IJITKM 0973-4414 Volume-8, Number-2 Jan-Jun 2015 pp. 188-196 **Impact Factor 2.8** available online at www.csjournalss.com

Correlational Study of Attention Task Performance and EEG Alpha Power

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Abstract: Attention is an act of processing specific information from the environment. The neural activity of brain is modulated in attention state. Increase in attention leads to enhanced firing of the neurons. This enhanced firing leads to increase in electrical activity which can be observed at different locations of the brain by electroencephalography (EEG). In this paper we have found correlation between the scores/accuracy of attention tasks with the alpha activity of brain at pre-frontal, frontal and occipital regions of the brain. It is observed that scores/accuracy of the tasks and EEG alpha activity hold negative correlation with each other i.e. the subject with higher score has a lower alpha ratio as compared to the subject with lower score. Alpha activity increases in the relaxed state and reduces in attention state. This fact is validated in this study.
Keywords: Attention assessment, Continuous Performance Task, Go/No-Go, Psychology Experiment Building Language, Electroencephalography, Pearson Coefficient.

1. Introduction

Electroencephalography or EEG is used to record electrical activity of the brain. This electrical activity is due to current flowing in the neurons of the brain. EEG is a non-invasive technique to record the brain's electrical activity. EEG is recorded by placing multiple electrodes on the scalp [1]. Most of the EEG signals lie in the range of 0.5-20 Hz. EEG signal can be subdivided into 4 basic bandwidths: 1) Delta- 0.5 to 4 Hz, 2) Theta- 4 to 8 Hz, 3) Alpha- 8 to 13 Hz and 4) Beta- 13 to 20 Hz. In the previous study it has been seen that alpha is modulated by attention and relaxed state of the brain. Alpha activity increases in the relaxed state and reduces in attention state [2 and 3]. In this paper EEG is acquired using a cap placed on the scalp in accordance with 10-20 system. Alpha band is extracted from EEG while doing task and during eyes closed and its power is calculated. Ratio of power during the task and during eyes closed is calculated. This ratio is called alpha ratio. Pearson coefficient is then computed between the scores of the subjects and the alpha ratio.

2. Experimental Methodology

In this experiment fourteen subjects are selected and are made to perform Continuous Performance Task and Go/No-Go from Psychology Experimental Building Language (PEBL) [4]. Performance in terms of accuracy is automatically calculated at the end of every task. EEG is also recorded for the subjects while they are performing the tasks. Correlation is computed between the scores/accuracy of the task and alpha ratio at different location on the scalp.

2.1 Participants

Fourteen subjects in the age group of 20 to 25 are selected to undergo the experiment. All the selected subjects are engineering students of Thapar University, Patiala. No subject has been under any kind of medication while performing the task. Selected students have no disease affecting the central nervous system including hypertension, diabetes, thyroid, multiple sclerosis or Parkinson's disease. All the subjects are taking part in the experiment according to their free will and are informed about the aim, experimental procedure and time taken by the experiment [5 and 6].

2.2 Experimental Setup for participants

The experiment is carried out in a quiet room. During the experiment the participants are made to sit in a comfortable chair. The screen is at a convenient distance from the subject. It is made sure that EEG acquisition device has no electrical interference which could distort the EEG signals [5].

2.3 PEBL Attention Tasks

2.4 PEBL Continuous Performance Task

It is a 14 minutes long task in which the subject responds to the any character that appears on the screen except for 'X'. Total 360 characters appear on the screen. PEBL computes the scores on the basis of correct responses out of 360 at the end of the task [3, 5, 7 and 8].

Go/No-Go

It is a 4 minute long task. Here the subject responds only to 'P' flashing on the screen and ignore the 'Q's.

The response is given by right shift key. The accuracy of responding to 'P' and 'Q' is calculated using (1) and (2)

$$\text{Accuracy of responding to 'P'} = \frac{correct\ response\ on\ P}{total\ number\ of\ P's\ flashed} \quad (1)$$

$$\text{Accuracy of responding to 'Q'} = \frac{correct\ response\ on\ Q}{total\ number\ of\ Q's\ flashed} \quad (2)$$

3. EEG Recording

3.1 10-20 System of electrodes

EEG is acquired with the help of EEG cap having electrodes placed according to 10-20 system. 10-20 system is the international system of electrode placement for acquiring EEG [1]. The electrode contact with the scalp is made with the help of conducting gel. Six electrodes are selected from the 10-20 system from prefrontal, frontal and occipital region on the cortex. The electrodes selected are FP1, FP2, F3, F4, O1 and O2 as highlighted in Figure 1. The voltage reference for these electrodes is taken as left ear mastoid whereas FPZ (highlighted in grey in Figure 1) is taken as ground.

