**Introduction**

The EEG is considered as building block of functional signaling in the brain. The role of EEG oscillations in human information processing has been intensively investigated. Brain oscillations at different frequencies in temporal and spatial domain, are considered as functional substrate for the higher-level information processing.

EEG power reflects the number of neurons that discharge synchronously, and is considered one of the markers of performance of cortical information processing. EEG oscillations in different frequency bands are associated with different cognitive processes. Alpha oscillations are considered as markers of attention, alertness and task load. Recent study findings suggest that alpha frequency play active role in storage of information in visual working memory and modulations of these oscillations predict successful short-term visual memory encoding. The Theta oscillations are associated with attentional processing and working memory operations.

Working memory (WM) may be conceptualized as the use of attention to manage the short-term memory load. Many variants of the Sternberg memory scanning paradigm have been used to study WM. Through the Sternberg memory paradigm, gradually increasing load of short term memory can be investigated. Quantitative EEG signal analysis can give insight into the global measure of functional brain states generated during gradually increasing load of short term memory. The present study explored the EEG signatures of dynamic global functional brain states induced during the Sternberg memory paradigm.

**Methods**

The study was conducted on 34 male healthy volunteers (age 18–30 years; mean ± SD, 24 ± 3.2). The participants with any history of substance abuse, smoking, alcohol, or those known to be having any medical disease or undergoing treatment for any medical condition were excluded. Ethical clearance for the study was taken from the ethics committee for human subjects. The participants were briefed about the study and informed written consent for participating in the study was obtained.

**Sternberg Memory Test (MEMSCAN)**

The program MEMSCAN runs a version of the Sternberg memory scanning paradigm. On each trial, a set of digits is first presented to be remembered. The memory set is then replaced by a plus-sign and, after a short delay, a probe digit. The subject’s task is to respond as quickly as possible whether the probe was a member of the memory set or not. The memory load in the task ranged from 1–6 digits.

**EEG signal acquisition and analysis**

Participants were asked to clean their head with shampoo without any conditioner or oil on the day of testing. An electrode impedance of less than 5 kohm was achieved by cleaning with alcohol swab followed by rubbing with “SKINPURE” skin preparation gel (supplied by Nihon Kohden). Silver-Silver Chloride (Ag-AgCl) disc type electrodes of 5–7 mm diameter with long flexible lead were placed on the scalp according to the 10–20 international system with the help of “Elefix” paste for EEG (supplied with Nihon-Kohden). EEG signal was acquired on RMS EEG-19 Superspec system at a sampling frequency of 256 Hz using high (0.5 Hz), low (99 Hz) and notch (50 Hz) pass filters.
**Signal analysis**

Signals were analyzed offline. Movement and eye blink artifacts were identified visually and the respective stretch of EEG was excluded from analysis. Ten epochs of 2 second duration were selected from artifact free region from Baseline eye open and during Sternberg memory test (MEMSCAN) condition. The outcome measures were FFT transformed absolute power in six bands at 19 electrode positions. Average of 10 epochs of eye open condition and Sternberg memory test were statistically compared and analyzed.

To overcome the problems of fixed band system, Individual Alpha Frequency (IAF) based frequency band division method was used. To determine IAF, FFT (Fast Fourier Transformation) was applied on baseline epochs at PZ electrode position. The peak power frequency among 8–12 Hz was designated as Individual Alpha Frequency. Frequency bands were determined individually for each subject by using IAF as the cut-off point between the lower and upper alpha band. Six EEG frequency bands were analyzed: (1) Theta band: IAF - 4Hz to IAF - 6 Hz (2) Lower 1 alpha band: IAF – 2 Hz to IAF - 4 Hz (3) Lower 2 alpha band: IAF to IAF - 2 Hz (4) Upper alpha band: IAF to IAF + 2 Hz (5) Beta band: IAF + 2 Hz to 30 Hz (6) Gamma band: 30 Hz to 99 Hz. Average of 10 epochs of different conditions were analyzed for Absolute Power (AP) which is Root mean area under power spectrum of a given band, expressed in microvolts squared.

**Statistical Analysis**

The statistical analysis was done using STRATA Software. The distribution of the data was found to be non- Gaussian type; therefore non parametric test (Wilcoxon Signed-rank) was applied. Comparison of MEMSCAN and Basal Eye Open data (Absolute Power) was done by paired t-test, and the p value less than 0.05 was considered significant and has been represented as * and p<0.01 as **.

