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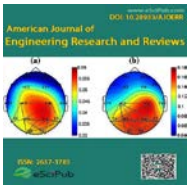

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COMPARATIVE ANALYSIS OF CONTROLLED HEALTHY AND MCI PATIENTS USING EEG STATISTICS

PARAG PURANIK[1], SANTOSH AGRAHARI[2], ASHISH PANAT[3]

[1]Research Scholar, Department of Electrical and Electronics Engineering, Poornima University, Jaipur; [2]Associate Professor, Department of Electrical and Electronics Engineering, Poornima University, Jaipur; [3]Dean, Innovation and Incubation, SNDT Women's University, Mumbai

ABSTRACT

This paper describes the statistical analysis of EEG signals. EEG examination is carried out and compared between controlled healthy and Mild cognitive impairment (MCI) patients which may further develop dementia or Alzheimer disease. The statistical techniques provide the comparative analysis of EEG signal. The correct evaluation of EEG provides the extraction of valuable information which is important clinically. Also, extracting significant features from EEG is an important task for classification between various patients. The analysis of EEG data provides correct frequency rhythms. The relative Power spectral density values by Auto Regressive-Burg process cleared that; associated with the control group, the relative PSD is improved in the theta rhythmic range while expressively reduced in the alpha-2 rhythmic range.

Keywords: EEG analysis, Mild cogbitive impairment (MCI), EEG statistics, Power spectral Density (PSD), coherence analysis

***Correspondence to Author:**
SANTOSH AGRAHARI
Associate Professor, Department of Electrical and Electronics Engineering, Poornima University, Jaipur

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INTRODUCTION

The correct evaluation of EEG provides the extraction of valuable information which is important clinically. Also, extracting significant features from EEG is an important task for classification between various patients. The standard analysis is to be used for proper automation and artifact free of EEG data. Since EEG is random signal its statistical analysis will provide correct information regarding patients, disease etc.

EEG statistical analysis is carried out using 16 channel RMS EEG machine. For EEG analysis technique, three set of judgements were suggested (Alzheimer Disease (AD) vs. controlled healthy, Mild Cognitive Impairment (MCI) vs. controlled healthy and MCI vs. AD) for the four EEG rhythms (alpha, delta, beta and theta) and for all sixteen channel electrodes. Hence, the entire amount of assessments were **192**. QEEG analysis techniques is used to perform specifically for controlled healthy and MCI. [1][2]

The set of digital filters were used to differentiate EEG power and rhythms for analyzing the EEG indication into particular alpha, delta, theta and beta frequency ranges. These investigations produced the average regular power evaluations for each of the rhythms, at each of the 16-electrodes channel sites (16- channel bipolar montage) for individual member. EEG data for the controlled healthy, MCI and established AD groups were examined by executing preplanned assessments of normal power for respective channel within a given frequency band. A typical two-tailed t-test is to be used later to control statistical implication.[7][16].

The EEG data gathered and processed at NIMHANS, Bangalore and Shantiniketan Hospital, Nagpur for EEG analysis in which 30 patients were considered.

- The EEG recorded for first 10 minutes as a start and relaxing state.
- The ANGEL gaming test was performed and EEG was recorded for 45 minutes.
- The 30 minutes EEG noted during meditation.
- The chanting of mantra was conducted and then the EEG recorded for next 15 minutes
- Lastly relaxing for 10 minutes EEG recorded.

The total time of EEG recording was nearly 1.30 hrs.

Total 30 Subjects were studied for analysis in above steps. According to the medical analysis, Mini mental state examination (MMSE) was conducted for the subjects with the help of the doctor and score below 14 was treated as MCI positive. The MCI level also can be categorized into low, moderate and high. During EEG analysis, subjects were asked to chant the mantra i.e. OM and Gayatri mantra. First OM chanting was considered. During EEG analysis when ‘OM’ was chanted that time duration was noted, this is called event related potential (ERP). [5][8]

During chanting whether ‘OM’ was chanted properly or not, also correct time duration of ‘OM’ is noted or not and lastly what changes are noted during mantra chanting is to be investigated and therefore statistical analysis is carried out.