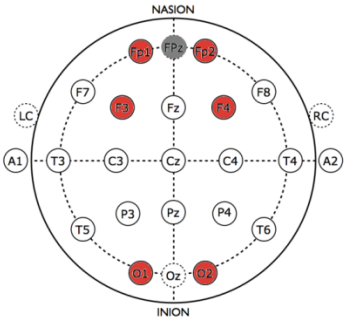

Figure 1: Selected electrodes from 10-20 system of EEG

3.2 Biopac MP150 and AcqKnowledge Software

The hardware used for data acquisition from six electrodes is Biopac MP150 EEG 100c as shown in Figure 2. The data is acquired at 1 KHz. The acquired signals are sampled at 500 Hz. The bio-signals are amplified with the help of amplifiers with the gain of 20000. The signals acquired are filtered with the help of offline filters in AcqKnowledge software and alpha, beta, delta and theta frequency band are extracted from it.

Figure 2: Biopac MP150 100c hardware

4. Power Calculation

Power spectrum density is computed for the four EEG bands extracted from the six electrodes. Power is then calculated for these bands using the power spectrum density as in (3) [9,10].

$$Power = \frac{\sum Amplitude\ of\ Power\ Spectrum\ Density}{Total\ Number\ of\ Samples\ in\ Frequency\ Band} X\ Range\ of\ Frequency\ Band \quad (3)$$

Figure 3 represents how power is computed from the acquired EEG. EEG is extracted from the cap containing electrodes. The EEG signals are filtered, amplified and digitized with the help of MP150. The signals are further filtered using offline comb filters to remove line frequency in AcqKnowledge. Alpha band is extracted from the filtered signals and power spectrum density is computed for each electrode. Power is calculated in Matlab using (4).

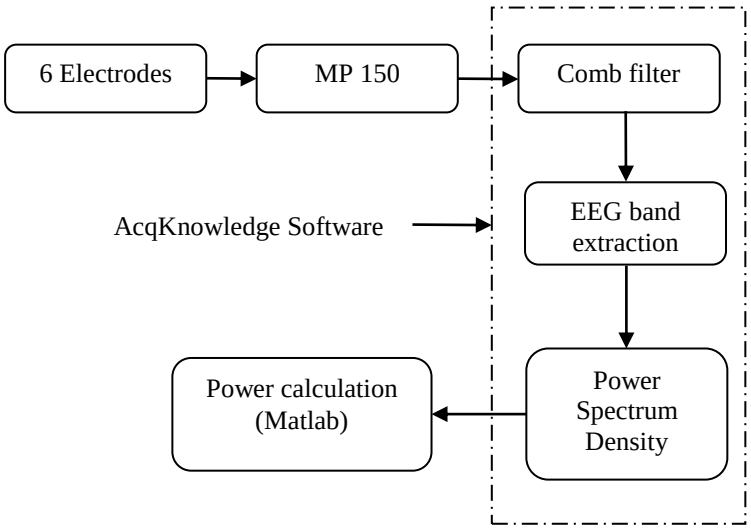

Figure 3: Schematic diagram of power calculation

5. Pearson Coefficient

Pearson coefficient is calculated to determine correlation between the accuracy of the task and parameters obtained from PEBL tasks. Pearson coefficient is given by

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})\,(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2}\ \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where r is the Pearson Coefficient, x_i is first vector, y_i is second vector, $\bar{x}, \bar{y}$ are the mean values of x_i and y_i respectively. Table 1 depicts the value of Pearson coefficient and their representation.

Table 1: Pearson Coefficient

Coefficient	Correlation
|0.1| to |0.3|	poor
|0.3| to |0.5|	moderate
|0.5| to |1|	strong

6. Data Analysis

Table 2 depict scores of PCPT and alpha power at six electrodes.

