Sustained Driving Attention
Online Summer Research Internship

IN

Center for Cognitive Computing
IIIT Allahabad

Submitted By-
Darshvir Singh Grewal
SRIP_2020_R08

UNDER THE SUPERVISION OF
Prof U.S. Tiwari
Professor
Mr. Mohd Asif
Mentor
IIIT Allahabad

INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, ALLAHABAD
(A UNIVERSITY ESTABLISHED UNDER SEC.3 OF UGC ACT, 1956 VIDE NOTIFICATION NO. F.9-4/99-U.3 DATED 04.08.2000 OF THE GOVT. OF INDIA)
A CENTRE OF EXCELLENCE IN INFORMATION TECHNOLOGY ESTABLISHED BY GOVT. OF INDIA

30th July 2020

CANDIDATE’S DECLARATION

I hereby certify that the work which is being presented in the report, entitled “Sustained Attention Driving” being submitted as a part of Summer Research Internship Programme, 2020; Centre for Cognitive Computing, Indian Institute Of Information Technology, Allahabad, is an authenticated record of my original work, thus far, under the guidance and supervision of Prof. U.S. Tiwari from 21.05.2020 – 30.07.2020. I have adequately cited and referenced the original sources and have adhered to all principles of academic honesty and integrity.

Date : 30th July 2020
Signature:

Darshvir Singh Grewal
(SIRP_2020_R8)

CERTIFICATE

This is to certify that the statement made by the candidate is correct to the best of my knowledge and belief. The project entitled “Sustained Attention Driving” is a record of the candidates’ work carried out by them under my guidance and supervision. I do hereby recommend that it should be accepted in the fulfillment of the requirements of the Summer Research Internship Programme, 2020; Centre for Cognitive Computing, Indian Institute Of Information Technology, Allahabad.

Prof. U.S. Tiwari,
IIIT Allahabad,
July 30,2020.

ACKNOWLEDGEMENT

I would like to acknowledge and extend our heartfelt gratitude to Prof. U.S. Tiwari, Indian Institute of Information Technology Allahabad, who guided us through this project. His keen vital encouragement, superb guidance, and constant support are the motive force behind this project work. I would also like to extend my warm thanks to Mr. Mohd Asif, who has been there to guide me as well, through thick and thin. I also thank my group mate for the enriching discussions we have had in the course of this project.

Darshvir Singh Grewal
(SIRP_2020_R08)

INDEX

1. INTRODUCTION

Human brain consists of millions of neurons which are playing an important role for controlling behaviour of human body with respect to internal/external motor sensory stimuli. These neurons will act as information carriers between human body and brain. Understanding cognitive behaviour of brain can be done by analyzing either signals or images from the brain. Human behaviour can be visualized in terms of brain such as eye movement, lip movement, remembrance, attention, hand clenching etc. These states are related with specific signal frequency which helps to understand functional behaviour of complex brain structure. **Electroencephalography (EEG)** is an efficient modality which helps to acquire brain signals corresponds to various states from the scalp surface area. These signals are categorized as alpha, beta, gamma, delta based on signal frequencies ranges from 0.1 Hz to more than 100 Hz.

Brain is a significant part of human body which controls entire parts of human body. Brain can be viewed as collection of interconnected neurons which decides human behaviour. Brain images/signals can be acquired by using modalities such as, Computed Tomography (CT), Positron Emission Tomography (PET), Magnetic Resonance Imaging (MRI) and Functional Magnetic Resonance Imaging (fMRI). Electroencephalography (EEG) is another modality which helps to analyse brain and its behaviour based on respective frequency of a signal. A significant characteristics of EEG includes, non destructive, pain less, side effect less and accurate interpretations for some brain diseases such as epilepsy, memory loss, Alzheimer and autism.

1.1 EEG and Lobes of Human Brain

Brain is the most important functional organ, which controls and coordinates other muscles and nerves in our body. Brain is divided into two hemispheres known as left hemisphere and right hemisphere. Each hemisphere is further divided into four lobes known as Frontal, Temporal, Parietal and Occipital lobes. Left frontal lobe is responsible for speech and language. It is concerned with planning, organizing, problem solving, memory, impulse control, decision making, selective attention and controlling behaviour and emotions. Frontal lobe gets damaged it may effect emotions, languages and memory.

Temporal lobe is responsible for sound and speech in various aspects of memory. It may create hearing, language and sensory problems during damage. Occipital relates perception and process visual information. It creates visual and perception defects after getting injury on this part. Parietal lobe integrates sensory information from different parts of body. It may create the inability problem for recognize and locate parts of body.

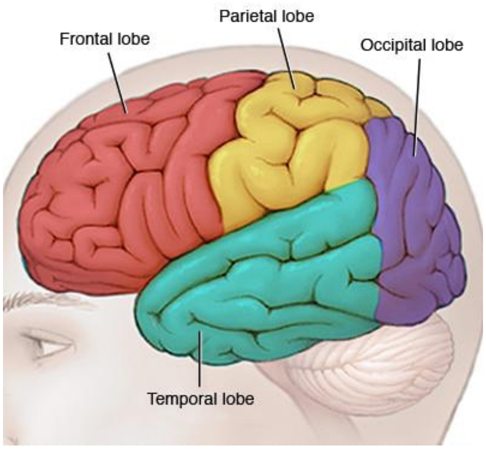


Fig 1

From the medical history, it is well known that specific action/ activity/ states are controlled by particular part of the brain. For example, table 1 represents cranial nerve and its associative functionalities. Functional behaviour of brain and their associated location are helpful to determine electrode position for EEG recordings.

