IJITKM Volume 7 • Number 2 • Jan– June 2014 pp. 71-97 (ISSN 0973-4414)

Changes in Brain wave rhythms during tasks involving Attention and Working memory

Mandeep Singh [1], Mahak Narang [2]
Department of Electrical & Instrumentation Engineering, Thapar University, Patiala, INDIA
[1]mandy_tiet@yahoo.com, [2]mahnarang755@gmail.com

Abstract
Electroencephalography (EEG) records the electrical activity from the scalp of brain. Different parts of brain show different electrical rhythms during different mental activities this research paper reports the changes in alpha and beta power for attentional task and for working memory theta and alpha band power. It is found that during attentional task FP1 do not show good results but for F3 and F7, results are verified. Also, in some other channels like F4, F8, FP2 , O1 and O2, alpha power decreases. For beta power, results are verified for F8 and FP2 but not for F4 and during working memory task in all the frontal channels (FP1, FP2, F3, F4, F7, F8), results are verified, i.e., theta power increases. As well, the results are not verified for alpha power of O1 and O2, but alpha power of FP1 and FP2 increases.

1. Introduction

Human brain is one of the most complicated and fascinated organ. It consists of billions of neuron cells which get activated during different tasks being performed by it. An interesting research area is to identify the changes in brain wave rhythms during tasks involving attention and working memory. EEG data was acquired using Biopac MP150 system and the electrodes are placed in accordance with international 10-20 system [1]. In various studies it is suggested that alpha and beta waves of EEG are associated with attention [2] and theta wave is associated with working memory [3]. In the present research, a pilot study is done on healthy engineering students and the results for changes in topic reported by past researchers are verified.

1.1 Literature survey

Previous research work showed an alliance between the Alpha/Beta waves with the attention/relaxation state [4-5].The previous research studied Alpha and Beta bands during visual attention [5]. Previous research examined the beta band during visual attention.

Earlier research work showed that theta band is associated with working memory [6-8]. The previous research studied theta and beta band during working memory [3].

1.2 Problem definition

In this research, we conducted a pilot study to verify the changes on EEG rhythms during tasks involving attention and working memory on healthy engineering students.

1.3 Hypothesis

(i) For task involving attention alpha band decreases and beta band increases
(ii) For task involving working memory theta and alpha band increases

2. Proposed method

Any Cognitive enhancement technique involves application of suitable intervention. Pre and post cognitive assessment is made to confirm the cognitive enhancement achieved, if any. The protocol proposed for this research involves the following:

a) Selection of participants

A group of 6 participants participated in the study. All the participants shall be engineering students from undergraduate or postgraduate level. None of the participant shall have any psychological or neurological illness history. The subjects shall be informed about the purposes, methods, and protocol of the experiment before

starting experiment. All the participants shall voluntarily participate in the study. All experiments shall be conducted in the Laboratory of Thapar University.

b) Preparation of participants for EEG

Participants shall sit on a comfortable armchair in the front of monitor. They shall be explained about complete procedure, that is, hardware (EEG system), data acquisition, and all the tests to be carried out, as a result of which subject shall become familiar with the experiment. The scalp of subject shall be prepared by light abrasion to remove dead cells.

c) Baseline data acquisition

For attentional task baseline data shall be collected from the participants with their eyes closed, as the visuo-spatial attention reduces with closing eyes. For working memory task data shall be collected from participants with eyes open as baseline. Details of data acquisition are given in section Details of data acquisition are given in section 3.

d) EEG data shall be acquired while performing cognitive tasks

Go/No-go task shall be used for assessing attention and for assessing working memory D-span task shall be used. Details of both tasks are given in section 4.

e) Statistical Analysis of data

Analysis of data for shall be done using one tail paired type t-test and correlational studies shall be also made. Details of both are given in section5.

3. Data acquisition

EEG data was recorded using 11 electrodes (10 channels) placed in accordance with complete international 10-20 system with linked eye lobe reference electrode. Data was recorded at a sampling rate of 500 Hz using MP150 Biopac system. Out of these eleven electrodes one is ground electrode. Conductivity of electrodes with scalp is made using gel. Impedance of each electrode is compared with reference to ground of cap and is set up approximately below 10 KΩ. Electrodes from which data is recorded is darkened in figure 1

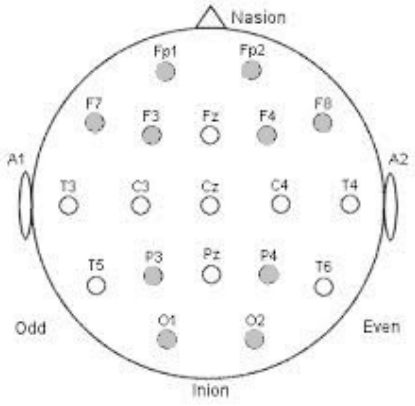

Figure1: Marked electrodes for recording

3.1 Signal conditioning and feature extraction

AcqKnowledge software is used for feature extraction. AcqKnowledge software not only makes data collection easier, but also performs analyses quickly and easily that are impossible on a chart recorder. There is inbuilt notch filter in MP150 which is used for signal conditioning. For feature extraction we computed power spectral density using AcqKnowledge software using hamming window. After that power of Alpha (8-13Hz) and Beta (13-30Hz) bands is extracted for attention and for working memory power of theta (4- 8 Hz) and alpha is extracted. Power is calculated from power spectral density using following formula.

$$power = \frac{\sum \frac{mv^2}{Hz}}{no\ of\ samples} \times frequency\ range$$

4.Tasks for assesment

For assessing attention and working memory standard cognitive assesment battery that is Psychology Experiment Building Language (PEBL) is used. In PEBL we can run as well as design computer-based experiments as it is a free cross-platform [9]. Following tasks are used

4.1 Go/no-go test

This test is used for assessing attention. In this test, subject will see a sequence of "P"s and "R"s on the screen. Whenever subject see a "P", react by pressing right shift key on the key board and don't react when see an "R".

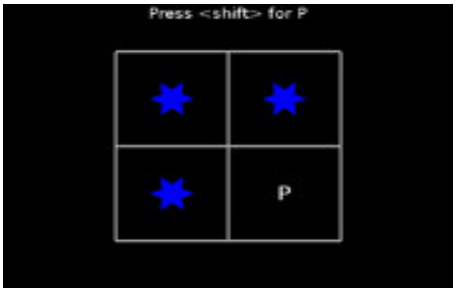

Figure 2: go/no-go test

4.2 D-span test

Digital Span (D-span) test is used for assessing working memory. In Digit Span, subject sees a sequence of digits existing in a box at the top of the screen and her task will be to keep in mind these numbers in sequence. After a brief period of time, the numbers will disappear and the subject will act in response by entering the digits.

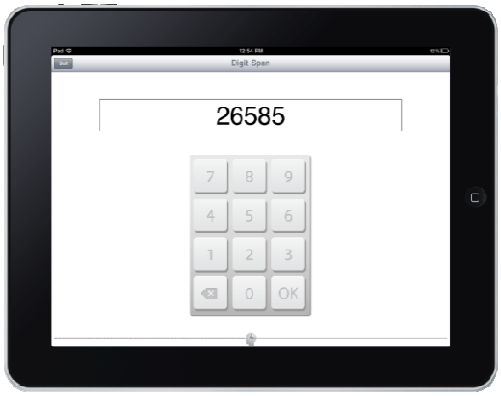

Figure3: d-span test

5. Data analysis

Statstically data is analyse using t-Test and correl.

5.1 t-Test

The t-Test is used to test the null hypothesis that the means of two populations are equal. For testing statistical significance of data either one tailed or two-tail test are computed. Depending on whether one trend is considered in extreme or both trends are considered equally likely one tail or two tail tests are considered respectively. t-Test can be type one, type two or type three depends on whether data is paired, homoscedastic or unequal respectively. It returns the value of probability associated with the t-Test i.e. "p" value.

5.2 Correl

Returns the correlation coefficient of the array1 and array2 cell ranges. Use the correlation coefficient to find out the connection between two properties. For example, you can study the connection between a location's average temperature and the use of air conditioners.

The correlation coefficient equation is:

$$Correl(X,Y) = \frac{\sum (x-\bar{x})(y-\bar{y})}{\sqrt{\sum (x-\bar{x})^2 \sum (y-\bar{y})^2}}$$

where

$\bar{x}$ and $\bar{y}$

are the samples mean AVERAGE of array1 and AVERAGE of array2.

6. Results and discussions

In this study results for attention and working memory are computed for both task oriented and physiologically assessment. For physiologically assessment EEG is taken and power of alpha (8-13 Hz) and beta (13-30 Hz) bands are computed for attention; and power of theta (4-8 Hz) and alpha (8-13 Hz) bands for working memory. In task oriented assessment computer based tasks like Go/No-go and D-span tests for attention and working memory respectively were performed and correlation between the task performance and physiological assessment derived.

6.1 Physiological assessment

1) Attention task

For attention task in particular channels alpha decreases and beta increases. Alpha in AF3 (fp1, f3) and F7 decreases and beta increases in F8 and AF4 (FP2, F4) [2].

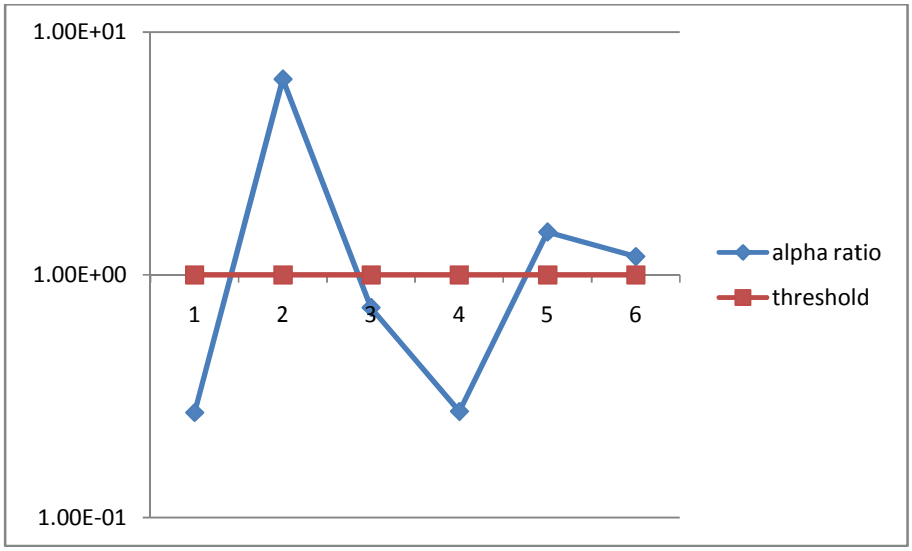

Figure4:Fp1 alpha (8-13 HZ) ratio during attentional task

From figure 4 it is inferred that in alpha band of FP1 no conclusion is drawn as expected, it may be due to some experimental errors. Results are also verified statistically using T-test. For Fp1 t-Test value is p=0.426346. Therefore nothing can be concluded from this pilot study.