Table 2: PCPT score and EEG alpha ratio

Subject Number	PCPT Score	ELECTRODES ALPHA BAND POWER RATIO (task power/eyes-close power)					
		FP1	FP2	F3	F4	O1	O2
1	352	0.48299	0.59488	0.39176	0.57613	0.10059	0.00905
2	348	0.473	0.43743	0.65042	0.42242	0.45121	0.21656
3	354	0.37648	0.39895	0.35043	0.30257	0.16256	0.15495
4	347	0.07849	0.14264	0.30228	0.05703	0.04001	0.03919
5	343	0.58637	0.42924	0.42794	0.49838	0.42261	0.19064
6	337	0.93023	0.83914	0.82436	0.5679	0.03302	0.14139
7	338	1.14237	0.88414	0.59749	0.68114	1.81904	0.58035
8	334	0.72526	1.42284	0.86832	0.87685	0.058859	1.85573
9	347	0.64264	0.46118	0.18055	0.15482	2.84989	0.06267
10	340	0.94141	0.5613	0.53589	0.51111	0.12912	0.25362
11	334	0.64441	1.09758	0.99609	0.93892	0.73435	0.4875
12	345	0.62514	0.73011	0.76233	0.54354	0.393296	0.27704
13	326	1.43273	0.80067	1.32613	1.22161	1.24845	1.53417
14	337	0.80652	0.95511	0.73248	0.84016	0.354	0.19577

Figure 4 shows correlation between alpha ratio and PCPT task score. The y-axis shows the Pearson coefficient and the x-axis shows alpha ratios at different electrodes.

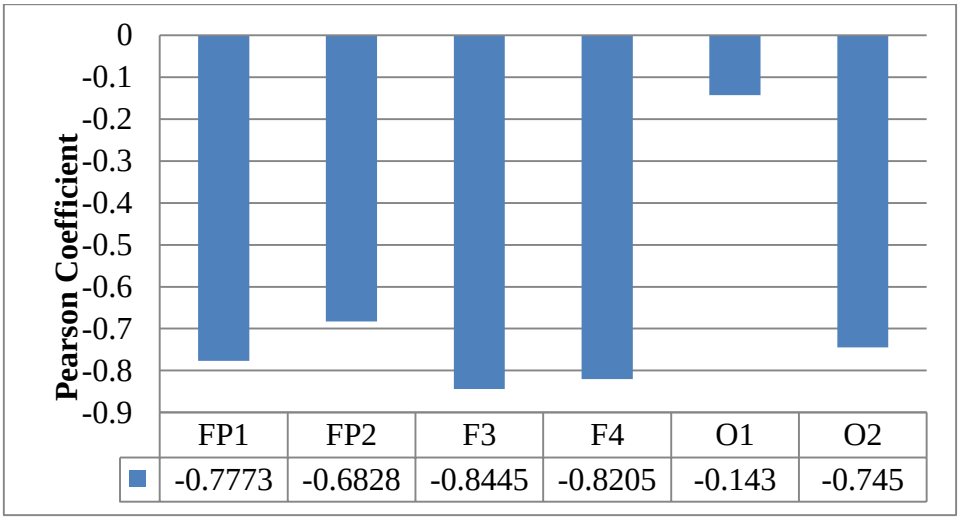

Figure 4: Pearson Coefficient between PCPT and alpha ratio

Table 1 shows that any correlation greater than 0.5 is a strong correlation. As seen from Figure 4 alpha ratio has a strong negative correlation with PCPT score at FP1, FP2, F3, F4 and O2. This means that participants with

higher score have lower alpha ratio as compared with the participants with lower score. Figure 5, 6, 7, 8 and 9 show the plot between PCPT score and alpha ratios of fourteen students at FP1, FP2, F3, F4 and O2.