The EEG of patients, especially students of colleges are taken for the analysis purpose. ERPs are voltage fluctuations along the scalp time-locked to a few physical or rational activities in the ongoing electrical mind activity recorded as electroencephalogram (EEG). ERPs are complicated waveforms with exceedingly correlated additives in time like short bursts of synchronized cortical activities. [14].The contemporary version of the ‘ERP’ package deal implements the adaptive issue-adjustment (AFA) technique (Sheu, Perthame, Lee, & Causeur, 2016) and a generalized useful likelihood ratio test developed in Causeur, Sheu, Perthame, & Rufini (submitted) for detecting and figuring out ERP indicators.

I. METHODOLOGY

In this topic, the procedure for calculating the PSD of EEG data is explained. Also, the sample size required for the analysis, EEG recording method is discussed and finally the results are elaborated.

The block diagram of the MCI patients before and after chanting of mantras is shown in figure.1. In this technique, a procedure to calculate PSD and relative PSD is explained.

In figure.1 EEG signals are extracted for all 30 patients. Depending upon the EEG characteristics of EEG the patients are classified as MCI and Controlled healthy with the help of the doctor. Then EEG preprocessing is performed. In EEG pre-processing specific duration EEG signals are extracted with the help of windowing techniques and low pass filtering. The correct information is extracted for further processing. The relative power spectral density and coherence analysis (t-test) is performed after EEG pre-processing. ANOVA analysis is carried out to differentiate between various patients for different EEG frequencies, by performing mantra chanting ('OM'). EEG is verified before and after chanting of mantras for all patients by extracting relative power spectral density and combining PSDs of all patients. [9]

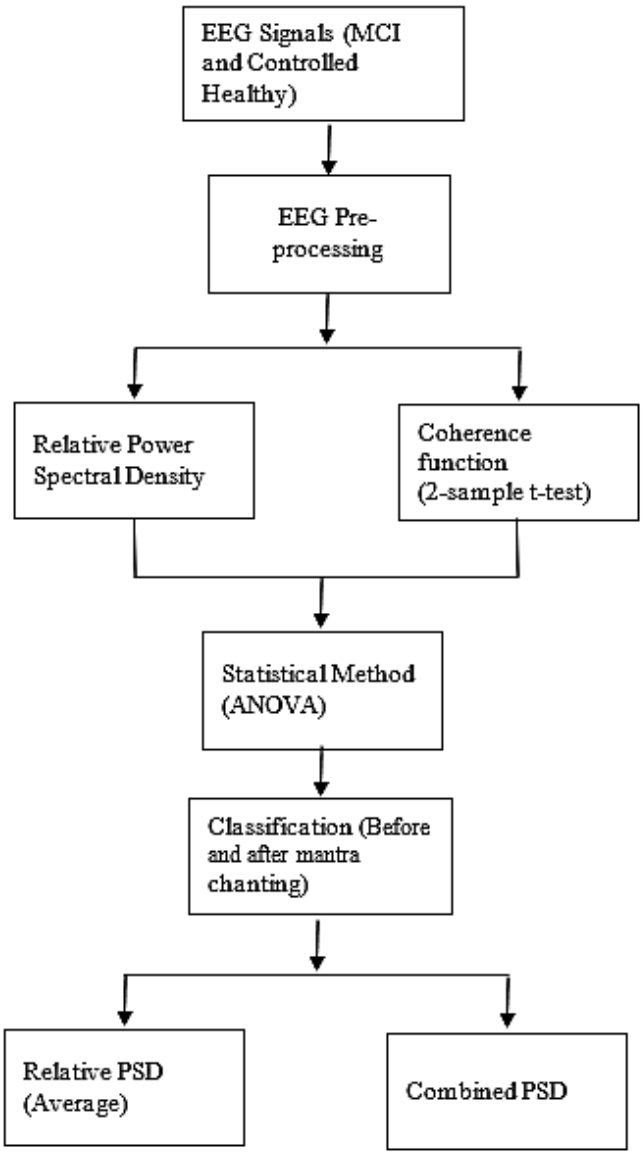


Figure.1 - Block Illustration of Organization of MCI patient-group before and after chanting mantras

A. Calculation of Power Spectral Density (PSD)

The PSD (power spectrum density) estimation is performed. The electrodes namely, AF3, AF4, CP1, C3, Fp1, F3, F4, F7, FC1, FC5, FC6, F8, T7, CP5, P3, P7, PO4, Pz, P4, P8, PO3, O1, O2, Oz, C4, CP2, CP6, T8, FC2, Fp2, Fz and Cz channels are used for PSD estimation.

