Computational Analysis of Brainwaves for Mind Relaxation during Meditation- A Survey

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***ABSTRACT*-- In the last few decades or so, various neuro imaging modalities have been used to answer questions regarding mind relaxation and anxiety states, ranging from EEG, fMRI, PET and others. Meditation as a mind relaxing technique is widely perceived to have potent, specific effects on both the body and mind. The researchers have traced the various spectral characteristics of EEG recorded during meditation. The changes of EEGs during meditation is analyzed by using various signal processing techniques. Also the statistical parameters are compared and results obtained. Lot of research is going on towards the same direction**
Some of very reputed Research institutes are involved in this field like S.Vyas University, Bangluru, Indian Institute of Technology (IITs), Institute of Neurosciences, Frontiers in Human Neuroscience, All India Institute of medical sciences, etc. This paper is an attempt to study the various method used by researchers, scientists and doctors to study the positive effects of meditation.

KEYWORDS*-- *Meditation, Signal processing, Electroencephalography, Wavelet transform, phase synchrony

I. INTRODUCTION

In the today's world, life has become very challenging and fast, where we are highly demanded with the difficult needs of our everyday life that requires more attention and efforts. Such daily needs eventually lead us to stress if not handled properly. These negatives effects if go undiagnosed, can be fatal. Some of the most recent studies to come out in the last few years show that meditation really does produce measurable changes in our most important organ "BRAIN".

With the stressed condition of mind there is Loss of prefrontal regulation in the brain. Under this condition brain react more from primitive part of brain and Perception is Narrowed, Memory is Imprecise and Learning is Blocked.

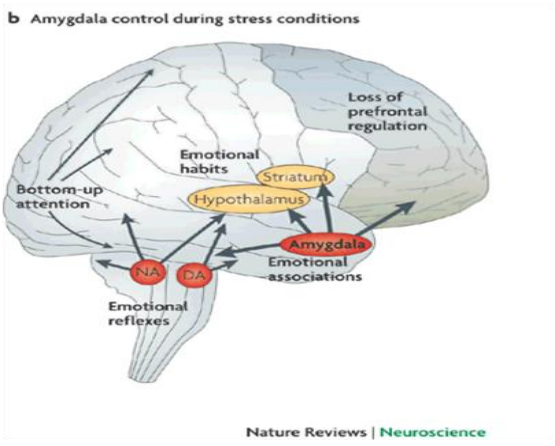

Fig 1: Brain in stress condition

On the other hand when the brain is in relaxed state, Prefrontal cortex is more active and leads to improvement in emotion regulation, self-regulation and responses.

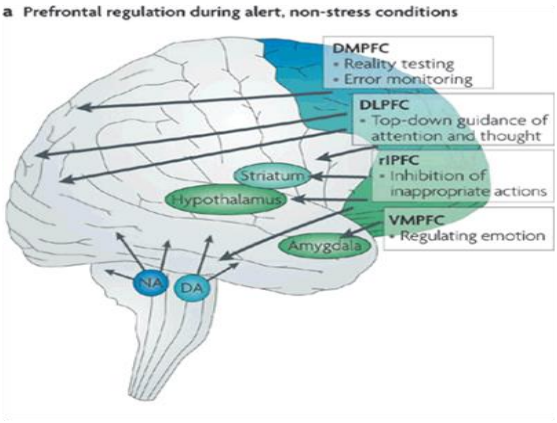

Fig 2: Brain in Relaxed condition

Meditation can be used to treat patients with neural disorders like depression, epilepsy, autism and insomnia. When a doctor is treating a patient by giving certain medicines, the treatment is from outside. In meditation a person is cured from inside his body. The results will thus be better and stable.

Meditation plays a significant role in treatment of various physical and mental disorders. Meditation helps relieve the subjective levels of stess, anxiety and depression, and improve attention, concentration, and overall psychological well-being.

II. LITERATURE REVIEW

Earlier, a lot of work has been done using different advanced signal processing techniques to study and analyze the brainwave changes. The findings have reported that increase in theta and alpha band power and decrease in overall frequency results in reduction of stress and mind relaxation with meditation.

In the various papers, the authors have analyzed the specific statistical features of EEG data collected during meditation and normal conditions. They have analyzed the changes of EEGs during meditation quantitatively. The authors have also studied the effect of meditation on stress relief and disease improvement. It was concluded that meditation gives direct access to hidden power and forces the mind to act differently to gain strength reducing pain and stress.