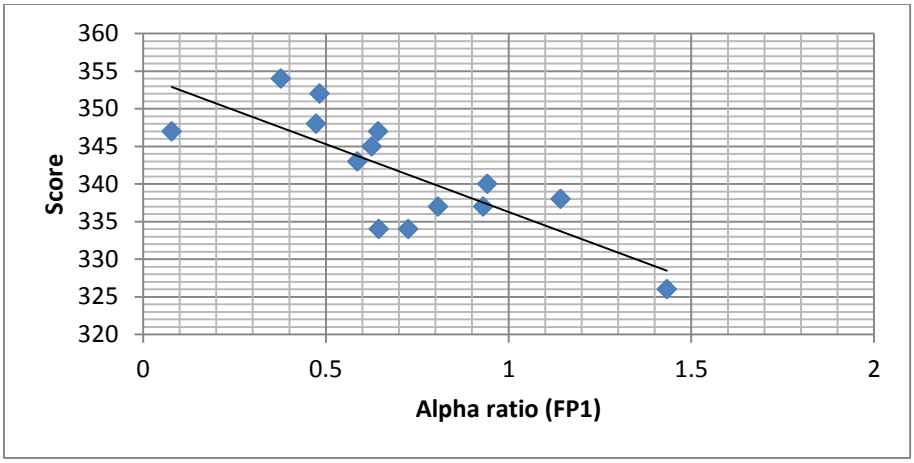

Figure 5: Plot between PCPT score and Alpha ratio at FP1

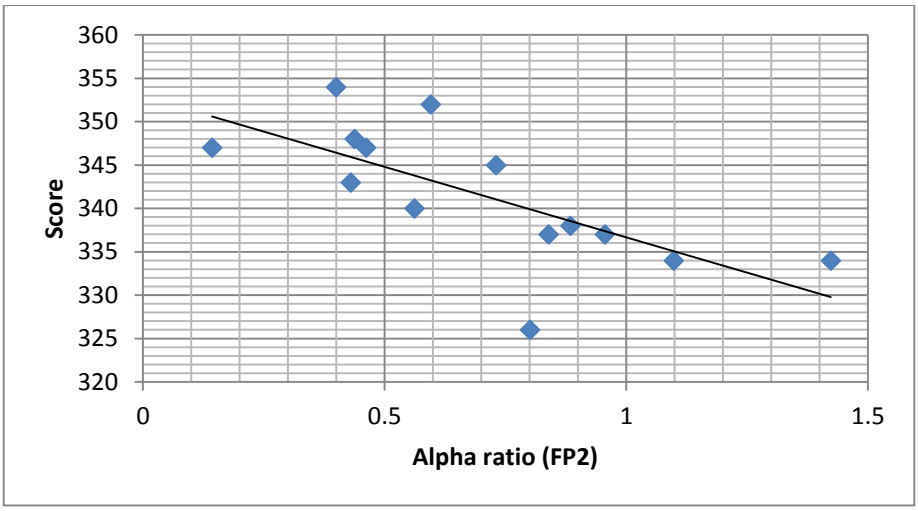

Figure 6: Plot between PCPT score and Alpha ratio at FP2

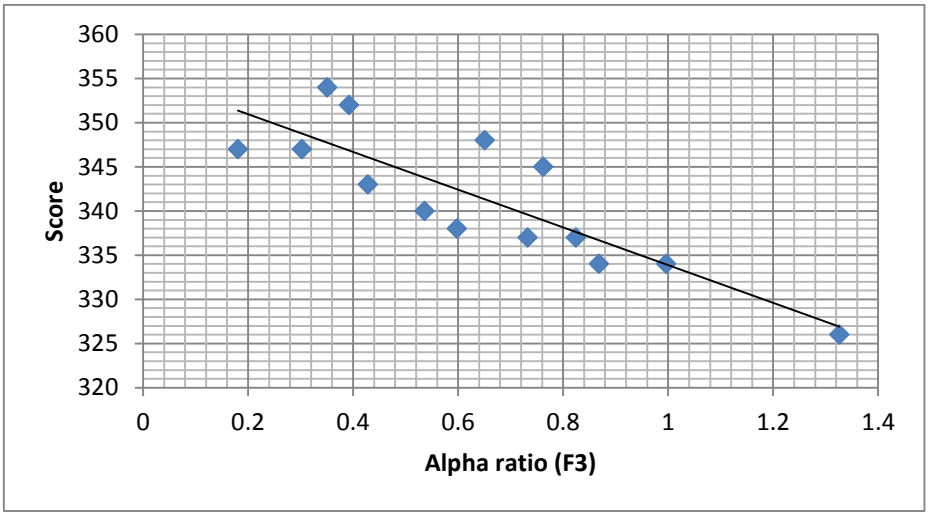

Figure 7: Plot between PCPT score and Alpha ratio at F3

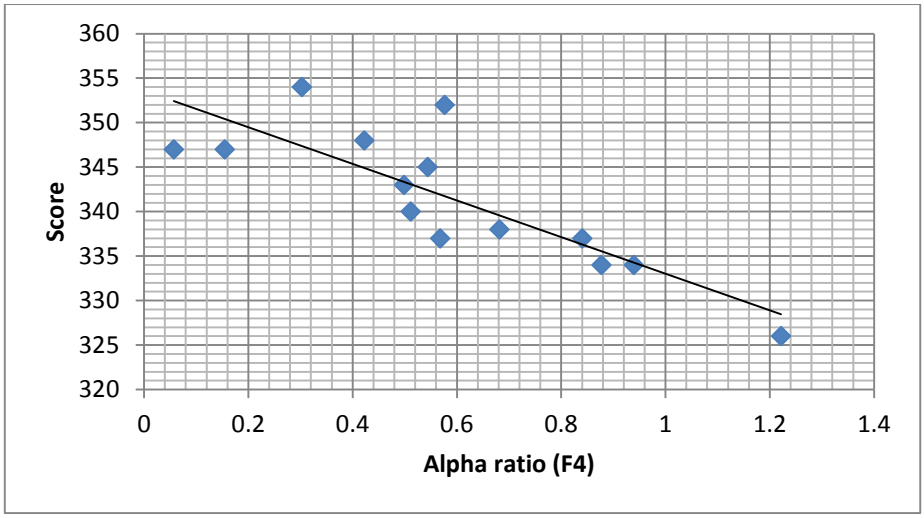

Figure 8: Plot between PCPT score and Alpha ratio at F4

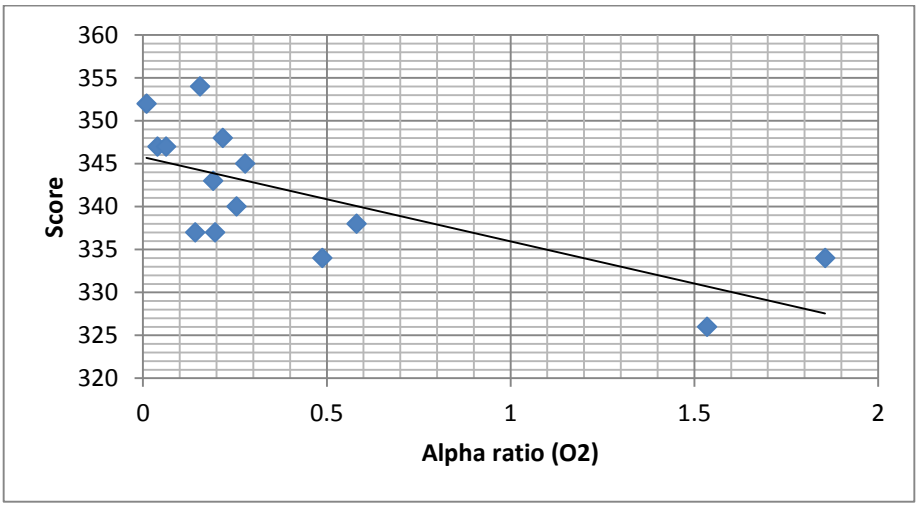

Figure9: Plot between PCPT score and Alpha ratio at O2

Table 3 Go/No-GoP accuracy and EEG alpha ratio

Subject Number	Go/No-GoP accuracy	ELECTRODES ALPHA BAND POWER RATIO (task power/eyes-close power)					
		FP1	FP2	F3	F4	O1	O2
1	0.890625	3.368272	4.404107	0.583273	0.427305	0.397159	0.053132
2	0.890625	1.294461	1.577126	0.782015	0.788173	0.203486	0.025823
3	0.875	0.422648	0.420238	0.431939	0.314557	0.177001	0.123884
4	0.71875	13.44556	11.95389	3.310122	2.446336	1.355299	0.906535
5	0.875	0.543816	0.619624	0.460988	0.317706	0.233665	0.190272
6	0.828125	0.260242	0.326383	0.257883	0.394341	0.121343	0.108746
7	0.96484	0.9734	0.910854	0.508861	0.424716	0.037837	0.102791
8	0.96875	0.601732	0.618261	0.156631	0.182518	0.080718	0.048215

9	0.887165	0.879225	1.18331	0.605148	0.661191	0.187095	0.284163
10	0.921875	0.819307	0.664764	0.263368	0.188824	0.179977	0.165075
11	1	0.498238	0.425189	0.32319	0.516697	0.10222	0.102361
12	0.859375	1.122876	0.668777	0.751634	0.327209	0.745258	0.456438
13	0.921875	0.743247	0.739892	0.419404	0.432243	0.04351	0.026571
14	0.9375	0.213687	0.164161	0.115456	0.210772	0.040151	0.337208

Figure 14 shows a graph of Pearson coefficient between Go/No-GoP and EEG alpha ratio .It can be seen that Go/No-GoP has a high negative correlation with the accuracy at all the six electrodes.