S.No.	NAME	FUNCTION
1.	Olfactory	Smell
2.	Optic	Vision
3.	Oculomotor	Eye movement
4.	Trochlear	Eye movement
5.	Trigeminal	Facial sensation
6.	Abducent	Eye movement
7.	Facial	Face movement
8.	Vestibulocochlear	Hearing and balance
9.	Glossopharyngeal	Taste
10.	Vagus	Involuntary muscles
11.	Accessory	Voluntary neckmuscle
12.	Hypoglossal	Tongue movement

Table 1:Function of Cranial Nerves

1.2 EEG Device and Its Characteristics

Electroencephalography (EEG) is a technique that reads electrical potential from the brain and measured using special device called Electroencephalogram (EEG). This device comprised of electrodes, conductive gel, amplifiers and Analog to Digital converter. The electrodes or leads are used to conduct electrical activity from the scalp of the brain. Different types of electrodes are used in general for EEG analysis. One type of electrode is reusable disk. These electrodes placed on the scalp with small amount of conductive gel (Ag-Cl) applied under the disk. Disk will be with gold, tin and silver compositions. The cost of the electrode is low and life may depend upon metal used on disk and insulating medium on wire. These electrodes have chance to fall down from the scalp which leads to higher chances of artifacts. EEG cap is another type, which is having facility to choose different number of electrodes and types of electrodes. EEG cap is also available with reusable disks where conductive gel will be injected on the holes of scalp. It is preferred for multichannel recording but a complex issue in this cap is that one electrode gets fail results in changing the whole cap and it is also difficult to trace the failed one.

Fig 2

Fig 3

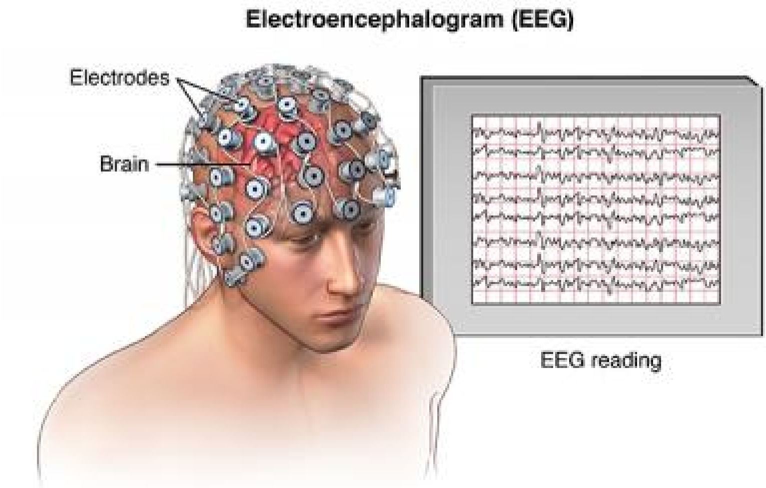


Fig 4

1.3 EEG Atlas Versus Lobes of Human Brain

The electrodes are arranged according to 10-20 standards for EEG placement. These electrodes are labeled by letters (i.e. F-Frontal, T-Temporal, P-Parietal, O-Occipital) which indicates the lobes of the brain. Midline region is referred by a label 'z'. Odd numbers indicates left hemisphere and even numbers are used to indicate right hemisphere. An additional sensor is used to record special applications such as, heart rate, skin conductance, eye movements and respiration.

Cortex around Cz, C3 and C4 locations deals with sensory and motor functions. Pz, P3 and P4 are related to cognitive processing. T4 and T6 represent emotional memory while T3 and T5 stands for verbal memory functions. Oz, O1, O2 deals with visual processing stimuli. Fz is placed near intentional and motivational centers, F8 and F7 are located close to emotional and verbal expressions. F3 and F4 are located at motor planning activities. FPz, FP1 and FP2 deals with attention and judgment impulses.

The positioning of electrodes also referred as Montages follows methods such as, Referential or bipolar electrodes. In Referential method, each electrode records the potential difference compared to reference electrode. The reference electrode is not perfect while placing it on nose tip or foot. Reference electrodes are placed on both Ear lobes called as linked ear lobes. In bipolar method, potential differences are recorded between paired active electrodes.

2. OJECTIVE

Driving safety has attracted public attention due to the increasing number of road traffic accidents. Risky driving states, such as fatigue and drowsiness, increase drivers' risk of crashing, as fatigue suppresses driver performance, including awareness, recognition and directional control of the car. In particular, high levels of fatigue and drowsiness diminish driver arousal and information processing abilities in unusual and emergency situations.

During a sustained-attention driving task, fatigue and drowsiness are reflected in driver behaviour and brain dynamics. Furthermore, electroencephalography (EEG) is the preferred method for human brain electro-physiological monitoring while performing tasks involving natural movements in a real-world environment.

Main objective of this study is to observe how neurocognitive state of driver varies during sustained attention situation broadly by the means of comparing the neurocognitive state of driving when reaction time of driver was less than 0.5 seconds to the neurocognitive state when reaction time exceeded 3 seconds.

2.1 METHOD

Driver behaviour and brain dynamics acquired from a 90-minute sustained-attention task in an immersive driving simulator. The data included 62 sessions of 32-channel electroencephalography (EEG) data for 27 subjects driving on a four-lane highway who were instructed to keep the car cruising in the centre of the lane. Lane-departure events were randomly induced to cause the car to drift from the original cruising lane towards the left or right lane. A complete trial included events with deviation onset, response onset, and response offset. The next trial, in which the subject was instructed to drive back to the original cruising lane, began 5–10 seconds after finishing the previous trial.