Some authors have investigated the EEG signal after meditation using Phase Synchrony (PS) estimation method. The result of both Phase Locking Value (PLV) and Improved Phase Locking Value (IPLV) has been shown and analyzed. Various tools have been used in various papers to study the effect of relaxing techniques on the mind. The aim of these studies is to assess and provide a comprehensive review of the benefits of meditation.

Some authors have analyzed brain signals while solving math problems. These findings provide evidence for replicable longitudinal changes in brain oscillatory activity during meditation and increase our understanding of the cortical processes engaged during meditation. The authors have analyzed the Electroencephalographic (EEG) peak alpha frequency (PAF). It has been correlated to compare the cognitive performance between healthy and clinical individuals. They concluded that PAF also varies within individuals across developmental stages, among different cognitive tasks, and among physiological states induced by administration of various substances.

III. SIGNAL ACQUISITION

EEG signals are highly random in nature and may contain useful information about the brain state. It is well known that the brain is an electrochemical organ; electrical activity emanating from the brain is displayed in the form of brainwaves. There are four categories of these brainwaves, ranging from

the most activity to the least activity. When the brain is aroused and actively engaged in mental activities, it generates beta waves. These beta waves are of relatively low amplitude, and are the fastest of the four different brainwaves. The next brainwave category is alpha. Alpha brainwaves are slower and higher in amplitude. The next state, theta brainwaves, is typically of even greater amplitude and slower frequency. The final brainwave state is delta. Here the brainwaves are of the greatest amplitude and slowest frequency.

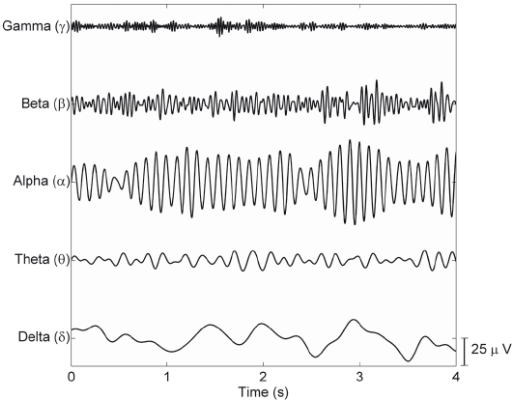

Fig 4: Basic EEG waves

However, it is not possible to get certain information from brainwave signals directly in the time domain just by observing them. They are basically non-linear and non-stationary in nature.

Significant features can be extracted for the analysis using advanced signal processing techniques.

EEG is the most used signal acquisition method for analyzing brainwaves because of the high temporal resolution, safety, and ease of use. In clinical contexts, EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 30 minutes, as recorded from multiple electrodes placed on the scalp.

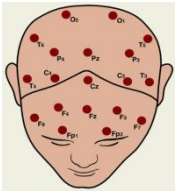

Fig 5: Electrode positions at Scalp

The EEG reveals not what is thought, but shows the context in which thinking occurs---state of arousal, state of vigilance and alertness, etc. A predominant feature of the EEG is rhythmic activity, or periodicity. These rhythms are very complex in nature generated by various cortical, sub-cortical, and cortico-subcortical dynamics.

In relation with the EEG signals, a lot of work has been done to find the significant changes after meditation by using different advanced signal processing techniques. Some of the changes in brainwaves which have been observed during meditation are:

- Higher intensity of neurophysiological processes in alpha, theta, delta, and gamma frequencies.
- Lower global synchronization than in depression, schizofrenia, epilepsy, etc.
- High speed of information propagation.
- High efficiency of cognitive processes and enhanced perception of reality.
- Delta activity is connected with recognition of unconscious phenomena that serve as novel and appropriate solutions to creative problems.
- The increased theta activity fosters the ability of encoding of new information.

IV. EEG SIGNAL PRE-PROCESSING

A typical EEG tracing is a rapidly changing composite or combination of different frequencies—waves moving up and down at different rates—some slow, some fast. During ordinary waking consciousness, EEG patterns are complex, scattered and disorderly.

Fig 6: Typical EEG Tracings

As a first step in EEG pre processing there is usually used a suitable filtering technique. High pass filters are used for low frequency removal (for f < 0.1Hz, such as baseline shift), low pass filters remove high frequency noise like EMG activity (f > 30Hz). Often removal of 50Hz noise from power supply is performed.

EEG signal are most of the times contaminated by certain artefacts. The artefacts are eye blinks, eye movements, heart beats. In addition to these, muscular movements and power line interferences are also mingled with brain signals. Standard filters (FIR, IIR) can be used in this case, often advanced method like PCA and ICA are needed.