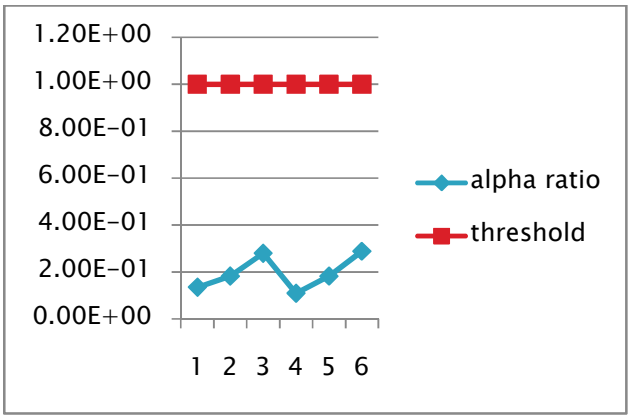

Figure5: F3 alpha (8-13 Hz) ratio attentional task

From figure 5 it is inferred that alpha band of F3 decreases in attentional task as expected. Results are also verified statistically using T-test. For F3 T-test value is p=0.002014. Therefore it is concluded from this pilot study that F3 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

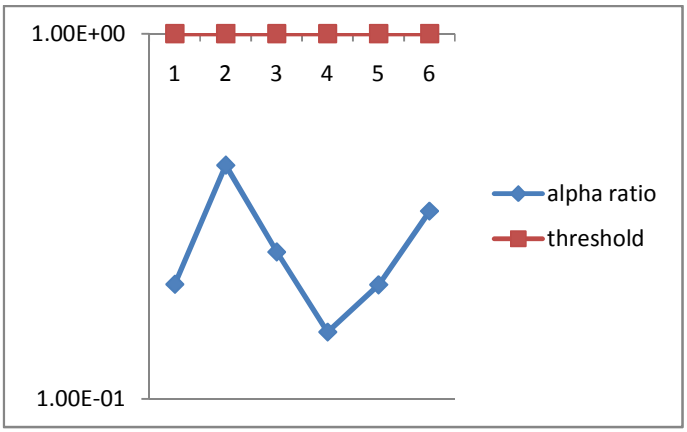

Figure6: F7 alpha (8-13 Hz) ratio attentional task

From figure 6 it is inferred that alpha band of F7 decreases in attentional task as expected. Results are also verified statistically using t-Test. For F7 t-Test value is p= 0.000423. Therefore it is concluded from this pilot study that F7 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

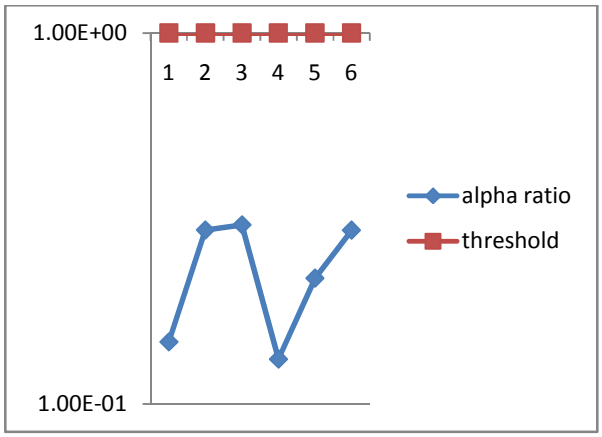

Figure 7: F4 alpha (8-13 Hz) attentional task

From figure 7it is inferred that alpha band of F4 decreases in attentional task, it is a new finding**.** Results are also verified statistically using t-Test. For F4 t-Test value is p = 0.002123. Therefore it is concluded from this pilot study that F4 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05.Though the numbers of subjects are less still the results are proven to be statistically significant.

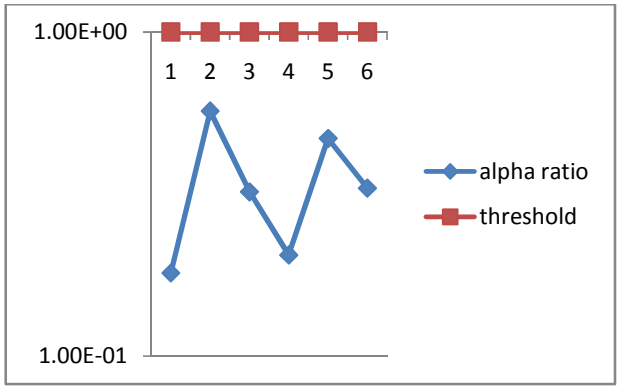

Figure 8: F8 alpha (8-13 Hz) ratio attentional task

From figure 8 it is inferred that alpha band of F8 decreases in attentional task, it is a new finding. Results are also verified statistically using t-Test. For F8 t-Test value is p = 0.001405. Therefore it is concluded from this pilot study that F8 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

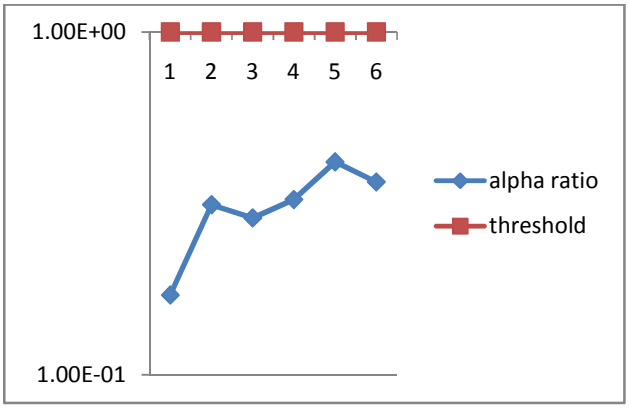

Figure 9: Fp2 alpha (8-13 Hz) ratio attentional task

From figure 9 it is inferred that alpha band of FP2 decreases in attentional task, it is a new finding**.** Results are also verified statistically using t-Test. For Fp2 t-Test value is p = 0.001744. Therefore it is concluded from this pilot study that Fp2 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

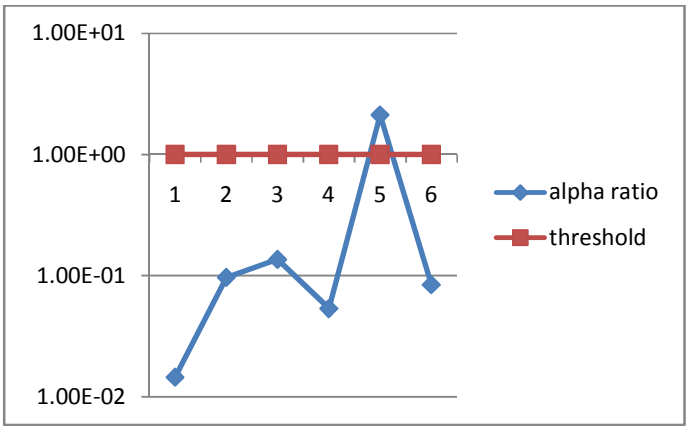

Figure10: O1 alpha (8-13 Hz) ratio attentional task

From figure 10 it is concluded that alpha band in O1 also decreases in attentional task and it is a new finding. Results are also verified statistically using t-Test. For O1 t-Test value is p = 0.005068. Therefore it is concluded from this pilot study that O1 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

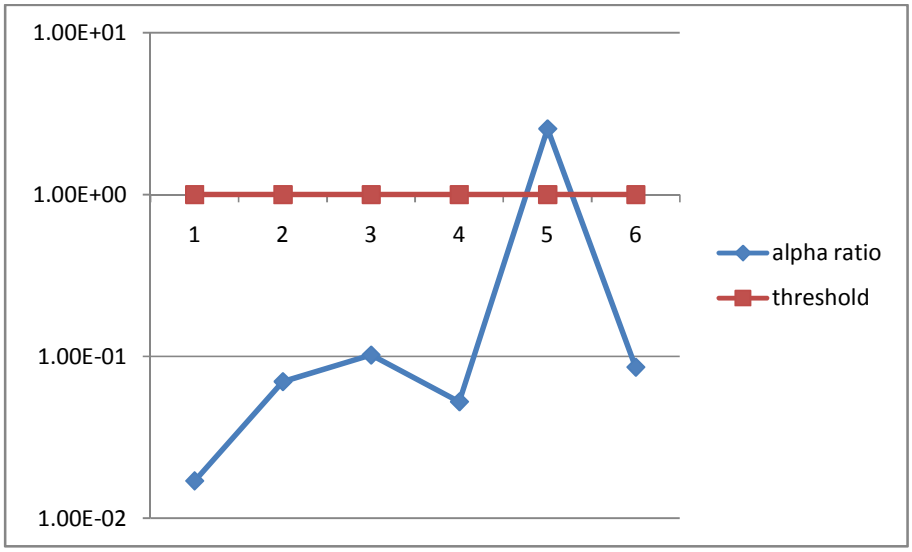

Figure 11: O2 alpha (8-13 Hz) ratio attentional task

From figure 11 it is inferred that alpha band in O2 decreases in attentional task and it is a new finding**.** Results are also verified statistically using t-Test. For O2 t-Test value is p = 0.008075.Therefore it is conclude from this pilot study that O2 decreases in attentional test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

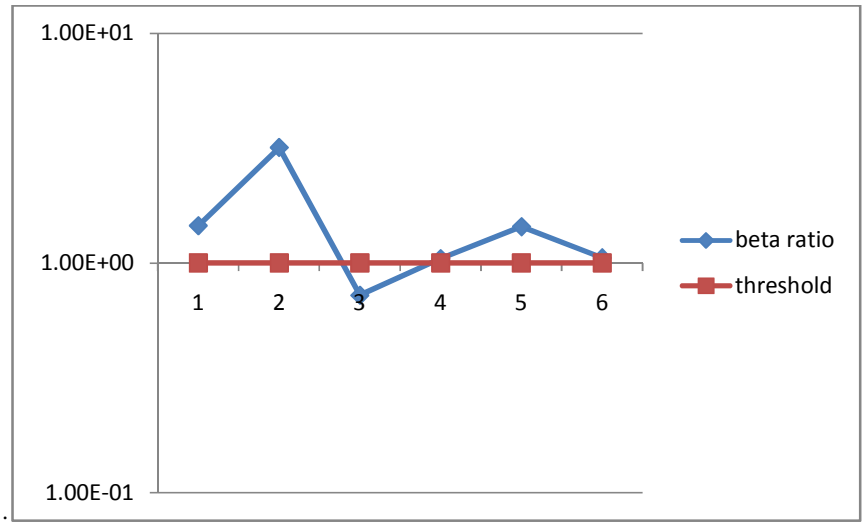

Figure 12: F8 Beta (13-30 Hz) ratio attentional task

From figure 12 it is inferred that Beta band in F8 does not represent good results (i.e. increase) as expected but acceptable in attentional task. Results are also verified statistically using t-Test. For F8 t-Test value is p = 0.146132.Therefore it is concluded from this pilot study that F8 increases in attentional test, which is evident from the figure.

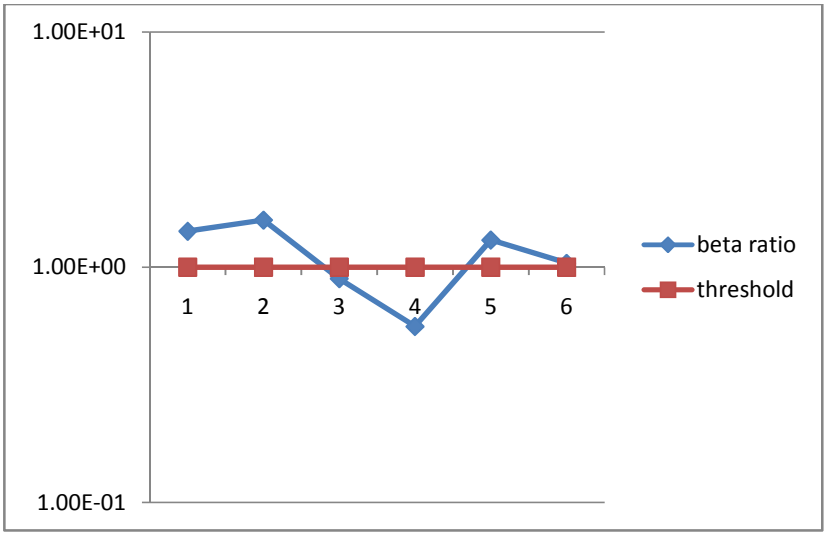

Figure 13: F4 Beta (13-30 Hz) ratio attentional task

From figure 13 it is inferred that in beta band in F4 no conclusion is drawn as expected, it may be due to some experimental errors. Results are also verified statistically using t-Test. For F4 t-Test value is p = 0.245644. Therefore nothing can be concluded from this pilot study as p value is not less than 0.05.

