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Electroencephalographic changes during selective attention

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ABSTRACT

Background: Though many studies are conducted during attention process, it is still not clear how brain deals with attention. So we conducted a study to find out the electroencephalographic changes during selective attention. **Methods:** Thirty healthy right handed male students aged 23.1 ± 2.8 yrs were asked to read congruent (red printed in red ink) and incongruent (red printed in blue ink) words printed in cards. EEG was recorded for ninety seconds during baseline (eye open) and reading of both cards. EEG epoch was analyzed by fast fourier transformation. Friedman test was used to compare EEG power spectra among baseline, congruent and incongruent reading followed by Wilcoxon's Sign Rank Test. Data were expressed as median with inter-quartile range. **Results:** Compared to congruent test during incongruent test there was selective increment of theta power at Fz [36.04 (28.30-46.19) vs. 47.89 (31.65-48.1)], Cz [36.13 (27.20-46.41) vs. 45.66 (37.15-49.4)] and C4 [25.11 (19.14-30.06) vs. 30.16 (21.43-33.8)] sites but it decreased at F7 [17.88 (14.49-20.93) vs. 11.31(8.96-15.975)] and F8 [19.23 (13.61-25.79) vs. 13.95 (10.40-16.67) sites. Also during incongruent card reading, alpha1 power significantly decreased in F8 [3.39(2.63-4.63) to 2.75 (1.93-4.7)] and alpha 2 power significantly decreased in P3 6.84 [(4.88-10.46) to 5.74 (4.78-19.95)] sites. **Conclusion:** During selective attention, theta gets synchronized at fronto-central regions and alpha2 desynchronized at parietal regions. The theta and alpha1 at inferior frontal regions were also desynchronized in selective attention.

Key words: Selective attention, Theta, Frontal and central regions, Alpha 2 parietal region

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INTRODUCTION

Attention remains a major area of investigation within education, Psychology and neuroscience. CT, MRI, PET and EEG studies suggest activation of different brain areas when subjects perform different activities. EEG can be used as an effective tool for CNS arousal.[1] EEG is divided into delta, theta, alpha and beta bands. Studies have shown changes in these frequency bands during attention.

EEG studies have found associations of theta-band, mainly frontal midline theta with the performance of working memory, emotional states, attention processes and also during relief from anxiety.[2] Frontal midline theta has been shown to increase in high load task than low load task.[3] Event related desynchronization of alpha waves suggest cortical arousal during attention.[4] The alpha band has been considered to be an idling rhythmbut now it is proposed that increased alpha power may index the active inhibition of non-task relevant cortical areas during memory and attention tasks.[5] The post-movement beta synchronization is also interpreted as a correlate of idling motor cortex neurons.[6] Beta band is strongest from frontal lobes and is produced by visual stimuli and mental activity.[7] Though studies are conducted to see the activities of different EEG bands during attention, it is still not clear how the change in EEG waves explains attention process. Selective attention is also a type of

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attention which emphasizes the efficient encoding of relevant target in spite of potential overwhelming quantity of sensory information.[8] EEG tracings during selective attention also showed theta oscillations in the anterior cingulate cortex which increased with task difficulty[9] but it is still not clear how brain deals with selective attention. So, we conducted the study to observe the EEG changes during selective attention compared to normal reading. So as to fulfil our objectives, we used a classical version of stroop card which has congruent card [naming of a colour printed in a colour denoted by the name (red printed in red ink)] and incongruent card [naming of a colour printed in a colour not denoted by the name (red printed in blue ink).

MATERIALS AND METHOD

This cross-sectional experimental study was conducted on randomly selected thirty healthy right handed male undergraduate and post graduate students (n=30) of age group 23.1±2.8 years with normal eye sight having normal color vision. Subjects with history of medical illness, physical disability, seizure disorder, neurological disorder, color blindness, psychoactive substance abuse/misuse and any drug intake that might affect EEG were excluded from the study. After detailed medical history, physical examination subjects were familiarized with the laboratory setup and conditions. Digital EEG machine, its accessories (OLV-1100/1200 series, Nihon Kohden) and Classical Stroop cards (congruent and incongruent)[10] were used in the study. Procedure was explained to them followed by obtaining the consent. Ten sample words from both control and experimental cards were given to read to make the subject acquaint with procedure. Subjects were asked to sit down and feel comfortable in a chair for the placement of electrodes and subsequent procedure. Electrodes were placed according to International 10-20 system. Electrooculographic activity was recorded from electrodes located in the center of the supraorbital ridge above each eye, referenced to an electrode at the outer canthus of each eye. Once they were in place, the impedance of each electrode was checked for impedance to be less than 5 kilo-ohms. Time constant was maintained at 0.3Hz and high cutoff frequency was maintained at 70Hz.