A. ICA

ICA separates the artefacts from the EEG signals into independent components based on the characteristics of the data. The ICA algorithm decomposes the multi-channel EEG data in to independent and spatial-fixed components. It is found to be computationally efficient.

B. CAR

This method removes the noise by subtracting the common activity from the basic position. The various referencing methods are used to improve the Signal-to-Noise Ratio (SNR). The presence of the artefacts yields lower SNR in EEG signals. In this method the removal of mean of all electrodes from all the electrodes results in noise free signals.

C. SL

An estimate of current density entering or leaving the scalp through the skull is referred to as the Surface Laplacian of the skull. Ocular eye movements can be efficiently eliminated during the signal acquisition using this method. For large artefacts ranging from 50μV (>50μV) visual inspection is also required and by taking into account shape of the artefacts the gradients of activities are obtained.

D. PCA

The PCA transforms the correlated vectors into linearly uncorrelated vectors. The uncorrelated vectors are called as “Principal Components”. It is a conventional method of Second Order Statistics. It depends on breakdown of covariance matrix. PCA helps in decrease of feature dimensions. Ranking is done by using PCA based on the variability of the signal properties. This ranking helps in classification of the data.

E. CSP

CSP can identify abnormal EEG activity. CSP performs conversion of EEG signal into a variance matrix that maximally discriminates between

dissimilar classes. CSP uses spatial filtering and with it detects the waveforms in EEG. During the training process the matching electrode positions is to be maintained to confine the signals.

F. Adaptive Filtering

Adaptive filters have the ability to alter signal properties according to the precise characteristics of the signals. If the signal and noise are overlapping then filters can remove the original signal. This setback can be overcome by using the adaptive filters. Various algorithms are used and it has been proved.

PCA is mathematically defined as an orthogonal linear transformation that transforms the data to a new coordinate system such that the greatest variance by some projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on.

Experimental results demonstrate that the performance and robustness of PCA are the best among all these methods, which implies that PCA is the most suitable method for EEG data pre-processing.

V. FEATURE EXTRACTION

After pre-processing of EEG signal, information needed for classification (features) has to be extracted. Due to harmonic nature of EEG signal, frequency domain analysis is more adequate. Maybe the most used are Fourier transform (FT), short time FT (STFT) and Wavelet Transform. Inter-electrode information coupling is often measured by coherence.

The first step was using filters to extract Alpha, Gamma, Beta, Delta and Theta waves.

The characteristics of these Brainwaves are:

DELTA	< 4 Hz	Deep sleep, pathological when in an alert state
THETA	4 - 8 Hz	creativity, falling asleep, pathological in adults when in an alert state, normal in kids
ALPHA	8 - 13 Hz	normal in an alert state with open and closed eyes, relaxation
BETA	13 - 30 Hz	normal in an alert state with open eyes, concentration, logic – analytical thinking, unrest,
GAMA	> 30 Hz	extreme concentration, deep meditation

Table 1: Brainwaves characteristics

In the next step, essential features from the brain signals were extracted. For feature extraction from EEG signals various methods were used.

A. ICA

ICA can also be utilized as a feature extraction method. ICA analyzes the components that are free from each other's influence. From the components required features can be extracted using ICA. It helps in finding the independent signals.

B. PCA

PCA is also a pre-processing technique and also a feature extraction method. It is a powerful tool for element reduction of data without loss of important data. Using PCA the information present at all the time series multi channel is extracted as principal components. The principal components PCA therefore reduces the dimensions of signals.

C. WT

Wavelet Transformation is specifically used for feature extraction. It is a method to perform the feature withdrawal with the B-Spline parameters. This function can act as low pass filter as well as high pass filter and with these filtering characteristics. By using multi resolution analysis filter coefficients can be obtained.

D. AR

AR method is used for feature extraction in time domain analysis. It uses shorter duration of data records and it yields better frequency resolution and reduces the spectral loss problems. It is the most frequently used method for un-stationary signals in which parameters are supplied to the model. The difficulty is in establishing the parameter model property. It achieves a classification accuracy of 83%.

E. WPD

WPD can extract features in both time and frequency domain with the coefficients mean of WT. In this method, the coefficients with higher separability were considered effective and formed as final vector. It divides the original signal into subspaces based on frequency. Wavelet packet tree shows the decomposition of low frequency wavelets. The conclusions by various authors show that WPD yields better performance results and it is superior to all other methods. It shows good performance in the extraction process of non-stationary signals like EEG.

F. FT

FT was identified by Joseph Fourier in 19th century. It extracts the signal quality by converting the signals from time domain to frequency domain. It works well for stationary signals and, linear random processes. It cannot measure both the time and frequency. This frequency based analysis is named as Discrete Fourier Transformation (DFT).