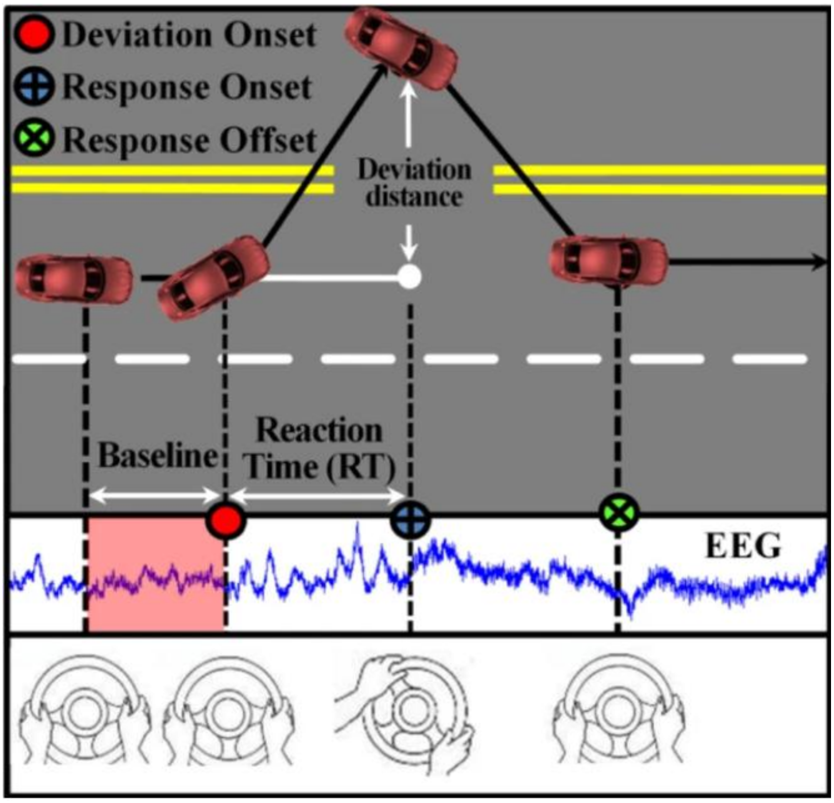


Fig 5

To acquire the experimental dataset an event-related lane-departure paradigm in a virtual-reality (VR) dynamic driving simulator was adopted to quantitatively measure brain EEG dynamics along with fluctuations in behavioral performance. All of the participants were required to have a driving licence, and none of them had a history of psychological disorders. The 32-channel EEG signals and vehicle position were recorded simultaneously, and all of the participants were instructed to sustain their attention in this driving experiment.
EEG signals were obtained using the Scan SynAmps2 Express system (Compumedics Ltd., VIC, Australia). Recorded EEG signals were collected using a wired EEG cap with 32 Ag/AgCl electrodes, including 30 EEG electrodes and 2 reference electrodes (opposite lateral mastoids). The EEG electrodes were placed according to a modified international 10–20 system. The contact impedance between all electrodes and the skin was kept under 5 kΩ. The EEG recordings were amplified by the Scan SynAmps2 Express system (Compumedics Ltd., VIC, Australia) and digitised at 500 Hz (resolution: 16 bits). Neuroscan's Scan 4.5 is the ultimate tool for data acquisition. The acquired raw data were saved as .cnt files on the PC and server.

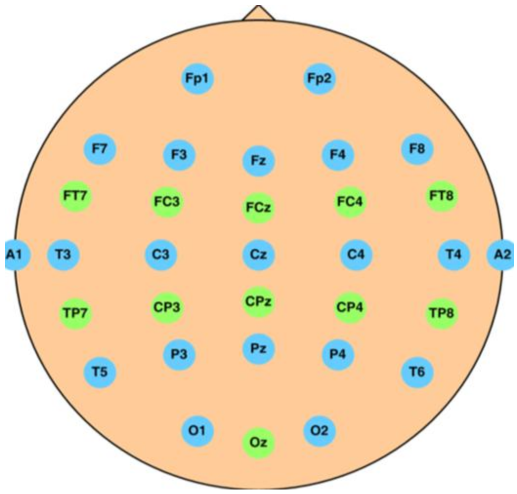


Fig 6

Twenty-seven voluntary participants (age: 22–28 years) who were students or staff of the National Chiao Tung University were recruited to participate in a 90-minute sustained-attention driving task at multiple times on the same or different days. In total, 62 EEG data sets were collected from these participants. The participants had normal or corrected-to-normal vision. In addition, none of the participants reported sleep deprivation in the preceding weeks, and none had a history of drug abuse according to the self-report. Every participant was required to have a normal work and rest cycle, get enough sleep (approximately 8 h of sleep each night) and not stay up late (no later than 11:00 PM) for a week before the experiment. Additionally, the participants did not imbibe alcohol or caffeinated drinks or participate in strenuous exercise a day before the experiments. At the beginning of the experiment, a pre-test session was conducted to ensure the participants understood the instructions and to confirm that none were affected by simulator-induced nausea.

2.1.1 EXPERIMENTAL PARADIGM

A VR driving environment with a dynamic driving simulator mounted on a six-degree-of-freedom Stewart motion platform was built to mirror reality behind the wheel. Six interactive highway driving scenes synchronized over local area networks were projected onto the screens at viewing angles of 0°, 42°, 84°, 180°, 276° and 318° to provide a nearly complete 360° visual field. The dimensions of the six directional scenes were 300 × 225 (width × height) cm, 290 × 225 cm, 260 × 195 cm, 520 × 195 cm, 260 × 195 cm, and 290 × 225 cm, respectively.

As shown in Fig 7, the experimental scenario involved a visually monotonous and unexciting night-time drive on a straight four-lane divided highway without other traffic. The distance from the left side to the right side of the road and the vehicle trajectory were quantised into values from 0–255, and the width of each lane was 60 units. The refresh rate of the scenario frame was set to emulate cruising at a speed of 100 km/hr. A real vehicle frame (Make: Ford; Model: Probe) that included no unnecessary weight (such as an engine, wheels, and other components) was mounted on a six-degree-of-freedom Stewart motion platform (Fig. 1d). In addition, the driver's view of the VR driving environment was recorded and is shown in Fig 7.

An event-related lane-departure paradigm was implemented in the VR-based driving simulator using WorldToolKit (WTK) R9 Direct and Visual C++. The paradigm was designed to quantitatively measure the subject's reaction time to perturbations during a continuous driving task. The experimental paradigm simulated night-time driving on a four-lane highway, and the subject was asked to keep the car cruising in the centre of the lane. The simulation was designed to mimic non-ideal road surface that caused the car to drift with equal probability to the right or left of the third lane. The driving task continued for 90 minutes without breaks. Drivers' activities were monitored from the scene control room via a surveillance video camera mounted on the dashboard. Lane-departure trials were obtained from experimental data collected from 2005 to 2012 at National Chiao Tung University, Taiwan.