Recording procedure

Before the beginning of experiment, subjects were asked to relax for 5 minutes. Baseline EEG was taken in eyes open condition for ninety seconds. During eye open condition the subjects were asked to stare at blank wall in front. Card was held in front of subject at about 50 cm from eye level. Then on the signal "1, 2, 3 go" the subjects were instructed to read aloud congruent words. Simultaneously, EEG record was taken for ninety seconds. After reading of control card was finished, subjects were asked to relax for 5 minutes. After relaxing, baseline eye open EEG record was taken. Then subjects were asked to read experimental incongruent card. All the procedures adopted were similar except the colors of the print of the words were to be read. (*red* word printed in *blue* color had to be called *blue*). All events (beginning and end) of each reading activity were marked on EEG to enable EEG epoch selection.

Data analysis

EEG waveforms were reduced and analyzed using "Focus" software (version 1.1). Initially, the records were visually inspected on the computer to check for eye blinks, detectable eye movements, and body movement artifacts during the procedure. After visual inspection, artifact free 3 sec epochs were selected at 20th, 40th, 60th and 80th sec from eye open, control and experimental condition. Thereafter Fast Fourier Transformation was performed on these data for decomposition of EEG waveform into sine wave components in terms of respective frequencies. The ethical clearance was received from the institutional ethical review board BPKIHS.

Statistical analysis

Median with interquartile range was obtained for theta alpha1, aplha2 and beta waves in all brain areas. Since our data was not normally distributed and it included more than two matched groups, first Friedman's analysis was used to compare power spectrum in different brain areas within same group. Afterwards Wilcoxon's Sign Rank Test was used to compare power spectrum of the bands between 1. eye open-congruent, 2. eyeopen -incongruent and 3. congruent- incongruent for only significant ones found from Friedman's test Stroop Test.

RESULTS

Compared with baseline, during both congruent and incongruent tests, theta power increased at Fz, C4, Cz and O1, F7 and F8 regions however increase in theta in Fz, C4, Cz, was even more significant during incongruent stroop test. Like in these regions power of theta also increased at F7 and F8 sites during both tests compared to baseline but in contrary theta power in these sites was significantly less during incongruent test than congruent test (Table 1, Figure 2, Figure 3, Figure 4). Similarly Alpha1 activity also increased in F7 and F8 regions during both tests compared to baseline but decreased activity at F8 during incongruent test was only in F8 region (Table 2, Figure 2, Figure 3, Figure 4).

Alpha 2 decreased at P4 and Pz sites during both tests compared to baseline. The decrement of alpha2 at these sites was significantly more during incongruent test. In addition there was significant decrease in alpha2 power at P3 region during incongruent test.

Beta was found to be increased at almost all sites during both tests except Fz, Pz Cz, P4 and P3 regions. But significant differences between two tests were not found. (Table 3, Figure 2, Figure 3, Figure 4).

DISCUSSION

Stroop test is a test of selective attention. Though some studies suggested frontal lobe acting as anterior

Table 1: Comparison of theta activities among eye open, congruent and incongruent tests

Electrodes sites	Eye open, (n=30) Power spectrum (μv^2) Median (interquartile range)		Congruent test, (n=30) Power spectrum (μv^2) Median (interquartile range)		Incongruent test, (n=30) Power spectrum (μv^2) Median (interquartile range)		p1	p2	p3	p4
Theta										
Fz	24.60	(21.13-38.26)	36.04	(28.30-46.19)	47.89	(31.65-48.1)	0.001	0.001	0.001	0.015
Cz	27.69	(20.34-38.73)	36.13	(27.20-46.41)	45.66	(37.15-49.4)	0.001	0.010	0.001	0.014
C4	16.54	(14.52-28.22)	25.11	(19.14-30.06)	30.16	(21.43-33.8)	0.001	0.018	0.001	0.007
F8	4.74	(3.73-7.42)	19.23	(13.61-25.79)	13.95	(10.40-16.67)	0.001	0.001	0.001	0.001
F7	6.30	(4.89-7.51)	17.88	(14.49-20.93)	11.31	(8.96-15.975)	0.001	0.001	0.001	0.001
O1	13.84	(11.51-18.91)	22.16	(17.61-32.70)	21.09	(17.28-28.1)	0.001	0.001	0.001	Ns

n=No. of subjects, p<.05=Significant, Overall comparison (p1) by Friedman's test and multiple comparisons between eye open and congruent test (p2), eye open and incongruent test (p3) and congruent and incongruent test (p4) by Wilcoxon's Sign rank test