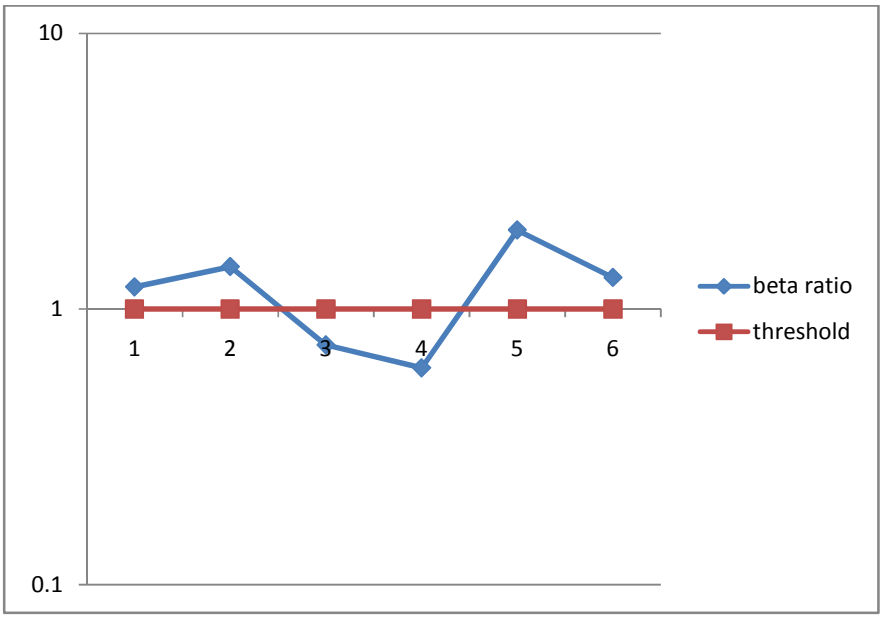

Figure 14 Fp2 Beta (13-30 Hz) ratio attentional tasks

From figure 14 it is inferred that beta band of Fp2 does not represent good results as expected (i.e. increase) but acceptable in attentional task**.** Results are also verified statistically using t-Test. For Fp2 t-Test value is p = 0.144092. Therefore it is concluded from this pilot study that Fp2 increases in attentional test, which is evident from the figure.

2) Working memory

For working memory in particular channels theta and alpha increases. Theta increase in frontal region (fz,f3,f4,fp1,fp2,f7 and f8) and alpha increase in posterior (Pz,Cz,O1,O2) and bilateral central areas (Fc5, T4, Fc8, T8)[3].

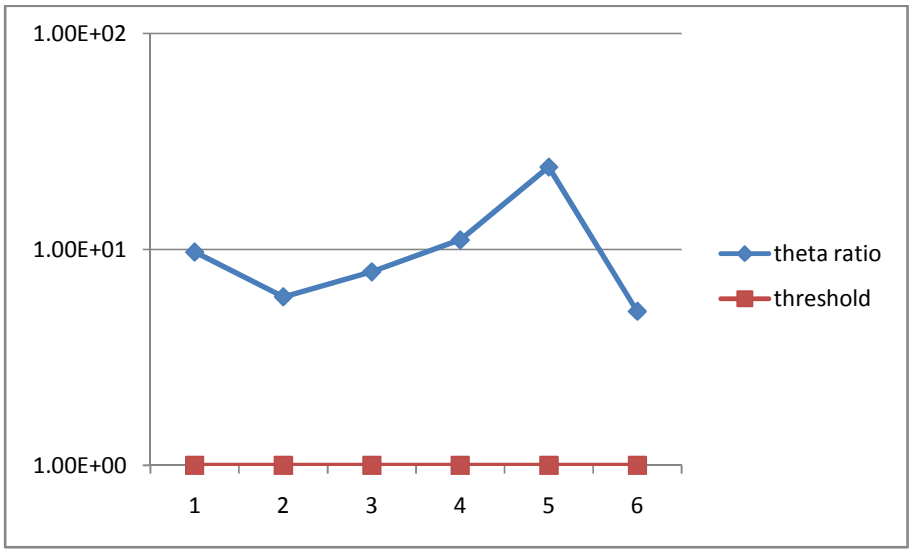

Figure 15: Fp1 Theta (4-8 Hz) ratio working memory task

From figure 15 it is inferred that theta band of Fp1 increases in working memory as expected. Results are also verified statistically using t-Test. For Fp1 t-Test value is p =0.007632 Therefore it is concluded from this pilot study that Fp1 increases in working memory test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

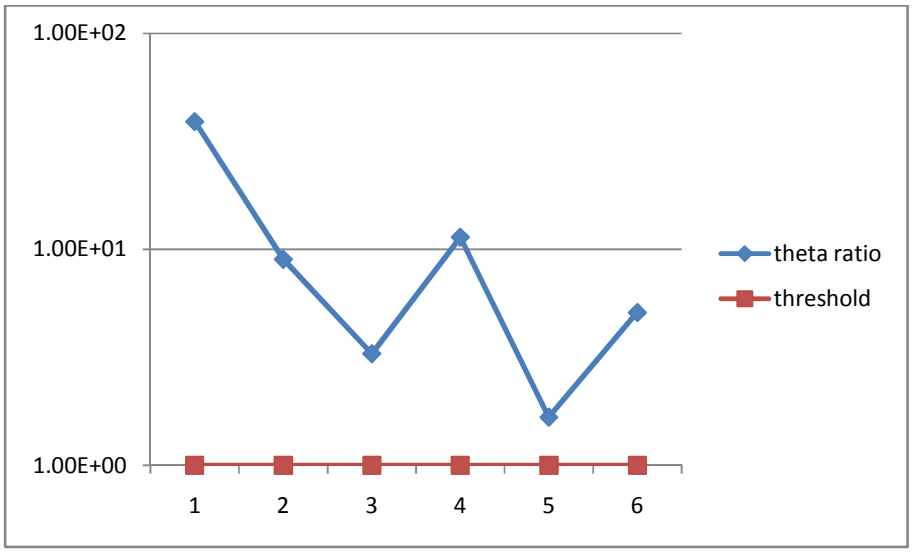

Figure 16: Fp2 Theta (4-8 Hz) ratio working memory task

From figure 16 it is inferred that theta band of Fp2 increases in working memory as expected. Results are also verified statistically using t-Test. For Fp2 t-Test value is p = 0.014948. Therefore it is concluded from this pilot study that Fp2 increases in working memory test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

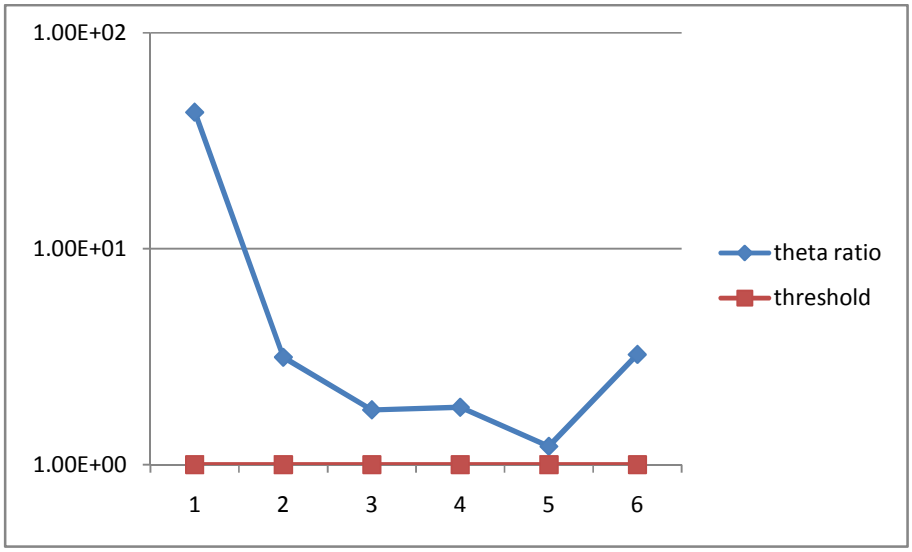

Figure 17: F3 Theta (4-8 Hz) ratio working memory task

From figure 17 it is inferred that theta band of F3 increases in working memory as expected. Results are also verified statistically using t-Test. For F3 t-Test value is p = 0.014948. Therefore it is concluded from this pilot study that Fp2 increases in working memory test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

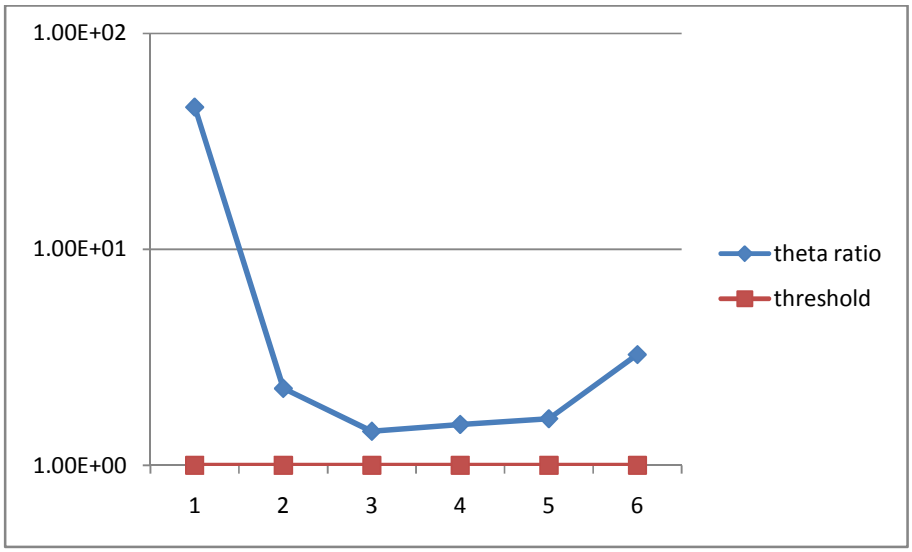

Figure 18: F4 Theta (4-8 Hz) working memory task

From figure 18 it is inferred that theta band of F4 increases in working memory as expected. Results are also verified statistically using t-Test. For F4 t-Test value is p = 0.080354. Therefore it is concluded from this pilot study that F4 increases in working memory test, which is evident from the figure. Moreover the p value is approximately equal to 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

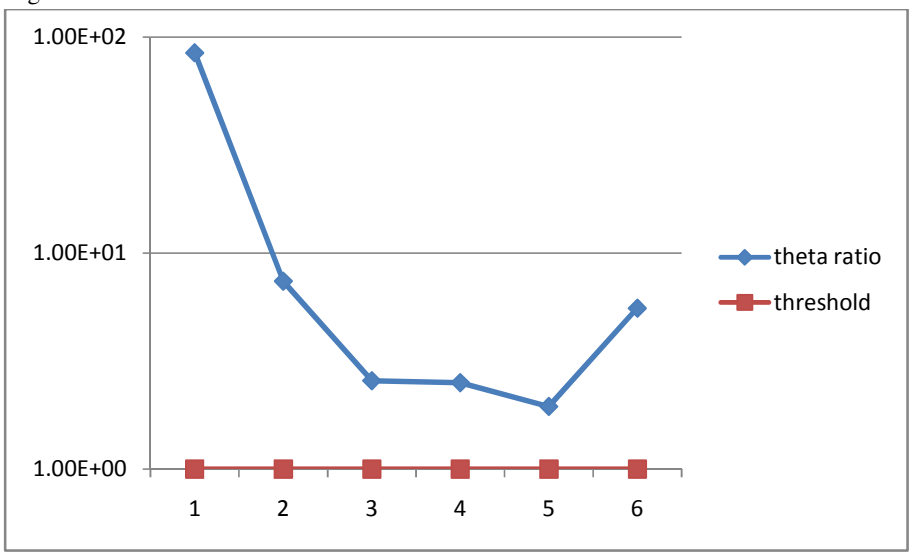

Figure 19: F7 Theta (4-8 Hz) ratio working memory task

From figure 19 it is inferred that theta band of F7 increases in working memory as expected. Results are also verified statistically using t-Test. For F7 t-Test value is p = 0.066967. Therefore it is concluded from this pilot study that F7 increases in working memory test, which is evident from the figure. Moreover the p value is approximately equal to 0.05.Though the numbers of subjects are less still the results are proven to be statistically significant.