Lane-departure events were randomly induced to make the car drift from the original cruising lane towards the left or right sides (deviation onset). Each participant was instructed to quickly compensate for this perturbation by steering the wheel (response onset) to cause the car move back to the original cruising lane (response offset). To avoid the impacts of other factors during the task, participants only reacted to the lane-perturbation event by turning the steering wheel and did not have to control the accelerator or brake pedals in this experiment. Each lane-departure event was defined as a "trial," including a baseline period, deviation onset, response onset and response offset. . Of note, the next trial occurred within a 5–10 second interval after finishing the current trial, during which the subject had to maneuverer the car back to the centre line of the third car lane. If the participant fell asleep during the experiment, no feedback was provided to alert him/her.

The reaction times (RTs) reflecting the participant's promptness to respond to regular traffic events are considered an instantaneous measure of the level of fatigue and drowsiness. The RT to each lane-departure event (i.e., the time between the onset of the deviation and the onset of the response) was used as an objective behavioral measurement to characterize all EEG epochs.

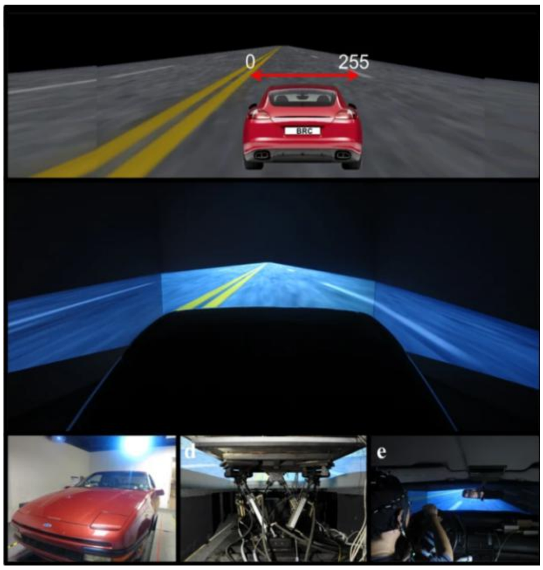


Fig 7

3. LITERATURE SURVEY

Sr. No.	Title	Year	Journal/Conference	Objective
1.	Analysis of Electroencephalography (EEG) Signals and Its Categorization	2012	International Conference on Modeling, Optimization and Computing (ICMOC 2012)	Getting familiarized to concept of EEG Analysis
2.	Artifact Removal from EEG Signals using Adaptive filters in cascade	2007	Journal of Physics: Conference Series	Theory behind artifact removal
3.	Artifact Removal from EEG Signals	2013	International Journal of Computer Applications	Sources of noise, Use of FIR filters
4.	Independent Component Analysis of Electroencephalograp-hic Data	1996		Use of ICA to correct EEG Data

4. DATASET

Experiment was performed on 27 subjects and in 62 sessions due to large size of each dataset only 14 datasets were used named as:

- s01_051017m
- s02_050921m
- s04_051130m
- s06_051119m
- s09_060313n
- s11_060920_1n
- s12_060710_1m
- s13_060217m
- s14_060319m
- s22_080513m
- s23_060711_1m
- s31_061020m
- s35_070115m
- s48_080501n

Reason for using these many datasets is because it is often advised to use about 15 datasets for a particular study if clustering (explained later) is involved in process of obtaining useful information. These datasets are publicaly available at this link.

5. SOFTWARE, ENVIRONMENT AND TOOLBOX USED

- MATLAB R2019a
- Windows 10
- EEGLAB Plugin
- Dipfit v3.3
- Fieldtrip-2019206

  Change was made at line number 145 of ft_version.m script of fieldtrip-2019206 where
  ftver = a.Version();
  was changed to
  ftver = a;
  This was because of the reason error message was being displayed during dipole fitting process of EEGLAB.

6. PREREQUISITES

- Critical reasoning and thinking
- Being curious and skeptical about the (discovered) results
- Basic MATLAB script coding ability
- EEGLAB usage
- English communication skill
- C language programming (suggestion)

7. METHODOLOGY

Each dataset was recorded using 33 channels and vehicle position was also recorded simultaneously at 500 Hz sampling rate. Dataset was first called and loaded as a structure named EEG. Few important aspects of EEG structure to start were EEG.trials which was initially one, it stores number of epochs, EEG.srate it stores sampling rate (500 Hz initially), EEG.data it stores actual electrode reading in a matrix of channels X times (EEG.times contains the time at which data was collected). EEG.events it contains the information regarding different events created by stimuli environment which also includes time at which a particular event occurred and latency of the event.

In EEG.events 251/252 depicts the deviation onset, 253 represents response onset and 254 is the response offset and are shown in vertical bars of green, red, purple and blue color in raw data. Time difference between 251/252 (deviation onset) and 253 (response onset) is the reaction time. To start of the process we need to add filename and filepath (where dataset is stored).First channels to which whole EEG dataset is referenced too were removed. Namely in this study A1 and A2 were removed. After loading the dataset, dataset was passed through a high pass basic FIR filter with 0.5 Hz as the threshold and then dataset obtained from previous process is passed through a low pass basic FIR filter with 50 Hz. Filtering is done to remove the slow and possibly large amplitude data components. Then dataset was downsampled from 500 Hz to 250 Hz this is because dataset with 500 Hz is too heavy for further processing. Initially when dataset is loaded the channel locations in EEG structure, channel locations are important because it helps in relating data collected from a particular channel to portion of head where electrode was initially placed. Without channel locations it is not possible to ICA and study scalp maps.

EEG data obtained so far is continuous our objective is to find the cognitive behaviour of human brain when reaction time during driving task is low(<0.5 secs) and when it is high(>3 secs).Therefore, this EEG data needs to be segmented depending upon different events. Dataset is first segmented into 8 second epochs, 1 second preceding to 7 seconds following deviation onsets. After segmentation EEG.trials get updated and its value corresponds to number of epochs present and then this dataset was saved. From the parent dataset again the segmented dataset were obtained this time these were 2 seconds preceding response onset and response offset and 4 second preceding these offset. These datasets were then saved into different files for further analysis.