**Results**

In the present study Sternberg memory test was selected as intervention for the short term memory load. EEG powers in various bands during short term memory load were compared with eye open alert state of recording. Findings in different frequency bands are as follows (Table 1):

**Theta band**

Short term memory load showed increased absolute power mainly in the Fronto-Temporal regions (F3, FZ, F4, and T6) of theta band only. Rest of the electrode positions did not show any significant change.

**Lower 1 alpha band**

Short term memory load showed increased absolute power mainly in the Fronto-Central regions (F4, C4) only. Rest of the electrode positions did not show any significant change.

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**Table 1: Effect of short term memory load on Absolute Power as compared to basal eye open alert condition:**

| Electrode | Theta | L1 Alpha | L2 Alpha | U Alpha | Beta | Gamma |
|-----------|-------|----------|----------|---------|------|-------|
| FP1       |       |          |          |         |      |       |
| FP2       |       |          |          |         |      |       |
| F3        | +*    |          |          |         |      |       |
| FZ        | +**   |          |          |         |      |       |
| F4        | +*    | +**      |          |         |      |       |
| F7        |       |          |          |         |      |       |
| F8        |       |          |          |         |      |       |
| C3        |       |          |          |         |      |       |
| CZ        |       |          |          |         |      |       |
| C4        | +*    |          |          |         |      |       |
| T3        |       |          |          |         |      |       |
| T4        |       |          |          |         |      |       |
| T5        |       |          |          |         |      |       |
| T6        | +**   |          |          |         |      |       |
| P3        |       |          |          |         |      |       |
| P2        |       |          |          |         |      |       |
| P4        |       |          |          |         |      |       |
| O1        |       |          |          |         |      |       |
| O2        |       |          |          |         |      |       |

(+) Indicates an increase and (-) indicates a decrease.

p value less than 0.05 is represented as * and p<0.01 as **
Upper alpha band

Short term memory load showed decreased absolute power in most of the electrode positions (FP1, F7, F3, F4, C3, C4 T3, T4, T5, T6, O1, O2) of the upper alpha band, however power of FP2, FZ, F8, CZ, P3, PZ and P4 electrode positions did not show any significant change.

Lower 2 alpha, Beta and Gamma band

Short term memory load showed no significant power change as compared to basal eye open alert condition in Lower 2 alpha, Beta and Gamma band in all electrode positions.

Discussion

In the present study, Sternberg memory was selected as a model of short term memory load. The task of Short term memory load was associated with interesting pattern of power changes in various alpha and theta bands. We found decreased power in Upper alpha band and increased power in Theta band & Lower 1 alpha band (Fronto-Central region) during the task. While Lower 2 alpha, beta and Gamma band power remained unchanged.

Since the work of Hans Berger (1873–1941), Alpha waves represent wakeful relaxation state, predominantly originating from the occipital lobe of brain. Recent studies of IAF based Alpha sub band (Lower 1 alpha, Lower 2 alpha and Upper alpha band) show significant active power changes during the performance of tasks. The different sub bands within the Alpha frequency may reflect different aspects of the memory task, like attention, sensory-semantic processing and active storage of information.13,4

Frontal midline theta has been reported during WM tasks17 attentional processes18-19 and tasks requiring memory retention & mental imagery.18 Lower 1 alpha band represent an index level of internalized attention, alertness and expectancy.19 In our Sternberg memory task alertness, expectancy and internalized attention are the key cognitive processes. Thus increased power in Theta and Lower 1 alpha band in present study may reflect the neural basis of dynamic functional signaling required during the execution of short term memory load. On the other hand decreased power in Upper alpha band may be reflective of desynchronization in neuronal assembly caused by superimposed gradual building up of mental stress and performance anxiety with the progression of task.

In present study we have found no significant changes in the power of Beta and Gamma bands. Gamma oscillations are important building blocks of synchronization of electrical activity of the brain and reflect local processing within short-range connections.20-21 No change in Frontal Gamma especially over the Frontal and Central areas is suggestive of fall in attention during heavy attention demanding task.21 Gradual fall in attention may be result of mental stress and fatigue with progression of task.

The EEG changes showed an interesting pattern which was quite different than wakeful alert state. An increase in the Theta power suggests increased memory load during the memory task. Theta power rises sharply when working memory is required, maintained throughout the memory task, and decreases when working memory is no longer required.22,4 A decrease in Upper alpha power compared to eye open resting condition suggests an increase in semantic memory related desynchroni-
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