Wavelet Transform is concluded to be the best method for the time-frequency analysis of EEG signals as it gives the required frequency information together with the time occurrence at which it occurs.

Generally, the wavelet transform can be expressed by the following equation:

$$F(a,b) = \int_{-\infty}^{\infty} f(x)\, \psi^*_{(a,b)}(x)\, \mathrm{d}x$$

where the * is the complex conjugate symbol and function ψ is some function chosen arbitrarily.

Wavelet analysis provides more precise information about signal data than other signal analysis techniques.

VI. RESULTS

The EEG signal before and after meditation is analyzed and results are obtained by various authors. It is proved that meditation training can enhance attention and improve emotion regulation. Subjects responded positively to mediation as evident from the increases in power in alpha, beta, and gamma bands as well as increase in alpha and beta coherence during meditation.

In case of Mediators the thoughts levels during meditation were found to be more reduced. It was proved by comparing the Histograms of alpha1, alpha2 and delta bands.

There is a domination of alpha band activation especially in prefrontal corte**x** of brain during meditation. It was concluded that the meditative signal shows enhanced phase synchrony in the alpha frequency which may improve functional

integration.

ESD provides information on distribution of energy of an energy signal per unit bandwidth as a function of frequency. The unit of ESD is Joules/Hz.

$$E_x = \int_{-\infty}^{\infty} |X(f)|^2 df$$

The ESD Alpha of no of electrodes were averaged. The same process was done for electrodes on the right hemisphere. These values represent Left Frontal ESD and Right Frontal ESD respectively.

The Frontal ESD Alpha Asymmetry is obtained from the formula:

$$\text{Frontal ESD Alpha Asymmetry} = \text{natural log}(ESD_{Right}) - \text{natural log}(ESD_{Left})$$

It was proved that Frontal alpha asymmetry level decreased during listening to the noise session and increased after meditation.

VII. REFERENCES

I] Laxmi Shaw, Aurobinda Routray, **Statistical features extraction for multivariate pattern analysis in meditation EEG using PCA** Published in:2016 IEEE EMBS International Student Conference (ISC) Date of Conference:29-31 May 2016 Page(s):1 - 4 DOI:10.1109/EMBSISC.2016.7508624

2] Norliza Zaini et al **Semantic-based Bayesian Network to determine correlation between binaural-beats features and entrainment effects** Published in: Computer Applications and Industrial Electronics (ICCAIE), 2011 IEEE International Conference on Date of Conference: 4-7 Dec. 2011 Page(s):574 – 579PrintSBN:978-1-4577-2058-1 DOI:10.1109/ ICCAIE.2011. 6162200

3] Seah Jia-Wei, Chin Siew Wen **A study on non-invasive brainwave optimization** Published in: Software Intelligence Technologies and Applications & International Conference on Frontiers of Internet of Things 2014, International Conference Date of Conference:4-6 Dec. 2014 Page(s):27 - 32 Print ISBN:978-1-84919-970-4DOI:10.1049/cp.2014.1530 Publisher: IET

4] Ale Procházka et al **Multi-channel EEG signal segmentation and feature extraction** Published in: 2010 IEEE 14th International Conference on Intelligent Engineering Systems Date of Conference:5-7 May 2010 Page(s):317 - 320 ISSN :1543-9259 Print ISBN:978-1-4244-7650-3 DOI:10.1109/INES.2010.5483824

5] Hüseyin Acar et al **The classification of alertness level from EEG signals by using TMS320C6713 DSK and MATLAB** Published in:2010 IEEE 18th Signal Processing and Communications Applications Conference Date of Conference: 22-24 April 2010

6] Prajakta Fulpatil, Yugandhara Meshram **Review on Analysis of EEG Signals with the Effect of Meditation** Int. Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 6(Version 6), June 2014, pp.51-53

7] Laxmi Shaw, and Aurobinda Routray, **A Measure of Phase Locking of Cortico-cortical Brain Rhythms in Meditation EEG** ISBN 978-93-84422-71-4 Proceedings of 2016 International Conference on Image Processing, Production and Computer Science (ICIPCS'2016) London (UK), March 26-27, 2016 pp.70-77

9] Yugandhara Meshram, Prajakta Fulpatil **Review Paper on Electroencephalographic Evaluation of Sudarshan Kriya** International Journal of Science and Research (IJSR) ISSN (Online): 2319-7064 Impact Factor (2012): 3.358 Volume 3 Issue 7, July 2014 www.ijsr.net