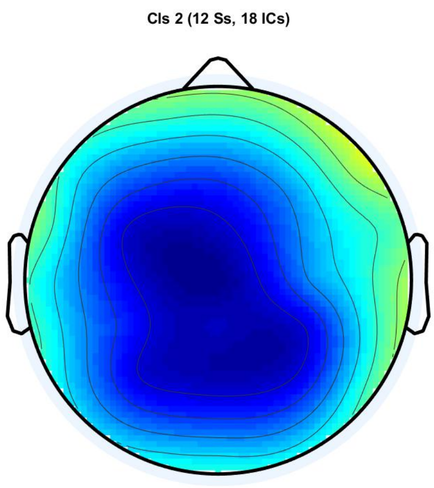
Segmented dataset obtained from the previous steps contains a lot of artifacts. Since the actual EEG signals are quite weak therefore, they tend to get distorted due to variety of reasons. Few of these reasons are muscle activity, eye blinks, channel noise, line noise and even heart activity can also cause artifacts. These artifacts are required to be removed before further analysis because we may get deviated from the desired results. Mode of artifact rejection in this study was by manual means. This means one need to examine the segmented data epoch by epoch and remove the epochs wherever there are large drifts or epochs having unnecessary peaks in any part of it. Epochs were the data lines formed zig-zag patterns and when data was not stable before deviation onset and after response offset were also removed. This whole process was carried out on the dataset segmented on the basis of deviation onset. After artifact rejection reaction times of different epochs were calculated and saved in a different file.

After manual artifact rejection dataset is ready for running ICA (Independent Component Analysis). ICA was applied to multichannel EEG dataset in order to remove wide variety of artifacts from EEG records by eliminating the contributions of artifactual sources onto the scalp sensors. For our study we have used jader algorithm. ICA helps to find unmixing matrix W, which decomposes or linearly unmixes the matrix, x into a sum of maximally temporally independent and spatially fixed components u, where $u = Wx$. The rows of the output data matrix, u, are time courses of activations of the independent component (IC). After running ICA we obtain scalp maps of different independent components. From these scalp maps independent component related to brain processes were again fed to from the command window in order to do dipole fitting. Dipole fitting is used to

determine from where a particular signal is originated from inside brain. Dipole fitting was done using automated dipole fitting. It is important to note that only independent components related brain were made to undergo dipole fitting because we only need these independent components for further analysis. After dipole fitting the dataset was saved and the variables containing information about ICA weights, activations were also updated in the other two datasets.
This results in obtaining 178 independent components obtained from all the 14 subjects. Independent components where then clustered on the basis of scalp maps, dipole locations, ERSP and ITC using K-means. This divided these independent components into 13 different clusters. However, few clusters contained lesser number of independent components. Clusters containing less number of components were not taken into account for further study. Therefore, we got 7 clusters containing independent components which had similar characteristics. For each cluster EEG data for different components were concatenated together in two different arrays. One array contained data of epochs whose reaction time was less than 0.5 seconds and second array contained data of epochs whose reaction time was greater than 3 seconds. In order to study alpha, beta, gamma and delta activities ERSP plots of both arrays for a particular components was plotted using newtimef() function, which is an inbuilt function of EEGLAB toolbox. While using newtimef() function 0.5 Hz and 20 Hz were chosen as frequency limits. Frequency scale was chosen to be log scale. Wavelets were used to obtain the power spectrum with wavelet cycles increasing frequency beginning at 3rd cycle with a factor of 0.8. Plot ERSP parameter was set to be ON in order to plot ERSP images to study the brain activity at different frequencies. This functions also returns the baseline power spectrum that was removed in each window to compute ERSP, ERSP data that is matrix of log spectral shifts and frequency bins centers. It also returns time frequency decomposition of single trials under tfdata.

8. OBSERVATIONS

8.1 CLUSTER 2



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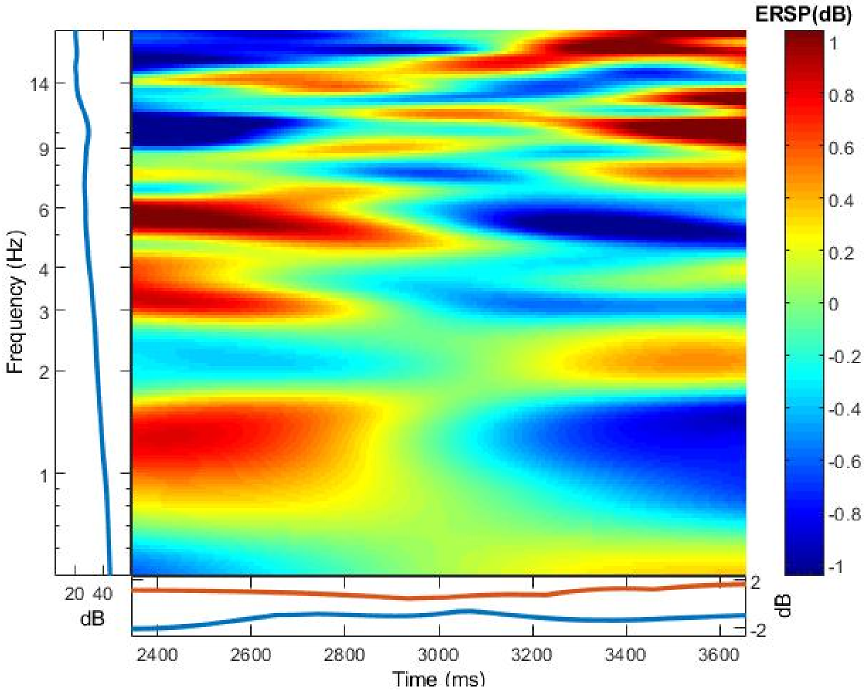