Table 2: Comparison of alpha 1 and alpha2 activities among eye open, congruent and incongruent tests

Electrodes sites	Eye open, (n=30) Power spectrum (μv^2) Median (interquartile range)		Congruent test, (n=30) Power spectrum (μv^2) Median (interquartile range		Incongruent test, (n=30) Power spectrum(μv^2) Median (interquartile range)		p1	p2	p3	p4
Alpha1										
Pz	10.58	(6.98-18.28)	8.49	(6.39-13.92)	9.58	(6.2875-19.525)	0.015	0.010	Ns	Ns
Fp2	5.26	(4.31-7.33)	6.30	(5.27-10.74)	6.93	(5.10625-11.75)	0.03	0.028	0.02	Ns
F8	1.63	(1.23-2.04)	3.39	(2.63-4.63)	2.75	(1.93-4.7)	0.000	0.001	0.002	0.039
P4	9.34	(5.95-21.09)	6.83	(4.99-10.26)	7.48	(4.9625-16.7)	0.045	0.05	Ns	Ns
F7	2.05	(1.35-2.69)	3.32	(2.48-4.88)	2.96	(2.16-5.1)	0.03	0.002	0.010	Ns
Alpha2										
Pz	10.83	(7.51-24.98)	7.68	(6.44-11.51)	6.45	(4.98-23.125)	0.016	0.006	0.001	Ns
F8	1.44	(0.87-2.43)	2.55	(2.01-3.44)	2.20	(1.4375-3.525)	0.01	0.002	0.018	Ns
P4	9.93	(5.95-19.48)	7.43	(4.49-11.50)	5.94	(4.53-20.275)	0.005	0.009	0.001	Ns
F7	1.50	(1.01-2.18)	2.28	(1.73-2.64)	2.28	(1.83-3.225)	0.02	0.003	0.012	Ns
P3	8.28	(4.64-19.96)	6.84	(4.88-10.46)	5.74	(4.78-19.95)	0.016	Ns	0.002	0.006

n=No. of subjects, p<.05=Significant. Overall comparison (p1) by Friedman's test and multiple comparisons between eye open and congruent test (p2), eye open and incongruent test (p3) and congruent and incongruent test (p4) by Wilcoxon's Sign rank test

Table 3: Comparison of beta activities among eye open, congruent and incongruent tests

Electrodes sites	Eye open, (n=30) Power spectrum(μv^2) Median (interquartile range)		Congruent test, (n=30) Power spectrum(μv^2) Median (interquartile range)		Incongruent test, (n=30) Power spectrum(μv^2) Median (interquartile range)		p1	p2	p3	p4
Beta										
Fp2	15.26	(12.44-30.84)	25.75	(19.86-36.85)	26.45	(18.45-34.37)	0.001	0.001	0.001	Ns
F8	6.10	(4.52-9.18)	12.09	(10.56-15.95)	11.15	(8.07-14.70)	0.001	0.001	0.001	Ns
C4	16.73	(13.11-32.38)	25.06	(18.10-30.63)	23.19	(15.71-34.12)	0.001	0.004	0.010	Ns
T4	16.71	(9.90-36.36)	43.75	(21.80-68.98)	33.45	(14.79-48.42)	0.001	0.001	0.001	Ns
T6	12.64	(9.66-20.17)	27.31	(16.56-44.86)	21.94	(16.75-42.07)	0.001	0.001	0.001	Ns
Fp1	16.54	(11.41-26.79)	24.95	(18.86-33.55)	27.39	(20.95-31.47)	0.001	0.001	0.001	Ns
F7	6.31	(4.44-8.32)	9.70	(7.68-11.24)	9.25	(6.66-10.85)	0.001	0.001	0.001	Ns
F3	13.80	(12.04-23.24)	18.89	(14.71-26.19)	21.29	(14.61-27.82)	0.001	0.001	0.001	Ns
C3	15.49	(11.50-24.27)	19.56	(15.13-27.95)	20.03	(12.71-29.77)	0.002	0.027	0.003	Ns
T3	15.30	(5.84-33.18)	37.88	(15.24-59.18)	26.21	(13.55-53.07)	0.001	0.001	0.001	Ns
T5	12.46	(7.90-21.54)	20.40	(14.93-28.33)	18.28	(13.91-31.07)	0.001	0.001	0.001	Ns
O1	17.03	(12.78-26.56)	23.36	(16.96-30.02)	22.56	(18.16-30.12)	0.001	0.002	0.006	Ns

n=No. of subjects, p<.05=Significant Overall comparison (p1) by Friedman's test and multiple comparisons between eye open and congruent test (p2), eye open and incongruent test (p3) and congruent and incongruent test (p4) by Wilcoxon's Sign rank test