A linear phase FIR bandpass bypass clear filter of 1–35 Hz band is functional on EEG information to keep away from baseline itinerant and direct current (DC) bias and excessive frequency noise. The 2 artifact elimination techniques have been finished on the records. A modest top and inferior voltage thresholding became used to evade high voltages length and flat channel results (two hundred μV as top certain and 2μV as decrease sure). Second, independent component analysis is used for casting off eye blink and eye measure artefacts. Subsequently, the wiped clean EEG was similarly decimated to 64 Hertz. It has cleared from EEG/EMG waves that contribution to gamma rhythms recorded from head/ scalp electrodes, have omitted gamma activity in the processing. The initial rare samples had been rejected from the information to sidestep filter out transient effect on signal. PSD is predicted at extraordinary electrode places (average of electrode channels at frontal, crucial, occipital, parietal, left and right temporal regions) and for exceptional frequency band (theta range (3-7)Hz, alpha-1&2 [8-12)Hz and beta-1&2[13-30)Hz).This spectral evaluation achieved on statistics recorded during the chanting and post sittings.

Due to limited size of the EEG statistics, possible PSD is assessed using Auto Regressive Burg's method (non-parametric method). Moreover, a sliding window Hamming technique is taken with a duration of 256 sampling frequency and overlay of 128-256 sampling issues to enhance the spectral values. Firstly, evaluation of the constraints of the version-primarily based approach from a facts series x(n), 0 < n < N - 1. Next step is to compute the PSD envisioned from those estimations.

PSD evaluation is a non-parametric approach used to compute strength of EEG spectrum which is a frequency function i.e. EEG is proportional to brain frequencies, whilst preserving the constancy among flattening in time and frequency decision. PSD is envisioned the usage of the Bartlett technique, in which the periodograms are averaged for smooth PSD ensuing in better time and frequency decision. This is executed by way of separating the statistics series into non-overlapping orders by a Blackman and Harris window and adding the ensuing PSD calculated from Fourier Transform coefficients. x(n) is the signal, EEG statistics, separated into successive orders $x_k[n]$; k =1,.. K, each with duration 'N' and w(n) be the windowing feature.

The AR technique is created on demonstrating the data order x(n) because causal and discrete filter output is generated where the contribution is white Gaussian noise, that is voiced as given:

$$x(n) = -\sum_{k=1}^{p} a(k).x(n-k) + \omega(n)$$

Where a(k) is A-R coefficients, $\omega(n)$ is white-noise whose variance is identical to standard deviation and p is the order of the Auto Regressive model.

With the help of A-R constraints by Burg algorithm, PSD is assessed as:

$$\hat{P}_{BURG}(f) = \frac{\widehat{e_p}}{\left|1 + \sum_{k=1}^{p} \hat{a}p(k)e^{-j2\pi fk}\right|}$$

e_p is the least square error; p=16

The relative PSD for all frequency bands is calculated as follows:

$$P_{Relative} = \frac{\sum_{f=f1}^{f2} Pi(f)}{\sum_{f=fl}^{fh} Pi(f)}$$

where [fL, fH] = [0.5, 40]and [f1, f2] is calculated by the occurrence of all-range selection.

B. Coherence Assessment

Coherence signifies the standardized co-variance of period sequence inside the frequency range area. Precisely,

$$C_{xy}(f) = \frac{\left|\langle P_{xy}(f)\rangle\right|}{\sqrt{P_{xx}(f)} * \sqrt{P_{yy}(f)}}$$

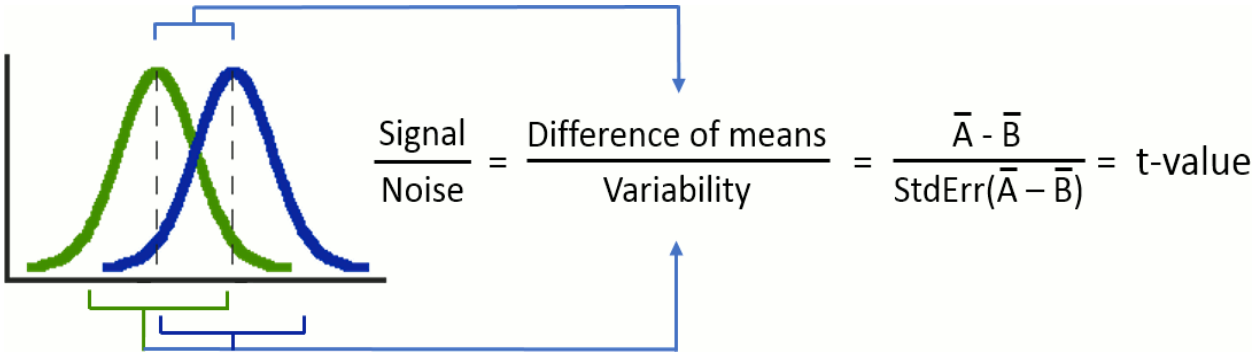
Pxy (f) is the cross-power spectrum of EEG signal of specified duration.