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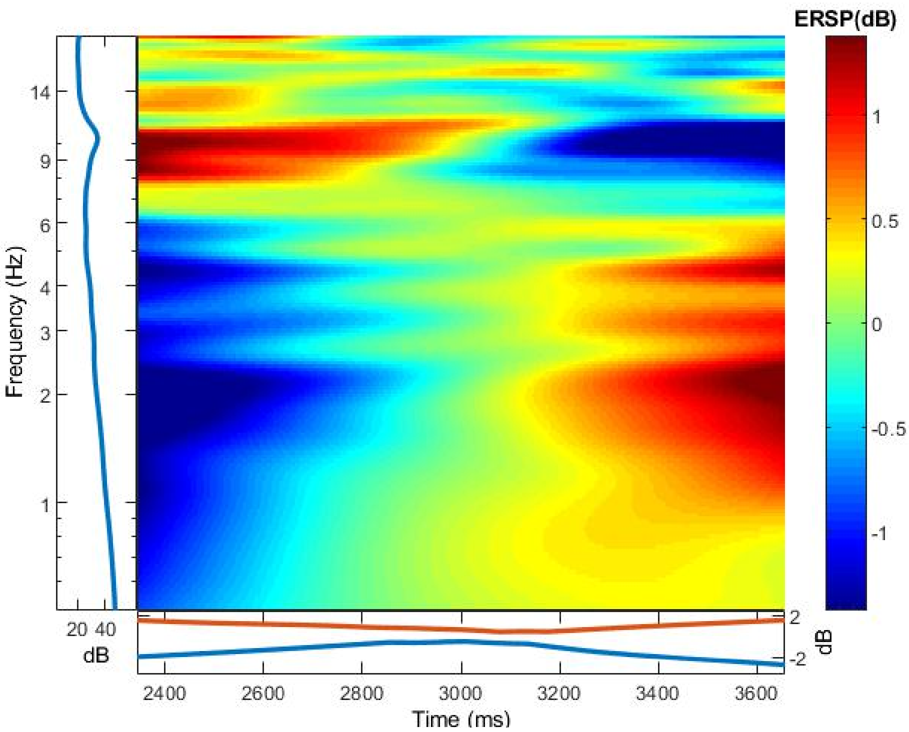
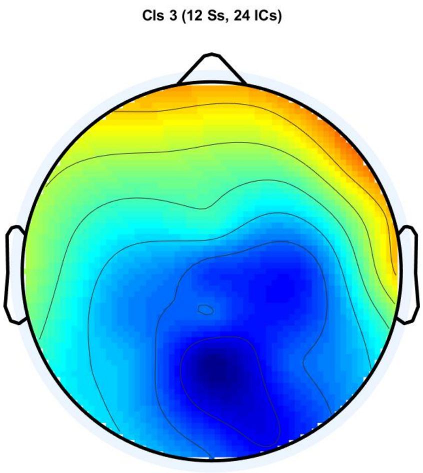


(c)

Fig (a) Scalp Map of Cluster 2
(b) ERSP Plot of Cluster 2 with Reaction Time<0.5
(c) ERSP Plot of Cluster 2 with Reaction Time>3

8.2 CLUSTER 3



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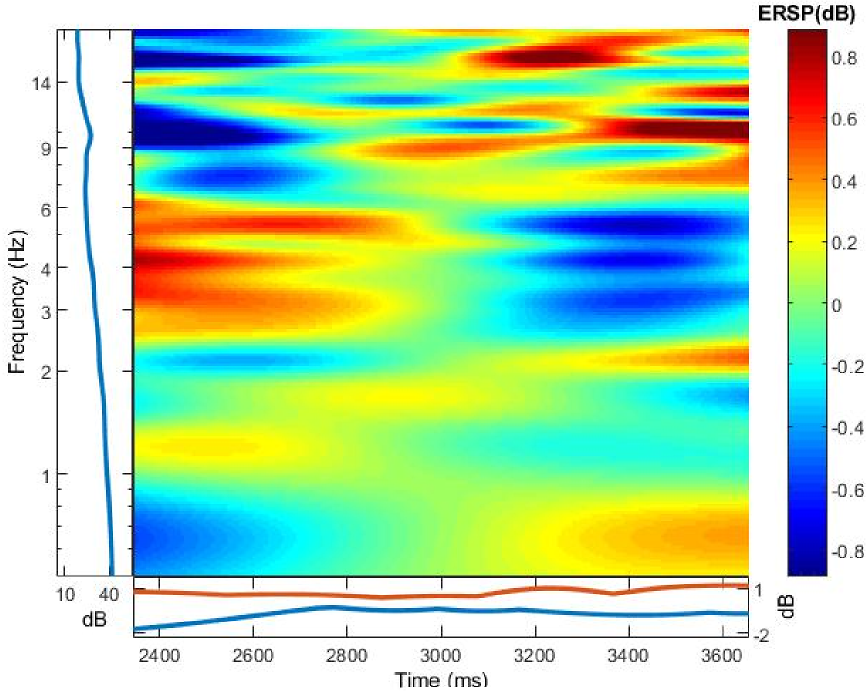

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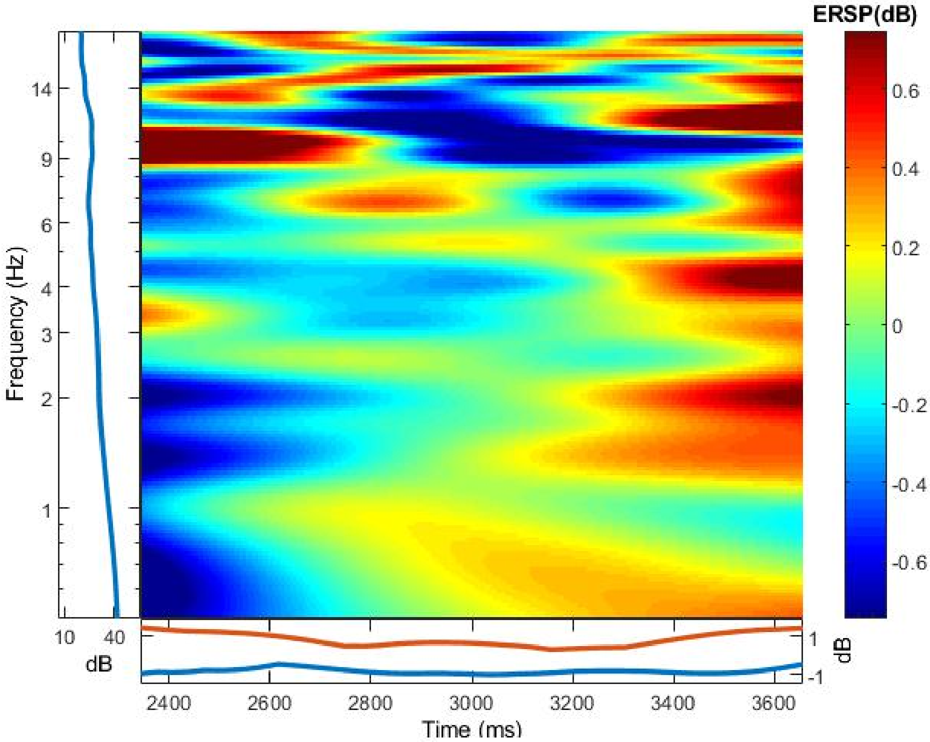