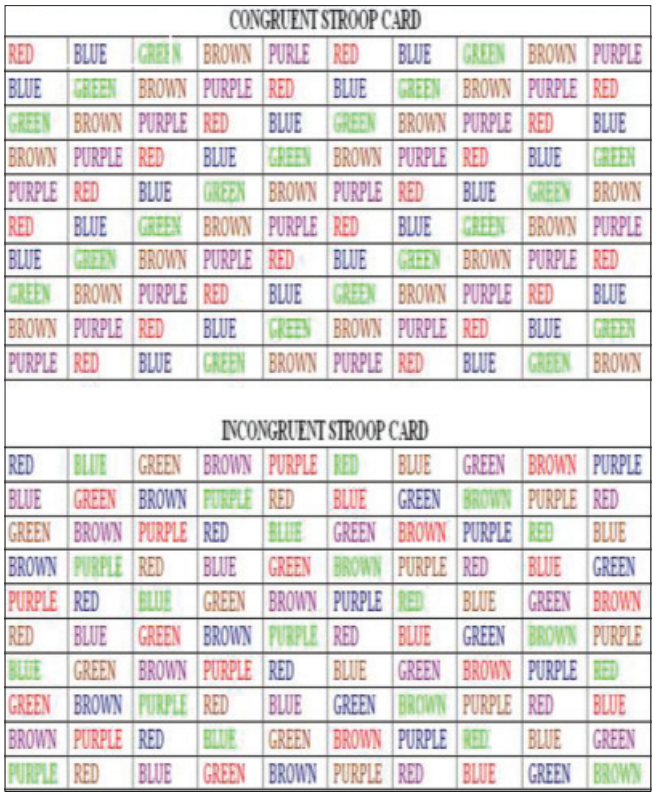

Figure 1: Congruent and Incongruent stroop test

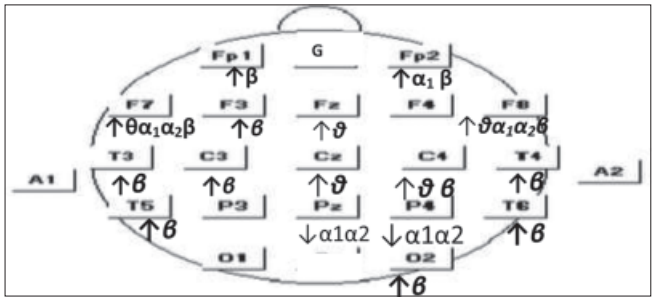

Figure 2: Baseline- congruent

network which is represented by production of theta waves and parietal lobe acting as posterior network which is represented by attenuation of alpha waves, there are still many controversies about how brain deals with selective attention. So, we conducted the study to observe what the changes in brain waves are during the selective attention.

So as to fulfil our objectives, our study was conducted on right handed 23.1±2.8 yrs male undergraduate and postgraduate students because the literature on handedness and hemisphericity has shown handedness related lateralization.[11] Also normal aging has shown changes in EEG with working memory process.[12] Therefore to reduce the confounding factors, right handed with narrow range of age were taken. For the same purpose males were taken because literature has shown that men and women have

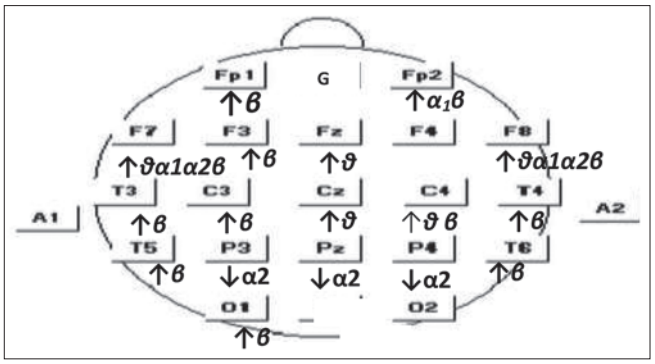

Figure 3: Baseline - incongruent

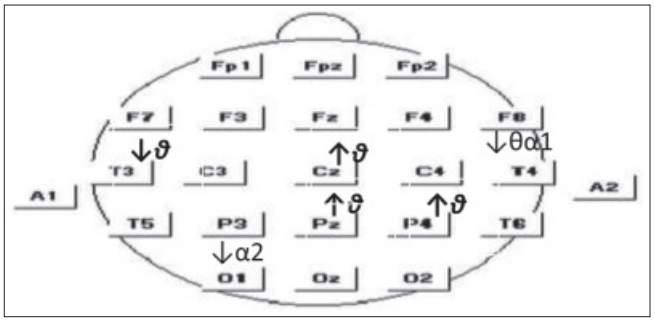

Figure 4: Congruent - incongruent

Brain area	Left	Midline	Right
Frontal pole	Fp1	Fpz (G)	Fp2
Frontal	F3	Fz	F4
Inferior frontal	F7		F8
Mid-temporal	T3		T4
Posterior temporal	T5		T6
Central	C3	Cz	C4
Parietal	P3	Pz	P4
Occipital	O1		O2