C. Statistical analysis

The EEG is recorded using standard 10-20 system with 16 electrodes. The EEG is recorded before and after chanting of OM for MCI and controlled healthy group. When 'OM' is chanted that particular frequency is noted for all electrodes. The EEG has deviated or not that is to be verified from all electrodes and therefore statistical analysis is carried out.

The PSD is calculated using AR-Burg's technique for all 16 electrodes before and after mantra chanting for MCI and controlled healthy group. When 'OM' is chanted the event potential is created at each electrode. The power spectral density is calculated at that instance. The relative PSD becomes bulky for long duration of EEG signal and for the said two groups. Therefore, statistical analysis is used.

The Student's t-test is a broadly accepted parametric assessment to assess the variation among the average of two arbitrary variables, or amongst the average of one variable and one identified value (1-sample test). If the norms are accurate, the t-statistic surveys a Student's t-distribution.



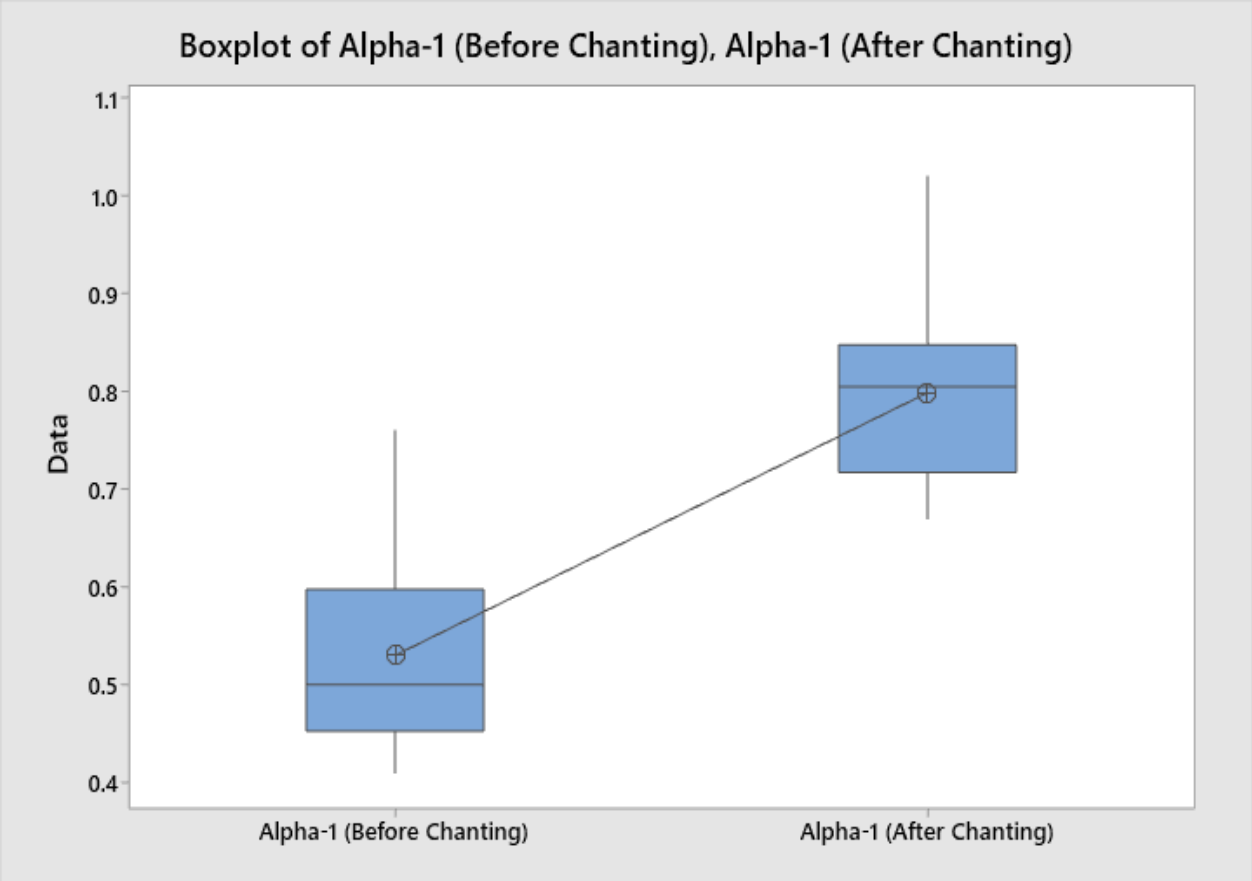
The standard 2-pair t-test is used for the comparison of various frequency ranges of EEG where mean value of alpha ranges is computed: (alpha is taken for explanation) is shown in figure 2.