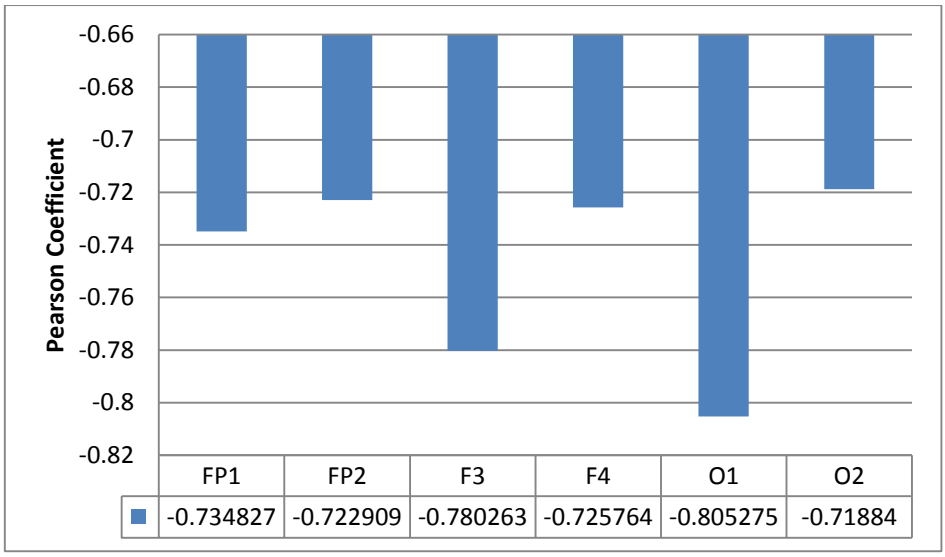

Figure 14: Pearson Coefficient between Go/No-GoP and EEG alpha ratio

Figure 15, 16, 17, 18, 19 and 20 show plot between the accuracy of the subjects and alpha ratio at FP1, FP2, F3, F4, O1 and O2 respectively.