different hemispheric lateralization, dominant hemispheres and rates of intrahemispheric transfer.[13] Undergraduate and post graduate were selected because studies have shown that age, sex and education affects the performance during Stroop test.[14] Also all the subjects having colour blindness, seizure disorder, using or abusing any drugs were excluded as these are shown to affect EEG. EEG was taken for ninety seconds while reading the cards.

EEG changes during normal reading and selective attention

Our study showed theta power increased at Fz, C4, Cz and O1 regions during both tests and increment was even more during incongruent stroop test which is also supported by other studies where they have shown increase in theta-band, mainly frontal midline theta (fm theta) with the performance of working memory, emotional states, and attention processes. They have also shown frontal midline theta increased in high load task than low load task.[3, 15] But in our study mid central

and right central theta power also increased during incongruent stroop test. This suggests these areas may also be involved during selective attention.

Since increased alpha power (alpha synchronization) is regarded to represent the active inhibition of non-task relevant cortical areas and desynchronization reflects the gradual release of inhibition associated with the emergence of complex spreading activation processes[5], the increase of alpha1 at F7 and F8 and Fp2 sites during both tests suggest the active inhibition of these areas during both tasks.[4,15] The alpha1 power was more in congruent test and less in incongruent test in F8 region which might suggest it was released from active inhibition during incongruent test. The release from inhibition might be due to sudden exposure to unusual environment. This is also similar to other study which suggested increased alpha1 during easy task and decreased alpha power 1 with task difficulty.[16] Along with alpha 1, power of theta also increased at F7 and F8 sites during both tests. Like alpha1, theta power (synchrony) in these sites also was significantly more in congruent test and less in incongruent test. For this, studies should be carried out on different theta bands to find out which one predominates in frontocentral region and which one in F8, F7 regions.

Alpha2 decreased at P4 and Pz sites during both tests compared to baseline. There was significant decrease in alpha2 power at P3 region during incongruent test. Studies have suggested alpha suppression as involvement of that area.[4] So we can say that during selective attention P3 is activated even more.

Studies have also shown that alpha 2 predominates over occipital or occipito-parietal junction and sensitive to visuospatial factors whereas alpha 1 component predominates over parietal and dorsolateral prefrontal cortex and highly sensitive to cognitive load that a task imposes.[16] This is also consistent with our study as decrease in alpha2 was shown at parietal region which may be due to visuospatial factors. Though alpha1 also decreased in Pz and P4 region, it was only in congruent test but there was no change in incongruent test. In contrary, though both alpha1 and alpha2 increased in F7 and F8 region during both tests, only alpha1 significantly decreased at F8 sites suggesting alpha1 at right inferior temporal responds to more attention. But it needs more study.

Beta was found to be increased at almost all sites during both tests except Fz, Pz Cz, P4 and P3 regions. Significant differences in beta band were not found. One of the studies showed enhanced upper beta (25-30) Hz and suppressed mid beta (13-20) Hz activity mainly localized to posterior electrodes where mid beta suppression indicated increased attentional processes and memory demands.[17] But we did not divide beta into upper and lower beta so we did not have the similar result. Other studies have also shown beta activity during different attention tests which was not found in our study. It may be due to difference in types of tests.

CONCLUSION

During more selective attention, the theta waves at Fz Cz and C4 gets synchronized while desynchronizing alpha2 at parietal regions. The theta and alpha1 at inferior frontal regions were also desynchronized in incongruent test than congruent tests.

Limitation and future scope

We used the manual version of stroop cards, computerized version would have precisely recorded the point of selective attention. The decrease in theta and alpha 1 at inferior frontal regions should be studied even more.

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Authors Contribution:
NG – Designing and planning of the research, performed the laboratory tests, analysed the data, reviewed the manuscript; **BHP –** Designing and planning of the research, analysed the data, and reviewed the manuscript; **RK –** Designing and planning of the research analysed the data, and reviewed the manuscript; **PNS –** Designing and planning of the research & reviewed the manuscript; **AD –** Designing and planning of the research.

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