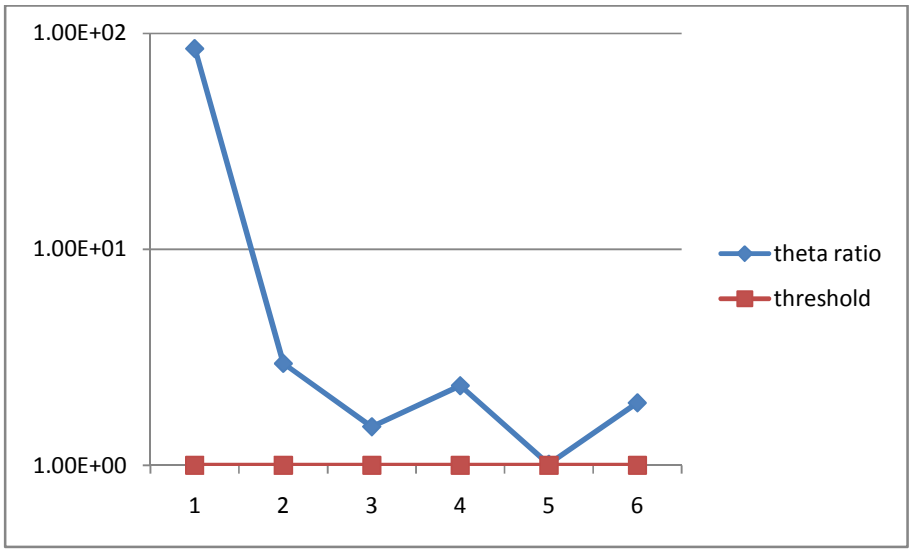

Figure 20: F8 Theta (4-8 Hz) ratio working memory task

From figure 20 it is inferred that theta band of F8 does not represent good results as expected (i.e. increase) but acceptable in working memory task**.** Results are also verified statistically using t-Test. For F7 t-Test value is p = 0.109599. Therefore it is concluded from this pilot study that F7 increases in attentional test, which is evident from the figure.

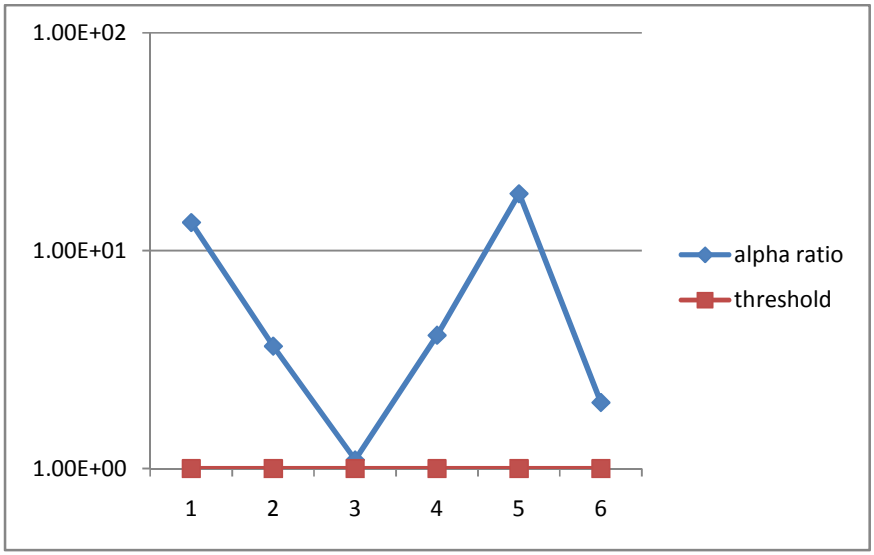

Figure 7.21: Fp1 alpha (8-13 Hz) ratio working memory task

From figure 7.21 it is inferred that alpha band of Fp1 increases in working memory as expected. Results are also verified statistically using t-Test. For Fp1 t-Test value is p =0.043337. Therefore it is concluded from this pilot study that Fp1 increases in working memory test, which is evident from the figure. Though the numbers of subjects are less still the results are proven to be statistically significant.

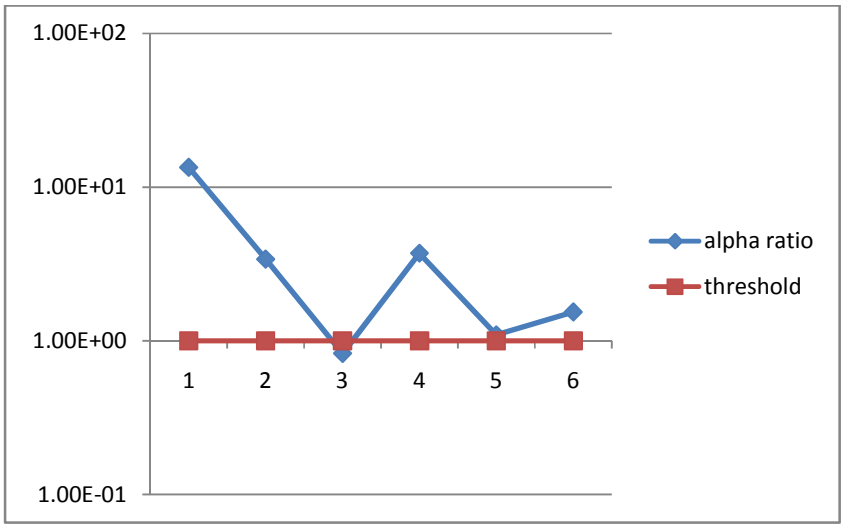

Figure 22: Fp2 alpha (8-13 Hz) ratio working memory task

From figure 22 it is inferred that alpha band of Fp2 increases in working memory as expected. Results are also verified statistically using t-Test. For Fp2 t-Test value is p =0.046564. Therefore it is concluded from this pilot study that Fp2 increases in working memory test, which is evident from the figure. Moreover the p value is less than 0.05. Though the numbers of subjects are less still the results are proven to be statistically significant.

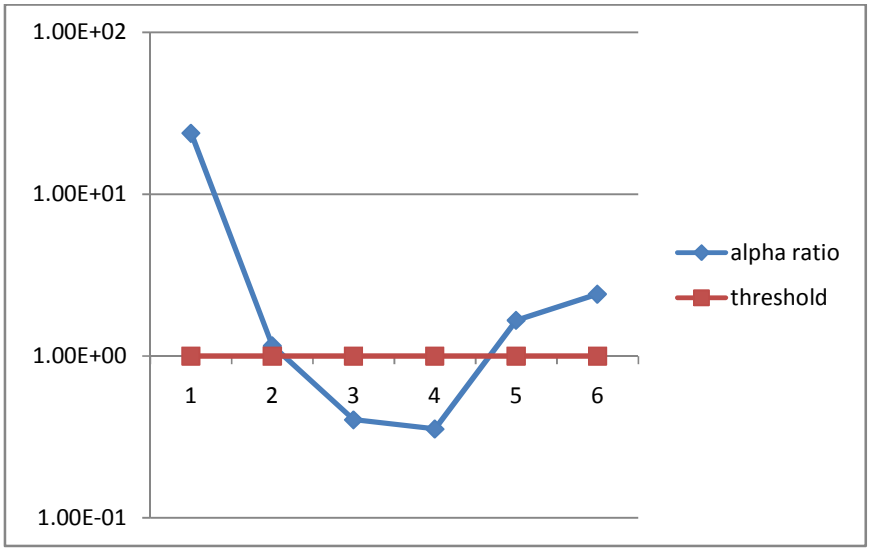

Figure 23: O1 alpha (8-13 Hz) ratio working memory task

From figure 23 it is inferred that in alpha band of O1 no conclusion is drawn as expected, it may be due to some experimental errors. Results are also verified statistically using t-Test. For O1 t-Test value is p=0.303206. Therefore nothing can be concluded from this pilot study as p value is not less than 0.05.

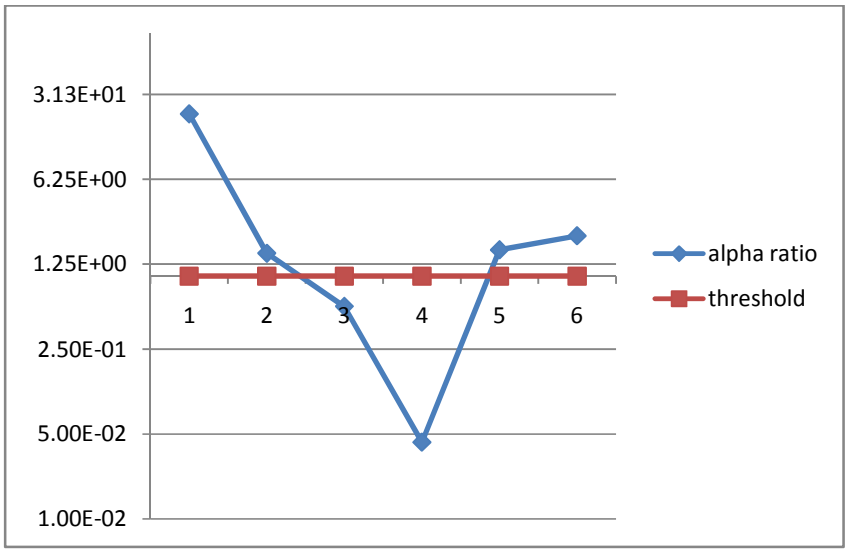

Figure 24: O2 alpha (8-13 Hz) ratio working memory task

From figure 24 it is inferred that in alpha band of O2 no conclusion is drawn as expected, it may be due to some experimental errors. Results are also verified statistically using t-Test. For O2 t-Test value is p= 0.395126. Therefore nothing can be concluded from this pilot study as p value is not less than 0.05.