1-way ANOVA examination is used for analyzing the average values of all electrodes for all 30 subjects. It has one independent variable i.e. PSD values before and after mantra chanting and one dependent variable i.e. electrodes (for both MCI and controlled group). ANOVA gives the details of following statistical parameters such as degree of freedom, sum of squares and mean square (MS=SS/ df) and p-value. The 'p' and 'f'-value provides the high significance to group difference. The following table 1 shows the mean values of all electrodes for different frequency ranges

Results

EEG comprises precise frequency ranges. Features in sub-ranges are specifically essential to depict distinctive brain situations. The sub-bands are: delta (0.4-4 Hz), theta (4.5–7 Hz), alpha-1 (7.5–10.5 Hz), alpha-2(10.5–12.5 Hz), beta (13.0–30.5 Hz) and gamma (31.0–40.5 Hz). The PSD relative value can be received by means of separating the PSD of every frequency rhythm by means of the whole spectral power density of the all occurrence range predicted by using the Auto regressive - Burg technique.

μ_1: mean of Alpha-1 (Before Chanting)
μ_2: mean of Alpha-1 (After Chanting)
Difference: μ_1 - μ_2



Identical variances not expected for this study

Valuation for Difference

Difference	95% CI for Difference
-0.2689	(-0.3406, -0.1973)

Test

Null hypothesis	H_0: μ_1 - μ_2 = 0
Alternative hypothesis	H_1: μ_1 - μ_2 ≠ 0

T-Value	DF	P-Value
-0.14	27	0.890

Figure 2. – T-test details on Alpha-1 frequency

TABLE I. MEAN VALUES OF ALL ELECTRODES FOR ALL EEG FREQUENCY BANDS

Factor	N	Mean	St. Dev	95% CI
Delta (before chanting)	16	0.4300	0.1060	(0.3811, 0.4789)
Delta (After Chanting)	16	0.4289	0.0918	(0.3800, 0.4778)
Theta (before chanting)	16	0.5200	0.1060	(0.4711, 0.5689)
Theta (After Chanting)	16	0.5289	0.0918	(0.4800, 0.5778)
Alpha-1 (Before Chanting)	16	0.5300	0.1060	(0.4811, 0.5789)
Alpha-1 (After Chanting)	16	0.7989	0.0918	(0.7500, 0.8478)
Alpha-2 (Before chanting)	16	0.7500	0.1060	(0.7011, 0.7989)
Alpha-2 (After Chanting)	16	0.8289	0.0918	(0.7800, 0.8778)
Beta-1 (Before Chanting)	16	0.7500	0.1060	(0.7011, 0.7989)
Beta-1 (After Chanting)	16	0.5300	0.1060	(0.4811, 0.5789)
Gamma (Before Chanting)	16	0.7989	0.0918	(0.7500, 0.8478)
Gamma (After Chanting)	16	0.4289	0.0918	(0.3800, 0.4778)

For both groups MCI and controlled healthy, the relative PSD is reduced with rise in the frequency. Before chanting of ‘OM’ PSD range is in [0.25 0.7] and in gamma band relative PSD is in the range [0.0045 0.025]. The observation are as follows:

1. In delta and alpha-1 band, relative PSD variations are not there in some electrodes while in some electrodes F8, FP1 and FP2, delta frequency variations are seen and in electrodes O1, O2, P4 and C4 alpha-2 frequency variations are observed.
2. The relative PSD values before and after chanting for MCI group patients were much on higher side than controlled healthy after mantra chanting in the theta frequency band.
3. In higher frequency bands, the PSD standards of MCI cluster are lesser than that of controlled healthy in parietal, temporal and occipital range.

