T7
Channel 2	C3
Channel 3	F3
Channel 4	Fz
Channel 5	Cz
Channel 6	F4
Channel 7	C4
Channel 8	T8

Table 2: Heart Rate and Blood Pressure recording session

SESSION NUMBER	SESSION STATE
1	BEFORE MEDITATION
2	AFTER MEDITATION
3	BEFORE PRANAYAMA
4	AFTER PRANAYAMA
5	AFTER PRANAYAMA AND MEDITATION

5 . CONCLUSION

It is clearly evident from the relative bar plot that "Pranayama with mediation" will bring more benefit emotionally, physically as well as controlling the devices based on BCI. Finally, we can infer that practices like meditation initiates various benefits to overcome stress. Also, the distinct statistical measurable factors indicate different signatures, and it can be put to practical use for enhancing the pattern categorizing ofthe EEG signals for various cognitive actions.

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