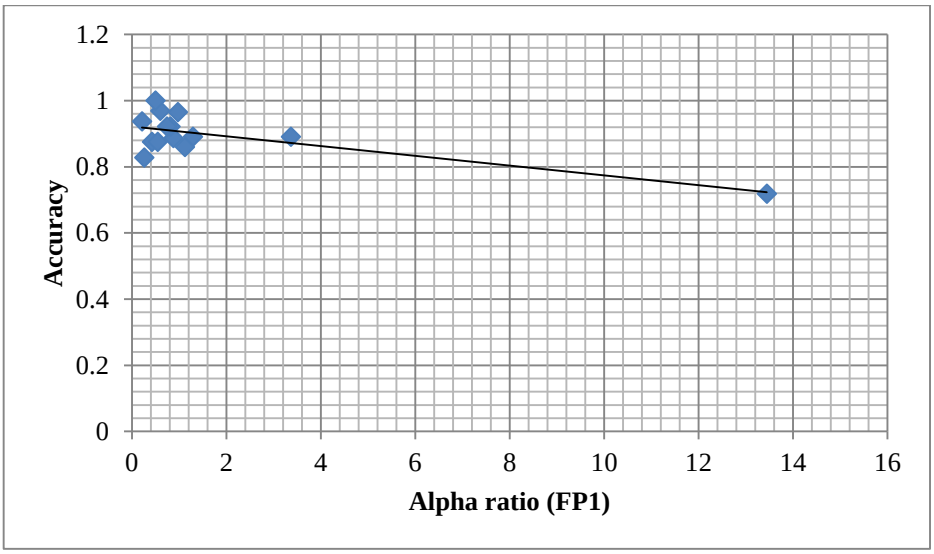

Figure 15: Plot between Go/No-GoP and Alpha ratio at FP1

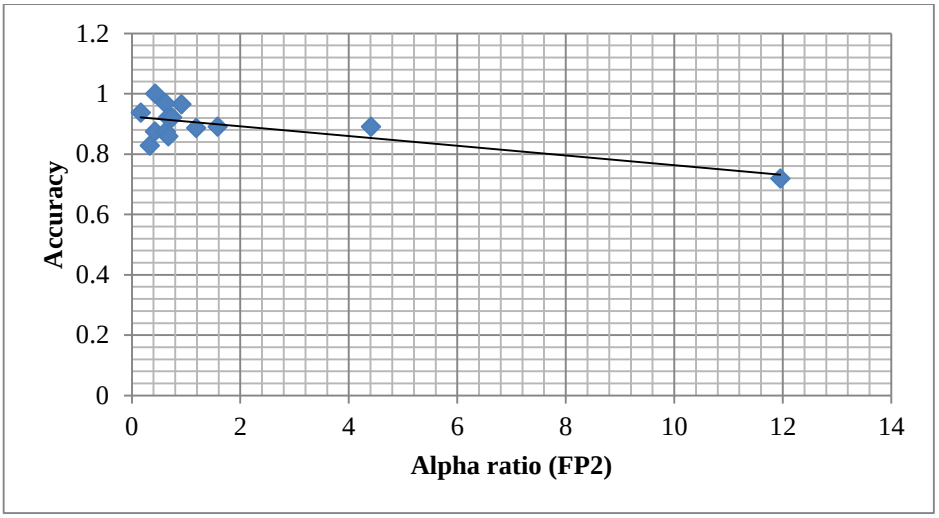

Figure 16: Plot between Go/No-GoP and Alpha ratio at FP2

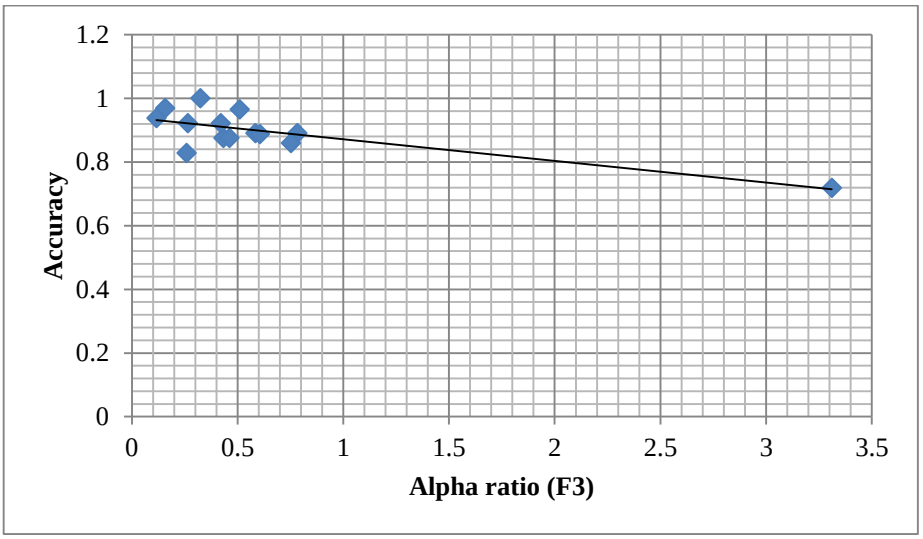

Figure 17: Plot between Go/No-GoP and Alpha ratio at F3

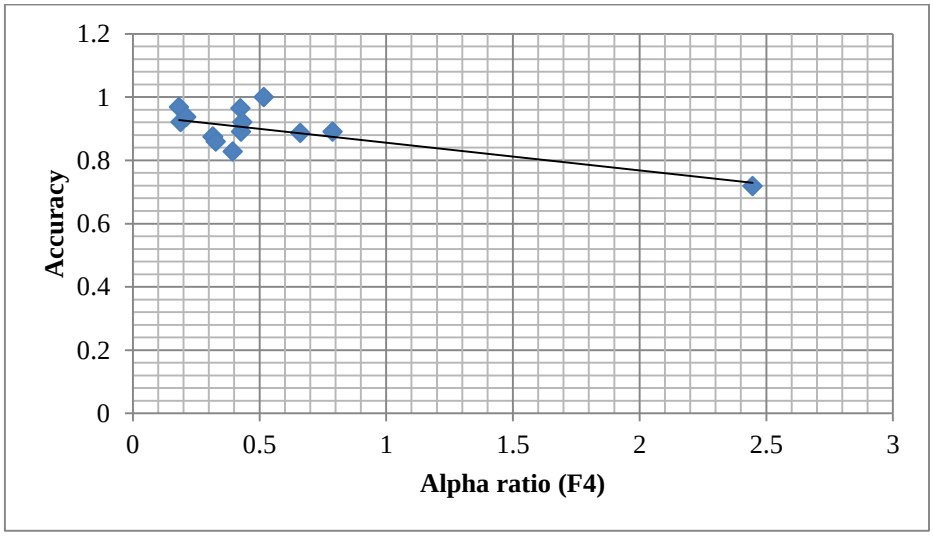

Figure 18: Plot between Go/No-GoP and Alpha ratio at F4

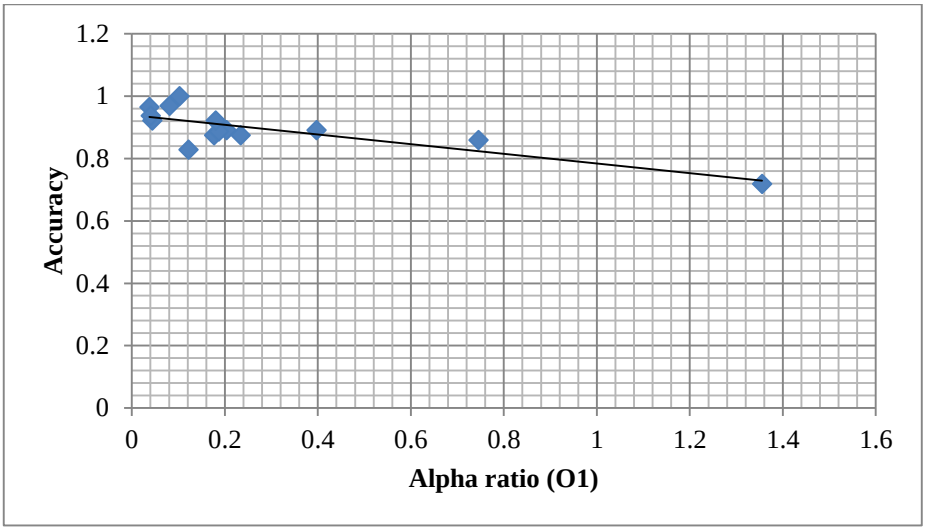

Figure 19: Plot between Go/No-GoP and Alpha ratio at O1

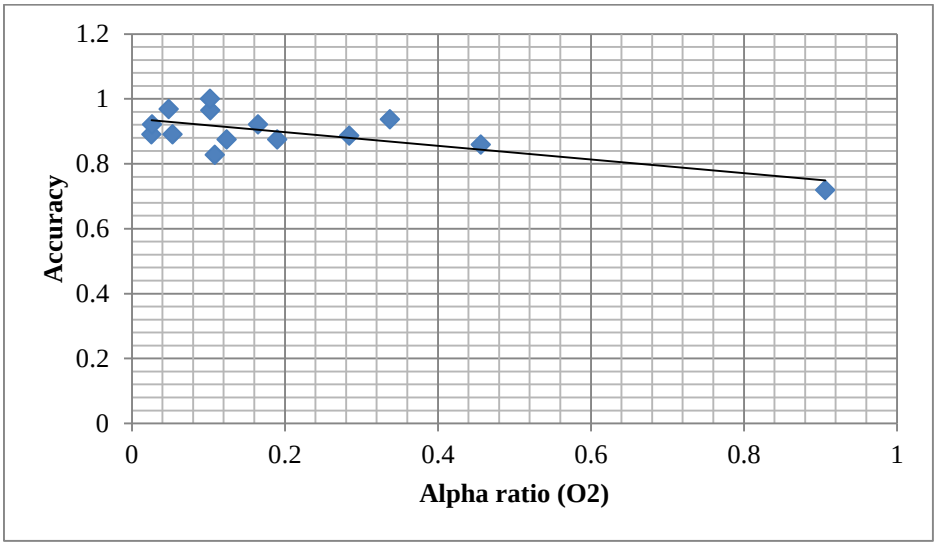

Figure 20: Plot between Go/No-GoP and Alpha ratio at O2

Conclusion

Pearson coefficient is calculated between scores/accuracy of tasks (PCPT and Go/No-Go) and the EEG alpha ratio. For PCPT, it is seen that alpha ratio bears a negative correlation with the task score. This correlation is observed to be strongly negative at FP1, FP2, F3, F4 and O2. For Go/No-Go also alpha ratio has a strong negative correlation with score at all the electrodes namely FP1, FP2, F3, F4, O1 and O2. Therefore we can conclude from our research that as the attention task performance increases, alpha ratio decreases. In other words, alpha ratio bears a negative correlation with attention task performance. This correlation is very prominent in pre-frontal, frontal and occipital regions of the brain. Alpha activity increases in the relaxed state and reduces in attention state. This fact is validated in this study.

Future Work

From our research it is observed that alpha ratio decreases as the attention task scores and accuracy increases. Thus alpha ratio can act as a physiological indicator for assessing attention. We can use alpha ratio for pre and post-intervention analysis of attention. Pre and post-intervention alpha ratios can be calculated for physiological attention assessment and comparative study can be done on the data to observe whether the intervention has enhanced attention or degraded it. In future we can find the mathematical relation between the task scores and alpha ratios which can used to determine alpha ratios from scores of PCPT and Go/No-Go and vice versa.

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