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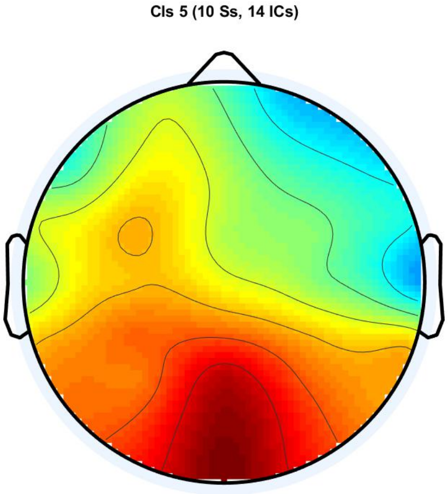
Fig (a) Scalp Map of Cluster 3
(b) ERSP Plot of Cluster 3 with Reaction Time<0.5
(c) ERSP Plot of Cluster 3 with Reaction Time>3

8.3 CLUSTER 5



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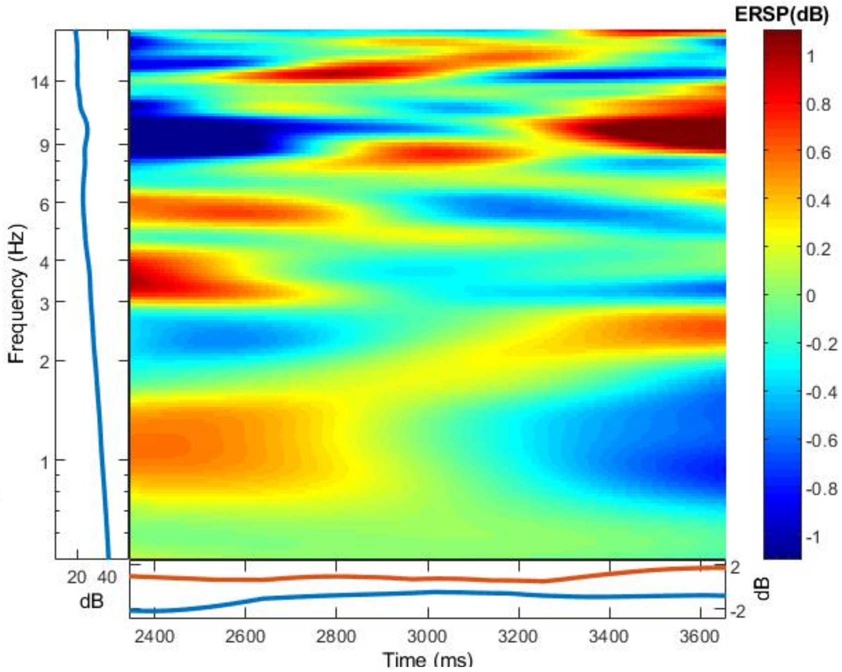

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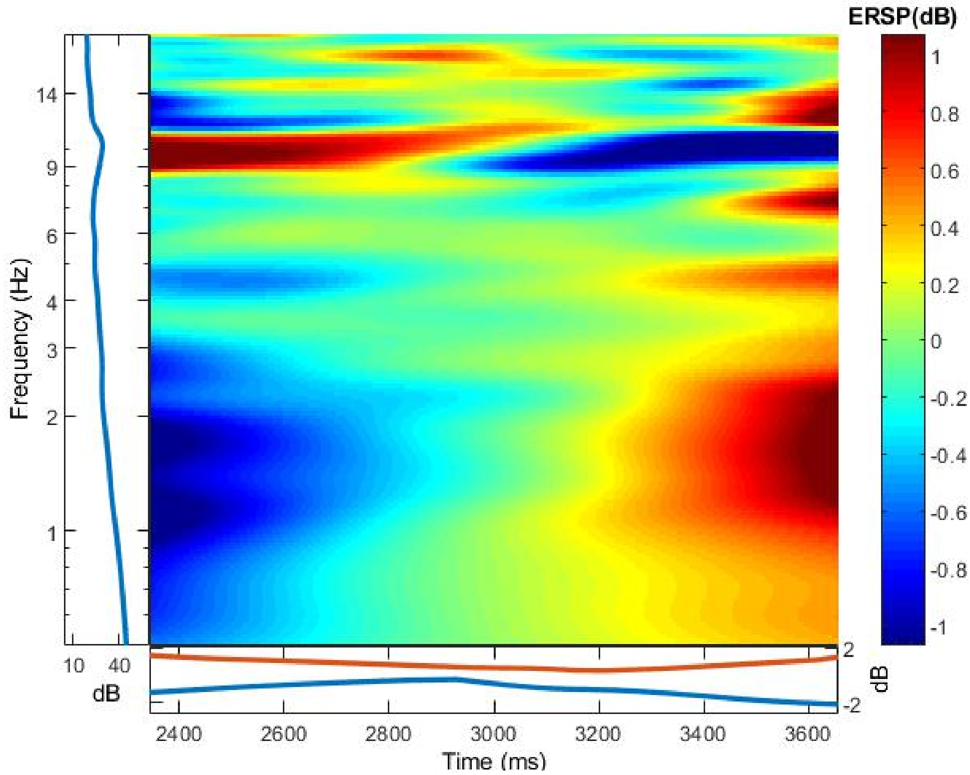
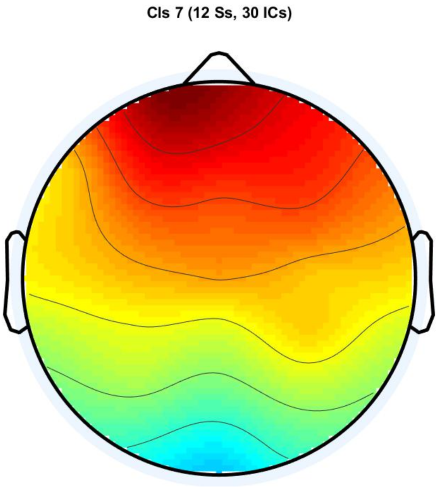