To calculate the overall PSD, before and after chanting, the averaged PSD values of all electrodes are to be observed. The ANOVA analysis for MCI patients before and after chanting of ‘OM’ is shown for different frequency ranges of EEG.

Delta Frequency

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05
Rows unused	2

Equal variances were assumed for the analysis.

Means

Factor	N	Mean	StDev	95% CI
Delta (before chanting)	16	0.4313	0.1061	(0.3806, 0.4819)
Delta (After Chanting)	16	0.4289	0.0918	(0.3783, 0.4796)

Pooled StDev = 0.0991971

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.000043	0.000043	0.632	0.948
Error	30	0.295202	0.009840		
Total	31	0.295245			

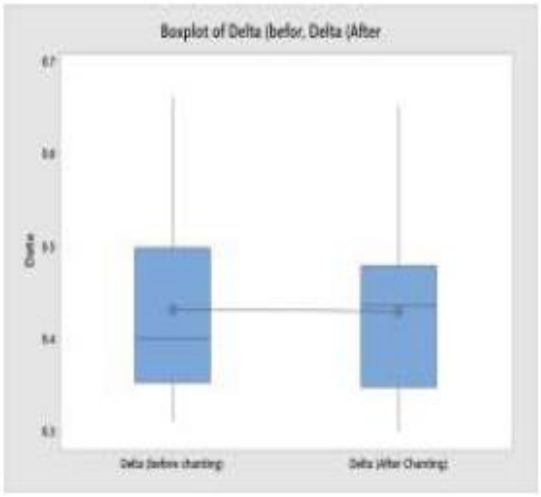


Figure 3. – Delta Frequency Statistics

Theta frequency

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05
Rows unused	2

Equal variances were assumed for the analysis.

Means

Factor	N	Mean	StDev	95% CI
Theta (before chanting)	16	0.2658	0.0438	(0.2459, 0.2857)
Theta (After Chanting)	16	0.14675	0.03360	(0.12682, 0.16668)

Pooled StDev = 0.0390382

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.11341	0.113407	74.41	1.23e-004
Error	30	0.04572	0.001524		
Total	31	0.15913			

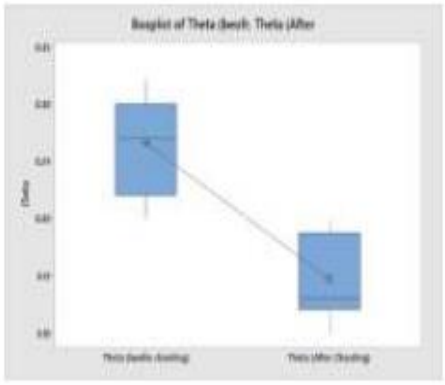


Figure 4. - Theta Frequency Statistics

Alpha-1 frequency

Method

Null hypothesis	All means are equal
Alternative hypothesis	Not all means are equal
Significance level	α = 0.05
Rows unused	2

Equal variances were assumed for the analysis.

Means

Factor	N	Mean	StDev	95% CI
Alpha-1 (Before Chanting)	16	0.09225	0.03445	(0.07677, 0.10773)
Alpha-1 (After Chanting)	16	0.09375	0.02553	(0.07827, 0.10923)

Pooled StDev = 0.0303172

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Factor	1	0.000018	0.000018	0.02	0.890
Error	30	0.027574	0.000919		
Total	31	0.027592			

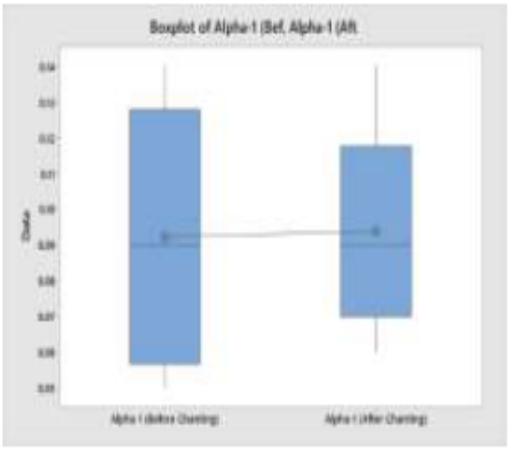


Figure 5. – Alpha-1 Frequency Statistics

In such a way, ANOVA analysis is done for all frequency bands and relative PSD is calculated for MCI group before mantra chanting and after mantra chanting. The summary of 'F'value and P-value is shown in the table below Table II