7.1.2 Correlational study of subject's performance in PEBL and EEG frequency band power

To verify correlation between the performance of the subjects on PEBL task and select EEG parameters in different frequency bands, same of the encouraging results obtained are being reported here. This being a pilot study with a small number of subjects may be taken a confidence building measure to improve the extent of research.

a) Correlation between attentional task Go/No-go and alpha (8-13 Hz) band power of Fp1

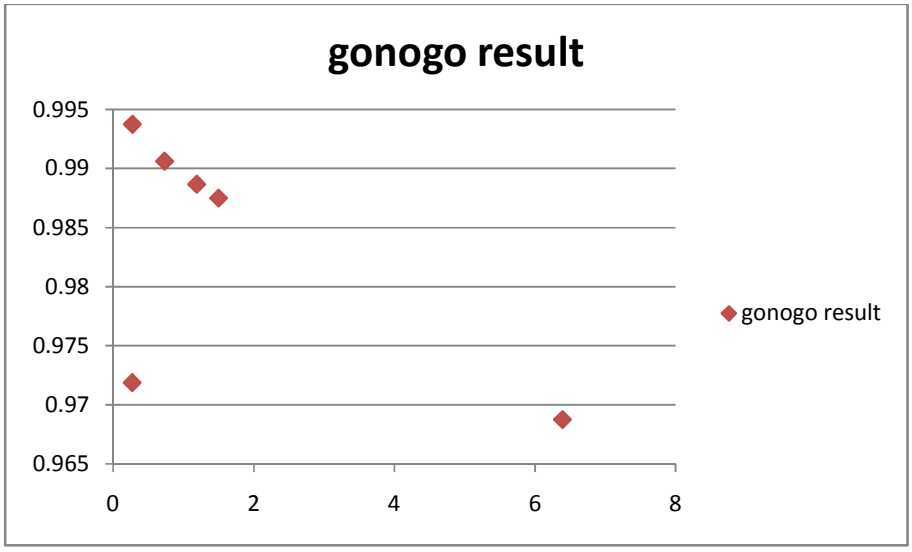

Figure 25:Fp1 alpha (8-13 Hz) band power and Go/No-go correlation

The correlation obtained for entire population is -0.63182.

For best five subjects, the graph is shown in following figure

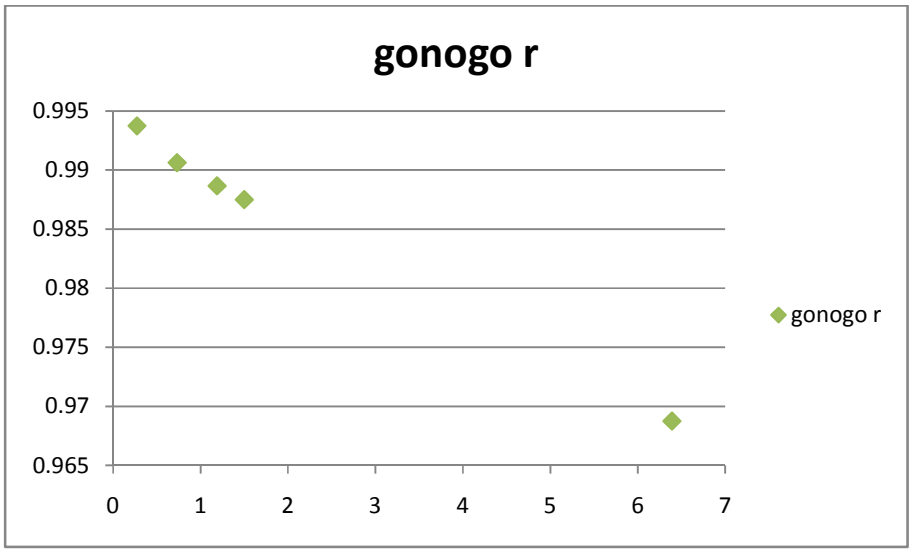

Figure 26: Fp1 alpha (8-13 Hz) band power and Go/No-go correlation best five

The correlation obtained for entire population is -0.99806

b) Correlation between attentional task Go/No-go and alpha (8-13 Hz) band power of F7

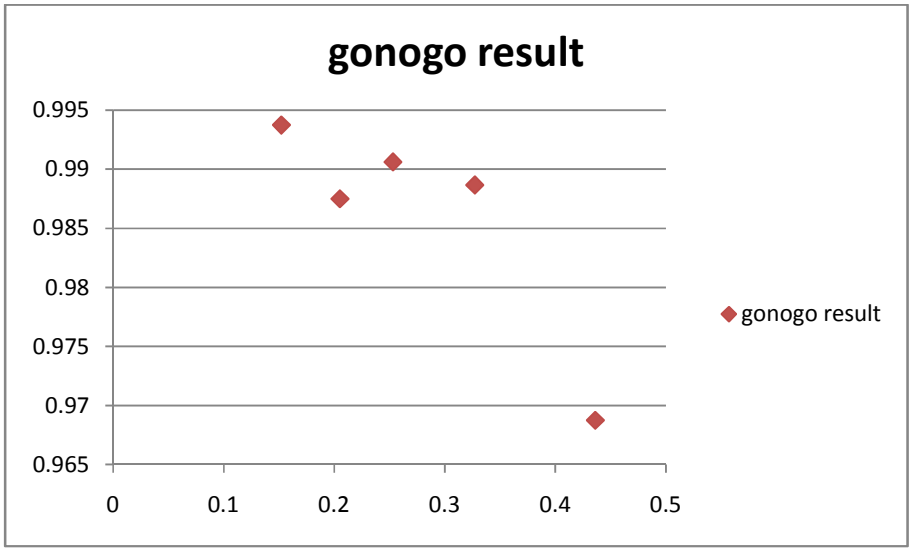

Figure 27: F7 alpha (8-13 Hz) band power and Go/No-go correlation

The correlation obtained for entire population is -0.55458.

For best five subjects, the graph is shown in following figure

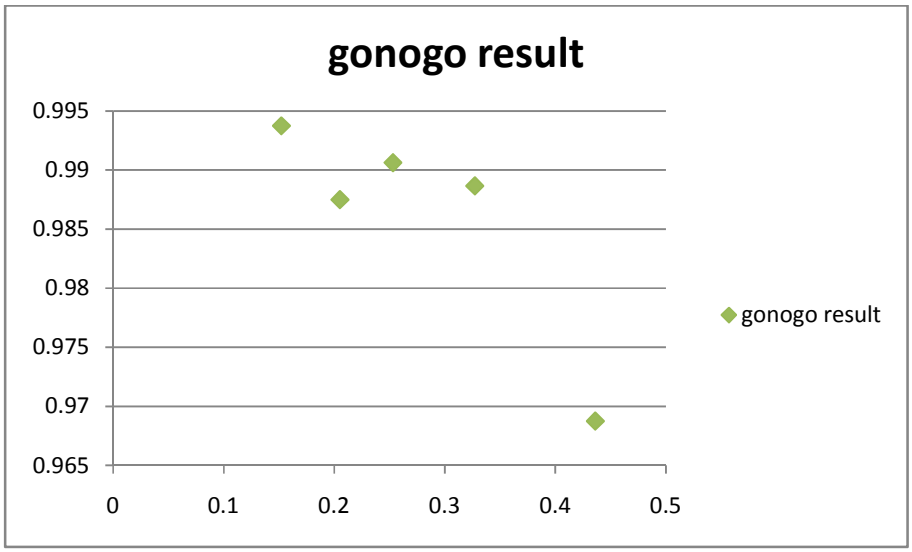

Figure 28: F7 alpha (8-13 Hz) band power and Go/No-go correlation best five

The correlation obtained for entire population is -0.86966.

c) Correlation between attentional task Go/No-go and alpha (8-13 Hz) band power of F8

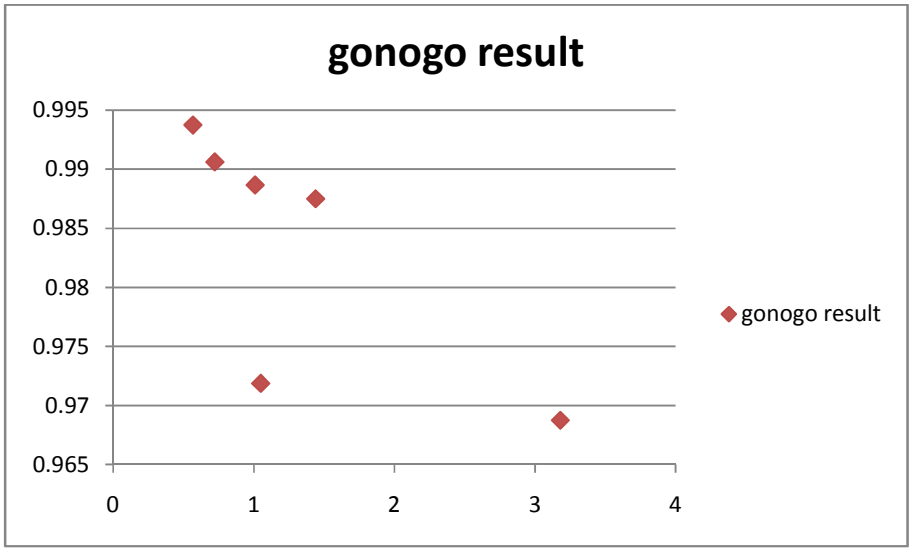

Figure 29: F8 alpha (8-13 Hz) band power and Go/No-go correlation

The correlation obtained for entire population is -0.74519.

For best five subjects, the graph is shown in following figure

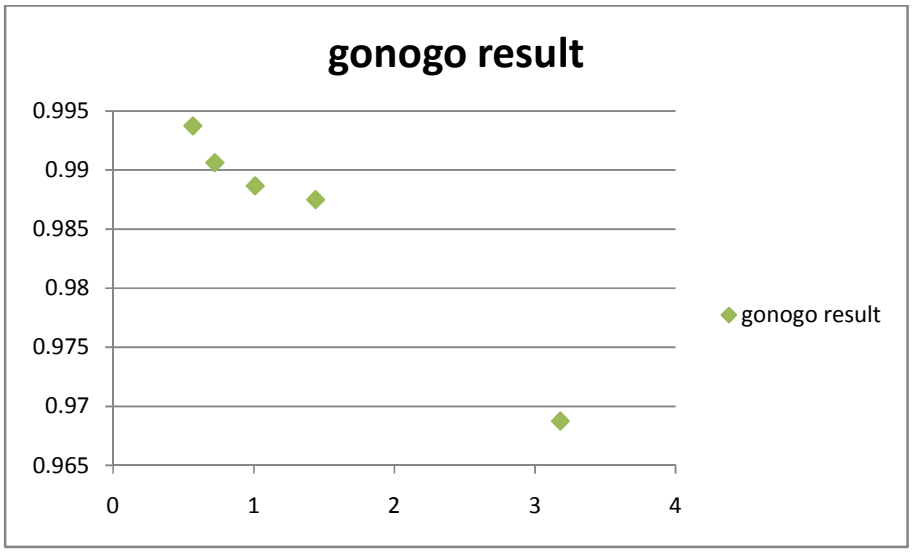

Figure 30: F8 alpha (8-13 Hz) band power and Go/No-go correlation best five

The correlation obtained for entire population is -0.99064.

d) Correlation between attentional task Go/No-go and beta (13-30 Hz) band power of F8

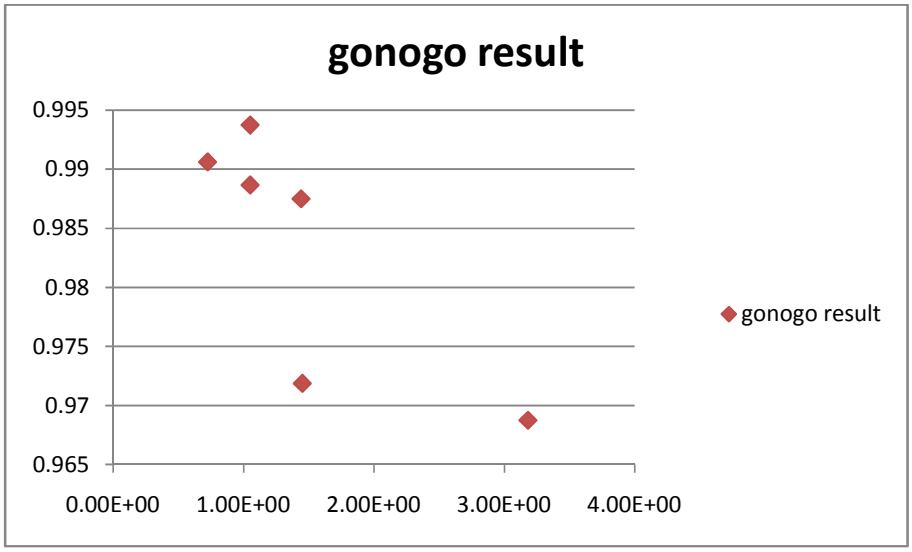

Figure 31: F8 beta (13-30 Hz) band power and Go/No-go correlation

The correlation obtained for entire population is -0.80275.