10] M. Rajya Lakshmi et al **Survey on EEG Signal Processing Methods** Volume 4, Issue 1, January 2014 ISSN: 2277 128X International Journal of Advanced Research in Computer Science and Software Engineering www.ijarcsse.com

11] Bhavna P Harne **Higuchi Fractal Dimension Analysis of EEG Signal before and after OM Chanting to Observe Overall Effect on Brain** International Journal of Electrical and Computer Engineering (IJECE) Vol. 4, No. 4, August 2014, pp. 585~592ISSN:2088-8708http://iaesjournal.com/online/ index.php / IJECE

12] Roshni D. Tale, Bhavana P.Harne **REVIEW: Previous Deception detection methods and New proposed method using independent component analysis of EEG signals** Journal of Engineering Research and Applications www.ijera.com ISSN : 2248-9622, Vol. 4, Issue 12(Part 6), December 2014, pp.178-182

13] Hussain AlHassan and Dr. Navarun Gupta **Brain Signals Analysis during Meditation and Problem Solving** ASEE Southeast Section Conference American Society for Engineering Education 2015

14] Vijayalakshmi et al **Quantitative Analysis Of EEG Signal Before And After Sudharshana Kriya Yoga** International Journal Of Public Mental Health And Neurosciences ISSN: 2394-4668 (Published jointly by Azyme Biosciences (P) Ltd., Sarvasumana Association and Subharati Niriksha Foundation) © IJPMN, Volume 2, Issue 2, August -2015

15] Saggar, M., et al., **Intensive training induces longitudinal changes in meditation state-related EEG oscillatory activity** Published online 2012 Sep 10. doi: 10.3389/fnhum.2012.00256 PMCID: PMC3437523 Frontiers in Human Neuroscience

16] Saggar, M., et al., **Mean-field thalamocortical modeling of longitudinal EEG acquired during intensive meditation training**,NeuroImage (2015),http://dx.doi.org/10.1016/ j.neuroimage. 2015.03.073

17] Subha, D.P., Joseph, P.K., Acharya U, R. et al. **EEG Signal Analysis: A Survey** J Med Syst (2010) 34: 195. doi:10.1007/s10916-008-9231-z

18] Efthymios Angelakisa,et al, **Peak alpha frequency: an electroencephalographic measure of cognitive preparedness** Published in Clinical Neurophysiology 115 (2004) 887–897,www.elsevier.com/locate/clinph

19] Atefeh Goshvarpour et al **Classification of Electroencephalographic Changes in Meditation and Rest: using Correlation Dimension and Wavelet Coefficients** published in I.J. Information Technology and Computer Science, 2012

20] Asieh Ahani et al **Change in physiological signals during mindfulness meditation** published in Neural Engineering (NER), 2013 6th International IEEE/EMBS Conference.

21] Vyšata, O et al **Non-Linear EEG Measures in Meditation.** J. Biomedical Science and Engineering, 7, 731-738.http://dx.doi.org/10.4236 /jbise.2014.79072

22] Sapana M Adhalli, H Umadevi et **Design and Simulation of EEG Signals Analysis - A Case Study**

23] Chee-Keong Alfred Lim and Wai Chong Chia **Analysis of Single-Electrode EEG Rhythms Using MATLAB to Elicit Correlation with Cognitive Stress** Published in International Journal of Computer Theory and Engineering, Vol. 7, No. 2, April 2015 DOI: 10.7763/IJCTE.2015.V7.947

24] Kaur et al. **Analysis of EEG Signals using EEGLAB** International Journal of Advanced Research in Computer Science and Software Engineering, Volume 5, Issue 6, June 2015 ISSN: 2277 128X pp. 999-1002,www.ijarcsse.com

25] Christos I. Salis et al **Denoising Simulated EEG Signals: A Comparative Study of EMD, Wavelet Transform and Kalman Filter** Published in: Bioinformatics and Bioengineering (BIBE), 2013 IEEE 13th International Conference **Electronic ISBN:** 978-1-4799-3163-7 **INSPEC Accession Number:** 14026437 **DOI:** 10.1109/BIBE.2013.6701613

26] Norhazman H. et al **The Effect Of Alpha Binaural Beat On Frontal Esd Alpha Asymmetry On Different Gender** www.arpnjournals.com ,VOL.11, NO. 7, APRIL 2016, ISSN 1819-6608 , ARPN Journal of Engineering and Applied Sciences

27] Priyanka Jain, Pradeep Kumar Govindaiah **Removal Of Artifacts And Analysis Of EEG Signal Using Data Driven Parameters**, Proceedings of IEEE TechSym 2014 Satellite Conference, VIT University