TABLE II. : ANOVA RESULTS FOR RELATIVE PSD OF SIX FREQUENCY RANGES OF MCI GROUP BEFORE AND AFTER CHANTING OF MANTRAS

EEG Rhythms	F-value	P-value
Delta	0.632	0.948
Theta	74.41	1.23e-004
Alpha-1	0.02	0.890
Alpha-2	37.73	1.002e-007
Beta	17.04	2.003e-005
Gamma	22.27	0.0321

After statistical corrections and calculations, it is revealed that the relative PSD value in theta and delta range is enlarged and is reduced in case of other frequency bands.

Coherence results

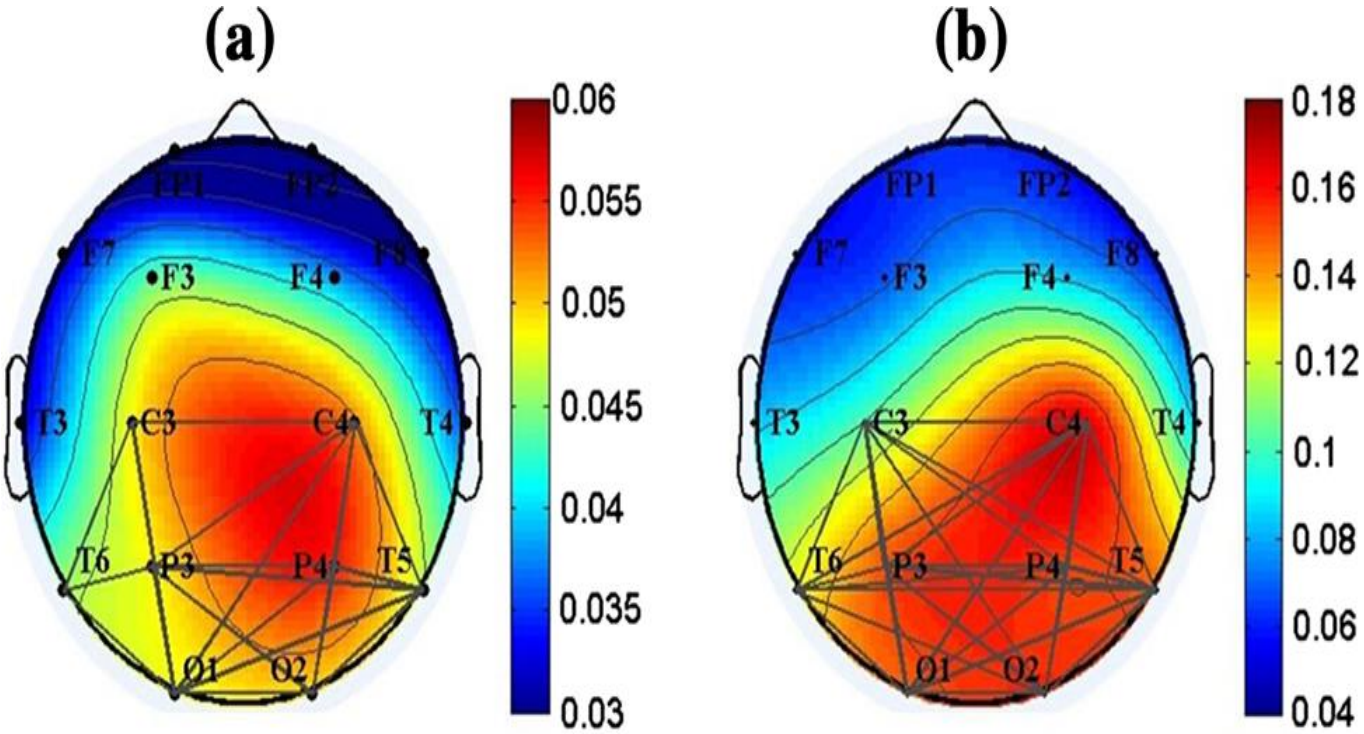


Figure. 6: Topographic charts of the R-PSD in the alpha-2 rhythmic range for (a) MCI patients before chanting (b) MCI patient after chanting. Temporarily, the coherence values nearby useful influences built are exposed among the channels/ electrodes with high PSD values (relative) in crimson coloration: P3, P4, C3, C4, O1, O2, T5, and T6. A part in gray is occurred when the coherence value is more than 0.34