For best five subjects, the graph is shown in following figure

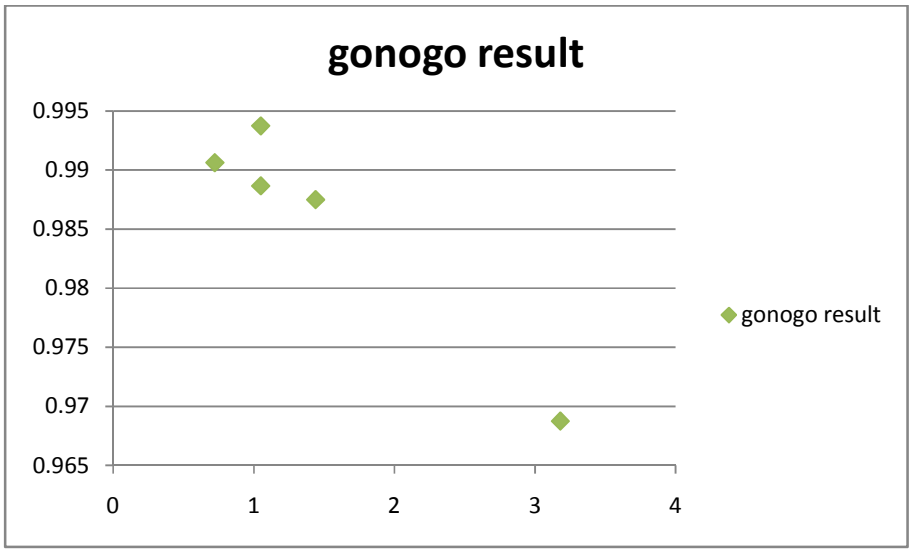

Figure 32: F8 beta (13-30 Hz) band power and Go/No-go correlation best five

The correlation obtained for entire population is -0.96835.

e) Correlation between attentional task Go/No-go and beta (13-30 Hz) band power of f4

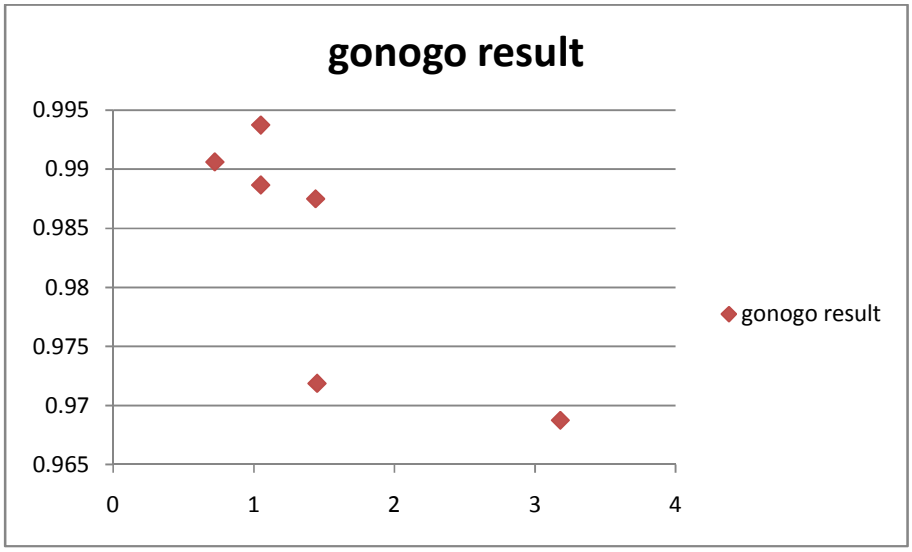

Figure 33: F4 beta (13-30 Hz) band power and Go/No-go correlation

The correlation obtained for entire population is -0.80275.

For best five subjects, the graph is shown in following figure

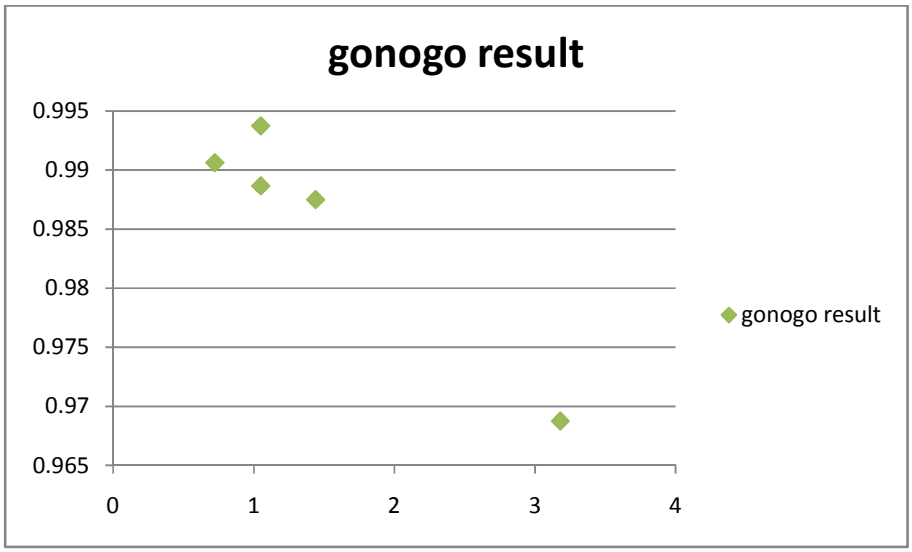

Figure 34: F4 beta (13-30 Hz) band power and Go/No-go correlation best five

The correlation obtained for entire population is -0.96835

f) Correlation between working memory task D-span and theta (4-8 Hz) band power of f3

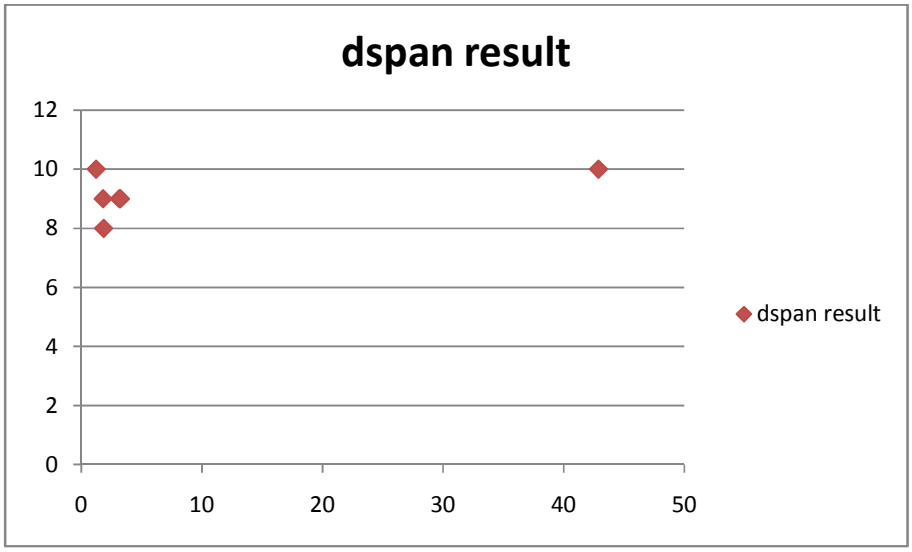

Figure 35: F3 theta (4-8 Hz) band power and D-span correlation

The correlation obtained for entire population is 0.53162.

For best five subjects, the graph is shown in following figure

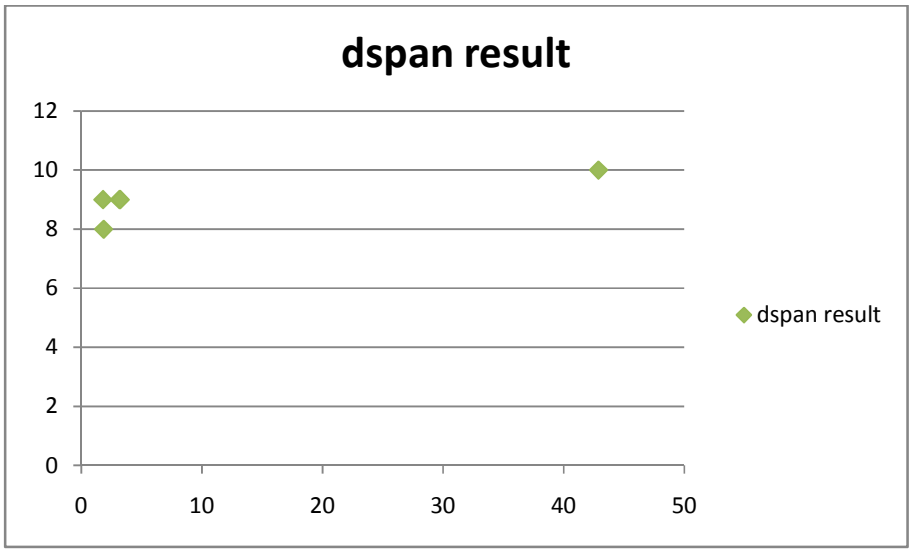

Figure 36: F3 theta (4-8 Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.802909.

g) Correlation between working memory task D-span and theta (4-8 Hz) band power of f4

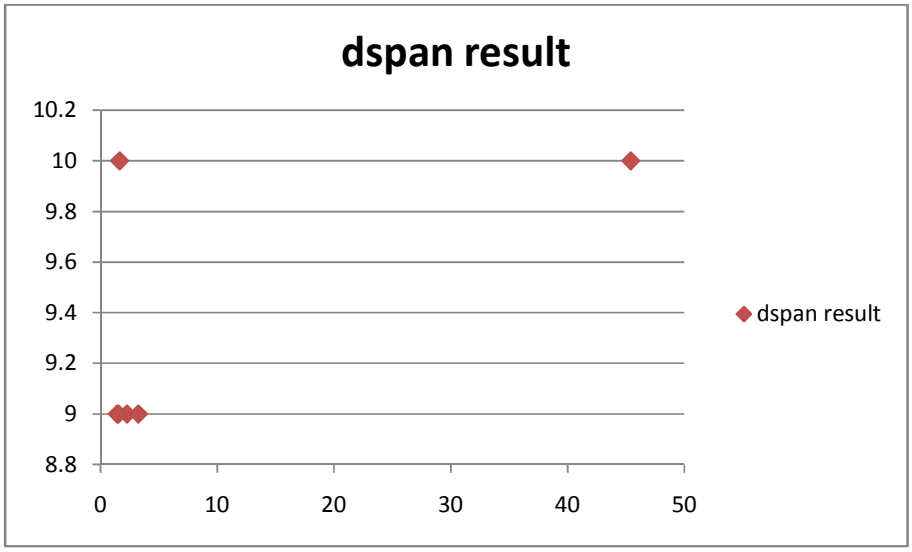

Figure 37: F4 theta (4-8 Hz) band power and D-span correlation

The correlation obtained for entire population is 0.623554.

For best five subjects, the graph is shown in following figure

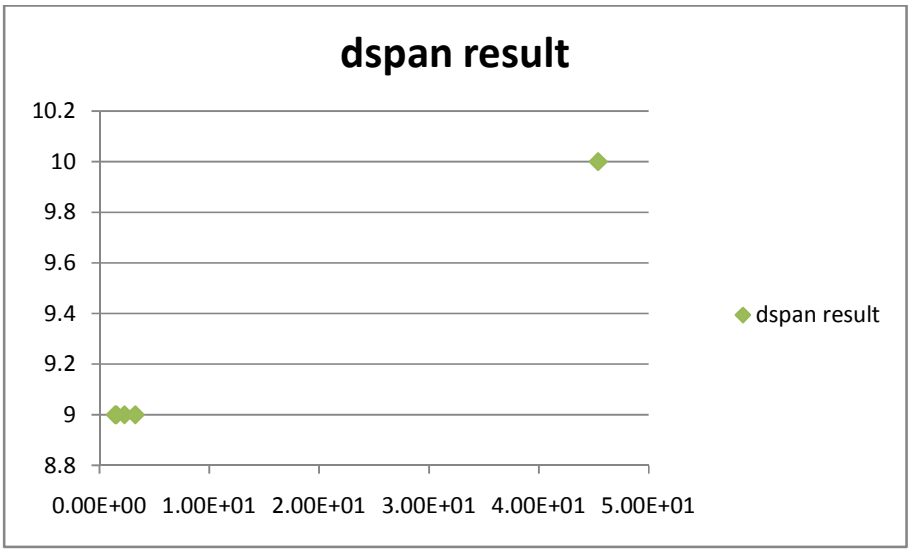

Figure 38: F4 theta (4-8 Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.999296.

h) Correlation between working memory task D-span and theta (4-8 Hz) band power of f7

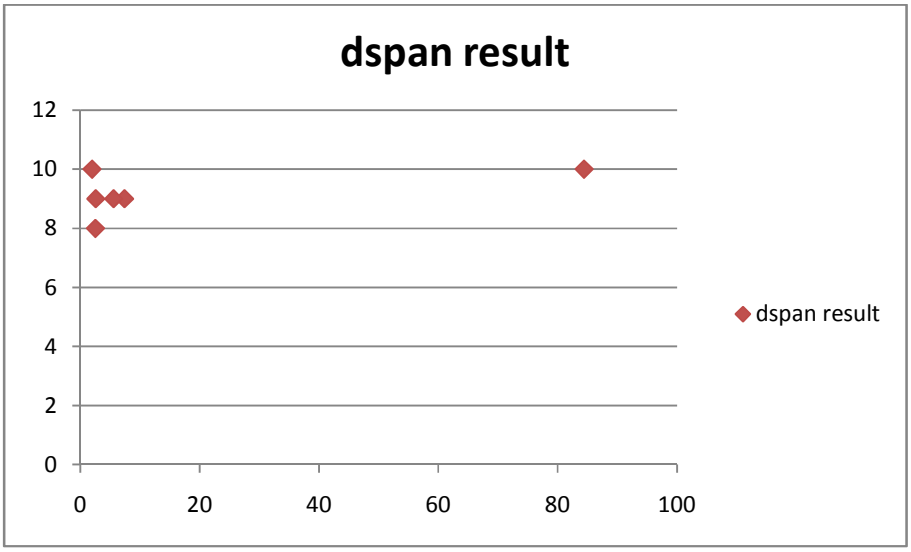

Figure 39: F7 theta (4-8 Hz) band power and D-span correlation

The correlation obtained for entire population is 0.536676.

For best five subjects, the graph is shown in following figure

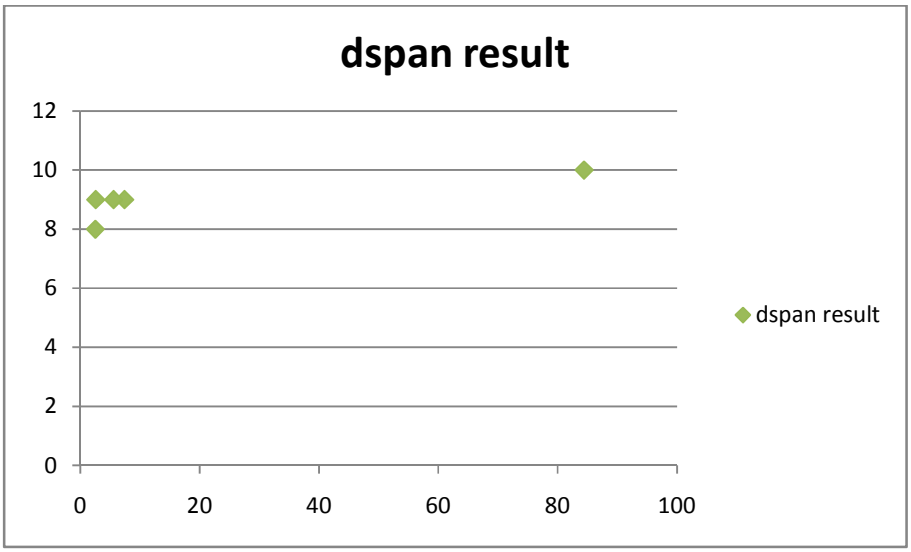

Figure 40: F7 theta (4-8 Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.808998.

i) Correlation between working memory task D-span and theta (4-8 Hz) band power of f8

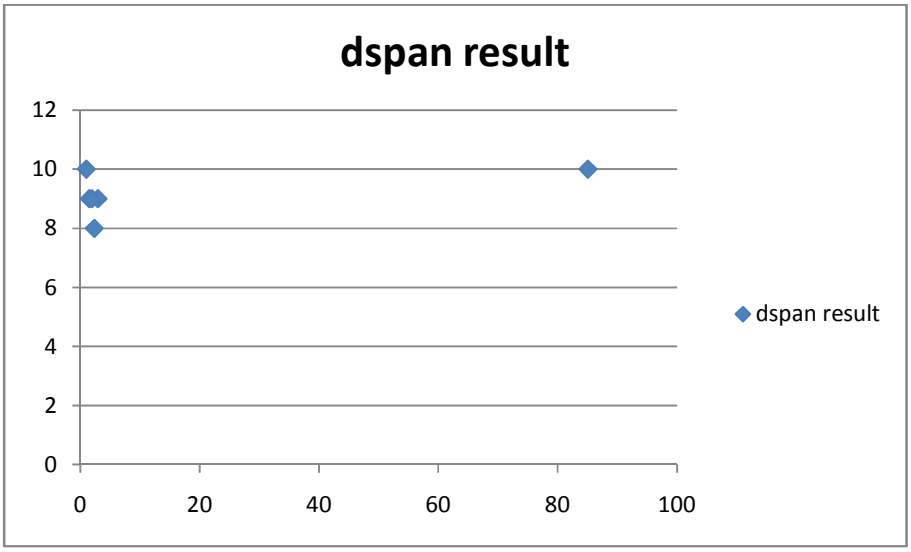

Figure 41: F8 theta (4-8 Hz) band power and D-span correlation

The correlation obtained for entire population is 0.531812.

For best five subjects, the graph is shown in following figure

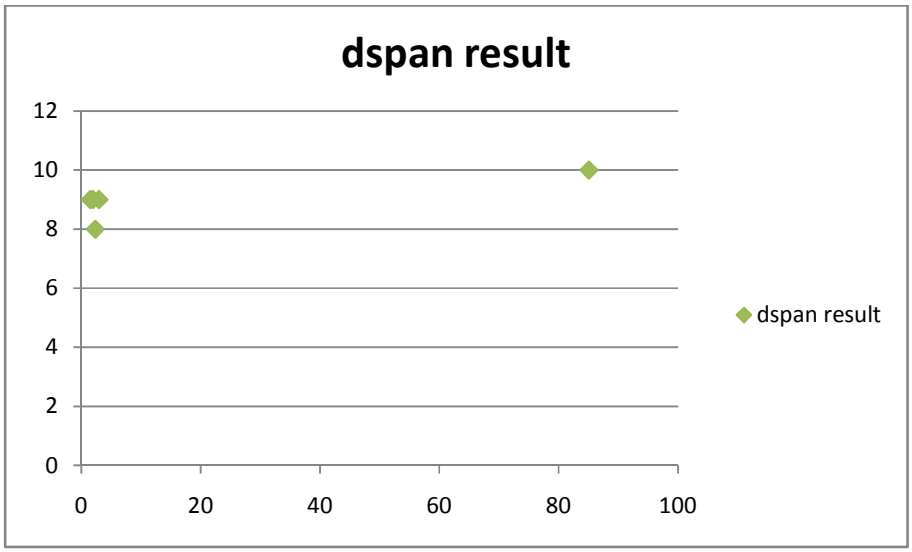

Figure 42: F8 theta (4-8 Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.789058.

j) Correlation between working memory task D-span and alpha (8-13Hz) band power of fp1

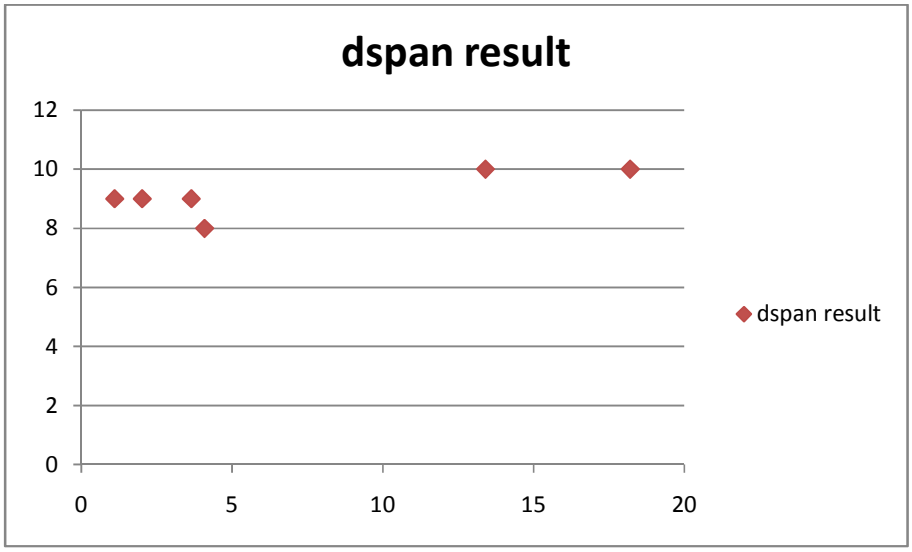

Figure 43: Fp1 alpha (8-13Hz) band power and D-span correlation

The correlation obtained for entire population is 0.774701.