Figure.6 confirmed the topographic diagram of the R- PSD in the alpha-2 rhythmic range for MCI organization before and after mantra chanting. Temporarily, the practical connections based totally on coherence (grey hyperlinks in Fig. 6) have been inspected among the channels with excessive relative PSD values in purple colour: P3, P4, C3, C4, T5, T6, O1, and O2. It was located that, for both type of patients: CT and MCI, the channel with excessive PSD standards had extra neighbourhood practical influences. Furthermore, it is recommended that, for MCI patients, the nearby practical connections in parieto-occipital regions have been tons scarcer than that of the controlled cluster, representing that the high level, inclusive of data transmission and interactions, had been decreased significantly.

DISCUSSION

The review on MCI group of trials showed the mass posterior lethargic incidence rhythms of EEG reducing the alpha rhythm and beta rhythm behavior while the occipital measure of the beta and alpha range in the CT (Healthy) group is increasing. The outcomes demonstrated the allocation of theta and delta power investigation or slow rational portion for both CT and the MCI patient group. A decline of delta frequency at the sub-frontal parts for the typical and mid areas is linked to the cognitive rebuff at the hippocampo part. Examination of EEG showed notable statistical changes of reducing the EEG movement of the MCI/AD-group. There is a improvement in theta and delta rhythms at the left temporal and posterior section of the brain

(electrode-T6 and T5) and pre-frontal part (F8, F7) of the brain amid the MCI over the normal aging set and rise in frequency-beta rhythm, over the chronological parts among AD-MCI group. Also, a notable decrease in alpha range is obtained at the posterior and vital region (C4, Cz, C3).

The remark on MCI group exposed the prevalence posterior, reducing the alpha and beta frequency rhythm actions while the occipital pastime of the alpha and beta range is growing with the age. The results showed a prevalence circulation of theta and delta power or sluggish rhythms for each CT and the MCI.

C**ONCLUSION**

The EEG statistics clearly differentiates between the patients i.e. controlled healthy and MCI. The coherence value depicts the changes in the alpha-1, alpha-2, delta and theta range. The delta rhythm is decreased on the pre-front areas for the regular and crucial areas which is probably connected to the cognitive weakening on the hippo-campal (occipital) place. Investigation found out statistically full-size slowing in EEG activity of the MCI category patients. Precisely, delta and theta frequency rhythms are increased at the left temporal and parietal locality (T5, T6) and prefrontal part (F8, F7) a number of the MCI over the healthful organization and boom in Both beta (β-1 and β-2) rhythms compared to the progressive (temporal) ranges between MCI category (before and after chanting of mantras). Besides, huge decrease in alpha rhythmic frequency on the valuable area (C4,C3,Cz) and at latter region takes place. The relative PSD valued by AR-Burg method cleared that; associated with the control group, the Relative Power Spectral Density is improved in the theta rhythmic range though expressively reduced in the alpha-2 rhythmic range. Also, coherence examination is functional to obtain the dissimilar electrodes in the alpha-2 range of frequency.

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AUTHORS PROFILE

Parag Puranik Research Scholar, Department of ECE, Poornima University, Jaipur, IEEE Member and Technical program committee member IEEE Signal Processing Society, Pursuing Research in EEG signal Processing, one copyright published. Completed M.Tech in Electronics Engineering from Nagpur University in 2009, has 15 years of teaching experience. The research interest includes signal Processing, biomedical (EEG) signal processing and statistical analysis.

Dr. Santosh Kumar Agrahari works as an Associate Professor, Department of Electronics & Communication Engineering, Poornima University. He has published more than 25 research papers in International Journals and Conferences. Currently he is supervising 6 candidates for their Ph.D. He has more than 17 years of experience in research and teaching and also one-year industry experience.

Dr. Ashish Panat, Director, Innovations, Incubation & Research, SNDT Women;s University, Mumbai and formelry Professor and Head Electronics Engg., Technology and Innovations, Relations at MIT Art Design and Technology University, Pune, Maharashtra, India. He has 32 years of experience in research and teaching, His research areas include speech processing and intelligent systems.