For best five subjects, the graph is shown in following figure

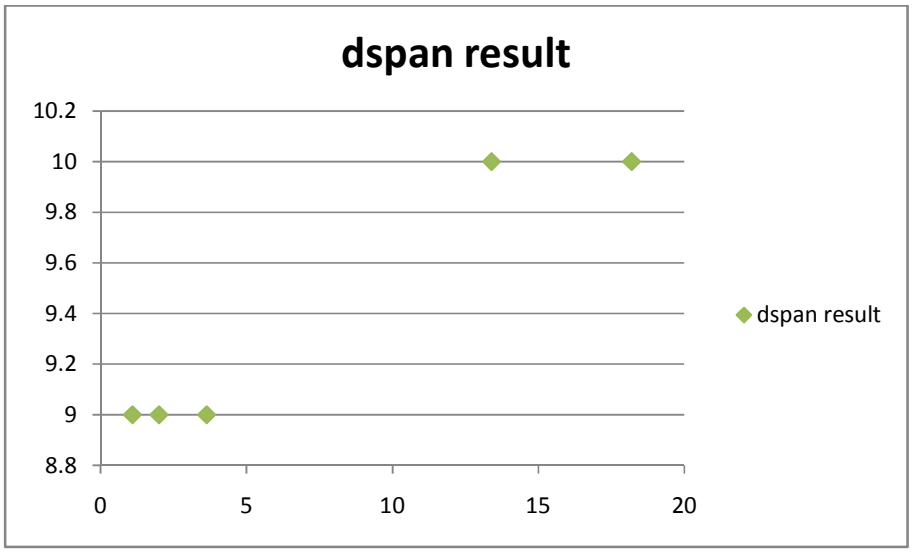

Figure 44: Fp1 alpha (8-13Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.967949.

k) Correlation between working memory task D-span and alpha (8-13Hz) band power of O1

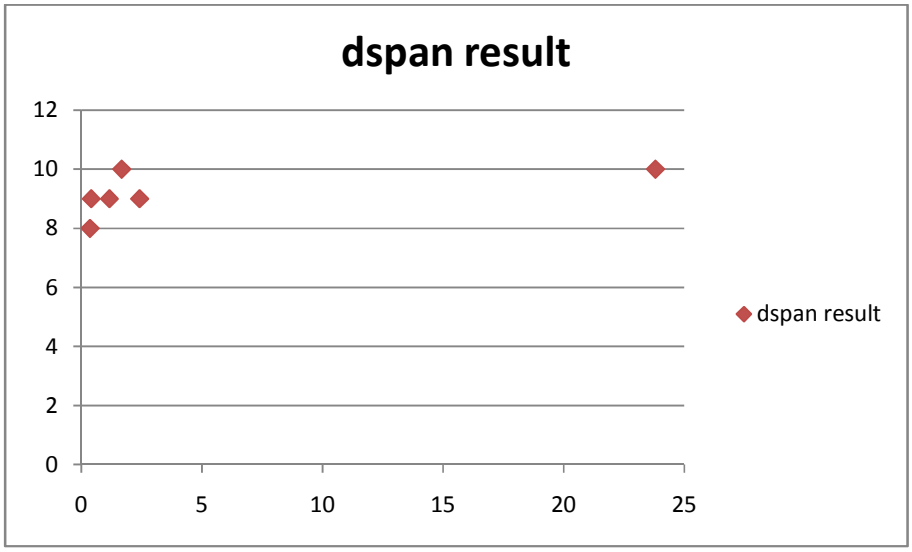

Figure 45: O1 alpha (8-13Hz) band power and D-span correlation

The correlation obtained for entire population is 0.578137.

For best five subjects, the graph is shown in following figure

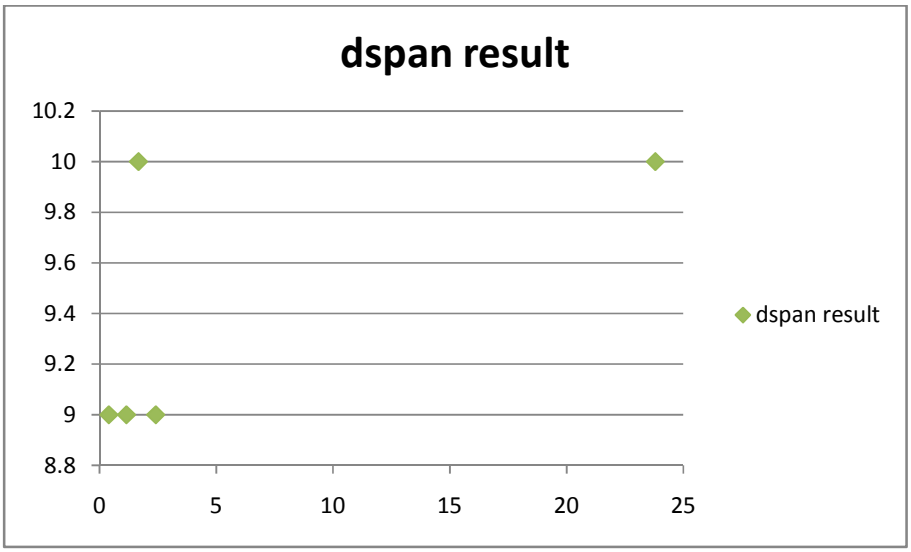

Figure 46: O1 alpha (8-13Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.622509.

l) Correlation between working memory task D-span and alpha (8-13Hz) band power of O2

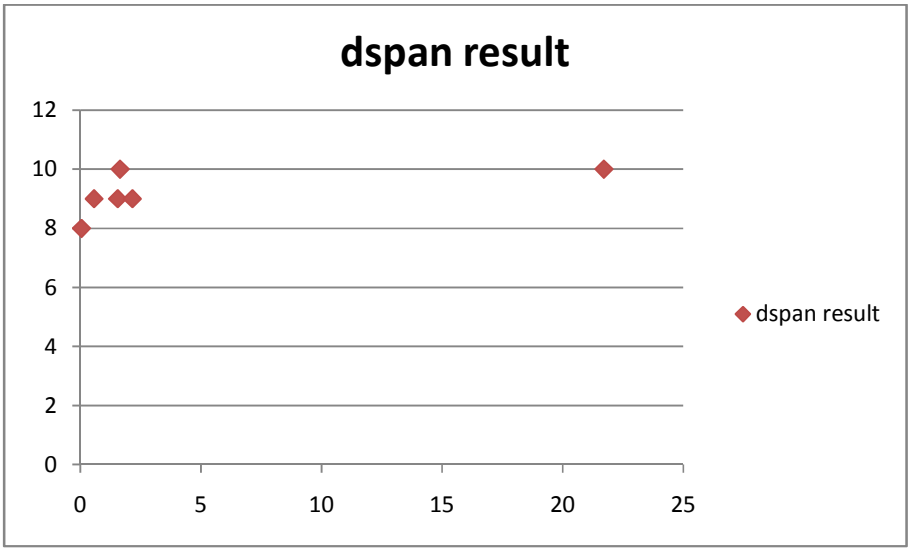

Figure 47: O2 alpha (8-13Hz) band power and D-span correlation

The correlation obtained for entire population is 0.590512.

For best five subjects, the graph is shown in following figure

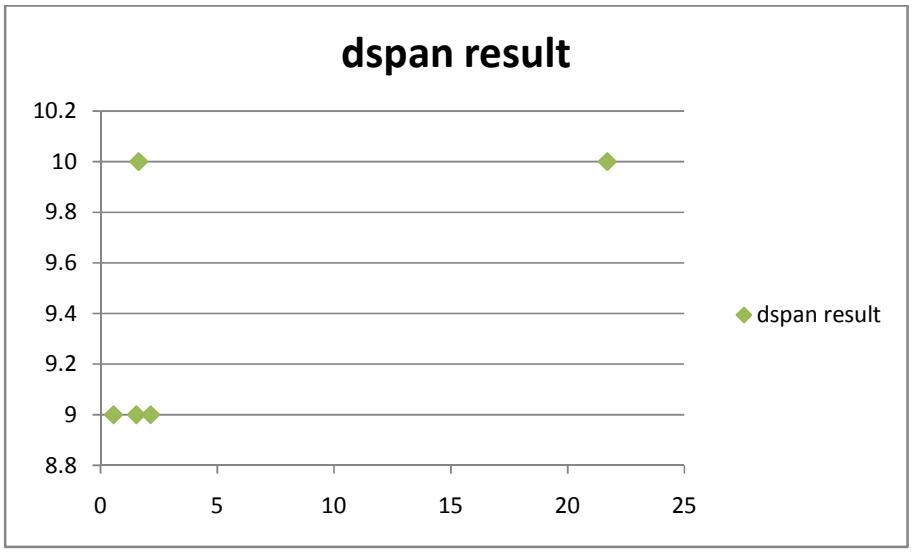

Figure 48: O2 alpha (8-13Hz) band power and D-span correlation best five

The correlation obtained for entire population is 0.61954.

Conclusion

It can be concluded that for attention task, results for FP1 are not so good but for F3 and F7, results are verified. Also, in some other channels like F4, F8, FP2 , O1 and O2, alpha power decreases. Hence, the results are verified with the previous studies. Along with this, for beta power, results are verified for F8 and FP2 but not for F4. For working memory, in all the frontal channels (FP1, FP2, F3, F4, F7, F8), results are verified, i.e., theta power increases. As well, the results are not verified for alpha power of O1 and O2, but alpha power of FP1 and FP2 increases. Therefore, it can be stated that if an individual gets involved in any task which gives rise to parameter changes like this, it can be said that he/she is going through a task comprising of attentive or working memory skills.

Future Scope

The study carried out is a pilot study. In near future, it is planned to carry out the study with 30 subjects. Also, some intervention will be provided like meditation, odor, music, etc. and after that pre and post intervention assessments will be done for better comparisons. Moreover, a control group will be added to compare the results.

REFERENCE

[1] M Singh, "Introduction to Biomedical Instrumentation", PHI learnings, 2010

[2]Kridsakon Yaomanee, Setha Pan-ngum, Pasin Israsena Na Ayuthaya,"Brain Signal Detection Methodology for Attention Training using minimal EEG channels", Tenth International Conference on ICT and Knowledge Engineering, 2012

[3] Ole Jensen, Jack Gelfand, John Kounios, John E. Lisman, "Oscillations in the Alpha Band (9-12 Hz) Increase with Memory Load during Retention in a Short-term Memory Task", Cereb. Cortex, Vol.12, No.8, pp. 877-882, 2002

[4] Kelly S P, Dockree P M, Reilly R B, and Robertson I H, "EEG Alpha Power and Coherence time courses in a Sustained Attention Task," Proc. of 1st Intl. IEEE EMBS conf. on Neural Eng. Capri Island, March 2003

[5] Manuel va'zquez Marrufo, Encarna Vaquero, Mar'ia Jesu's Cardoso, and Carlos M. Go´mez, "Temporal evolution of alpha and beta bands during visual spatial attention," In Cognitive Brain Research, vol.12, pp. 315–320, 2001

[6] Allison Bell, Tanya Harnpattanapanich, Meghan Hash, Jianbo Xiao, "Effect of Eye-Closure on Working Memory: An Analysis of Theta Wave Forms", Journal of Advance Student Science, Issue-01, 2011

[7] Joshua Jacobs, Grace Hwang, Tim Curran and Michael J. Kahana, "EEG oscillations and recognition memory: Theta correlates of memory retrieval and decision making", NeuroImage, Vol. 32, pp. 978–987, 2006
[8] Ole Jensen and Claudia D. Tesche, "Frontal activity in humans increases with memory load in a working memory task", European Journal of Neuroscience, Vol. 15, pp. 1395-1399, 2002
[9] M. Singh, S. Sachdeva , "Cognitive assessment techniques", International journal of information technology and knowledge management, Vol.7, 2014