(c)

Fig (a) Scalp Map of Cluster 5
(b) ERSP Plot of Cluster 5 with Reaction Time<0.5
(c) ERSP Plot of Cluster 5 with Reaction Time>3

8.4 CLUSTER 7



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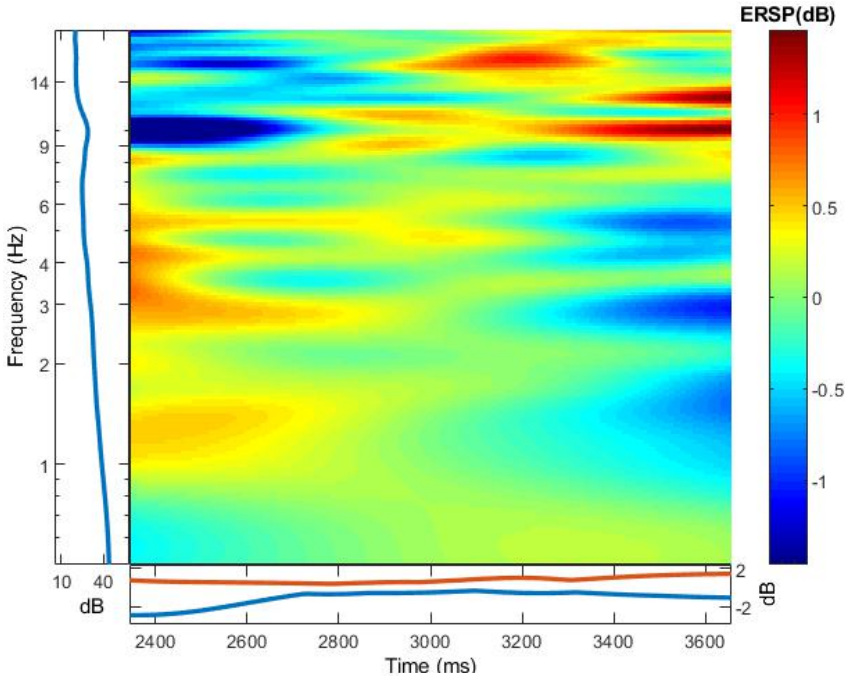

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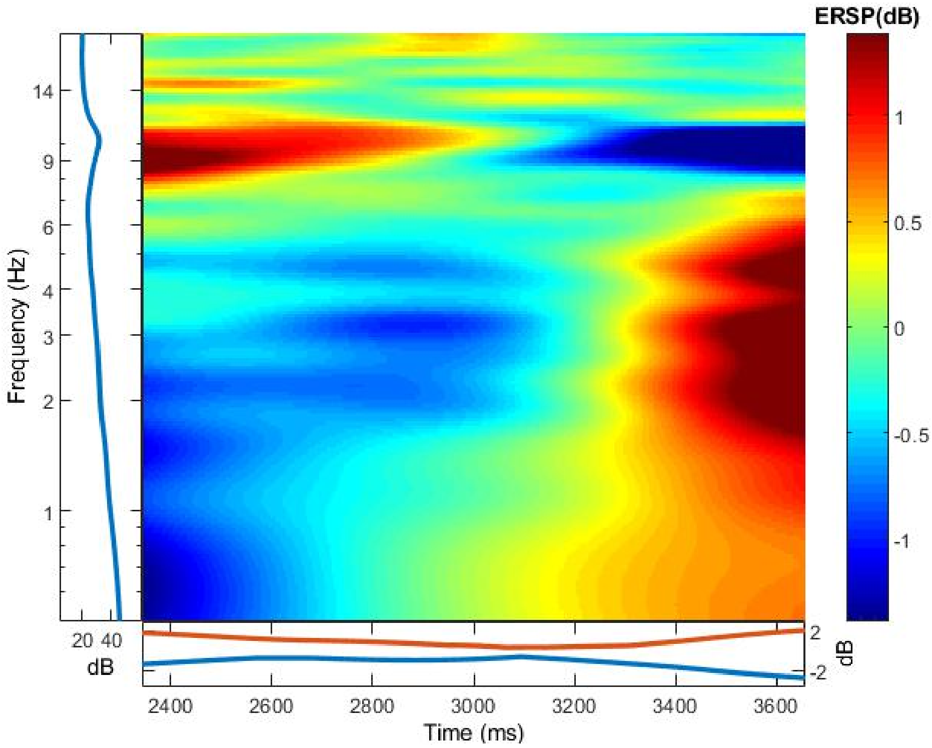
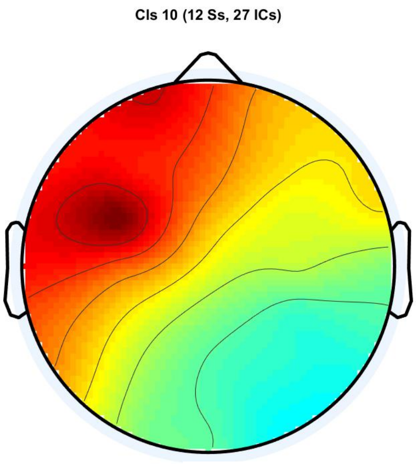


(c)

Fig (a) Scalp Map of Cluster 7
(b) ERSP Plot of Cluster 7 with Reaction Time<0.5
(c) ERSP Plot of Cluster 7 with Reaction Time>3

8.5 CLUSTER 10



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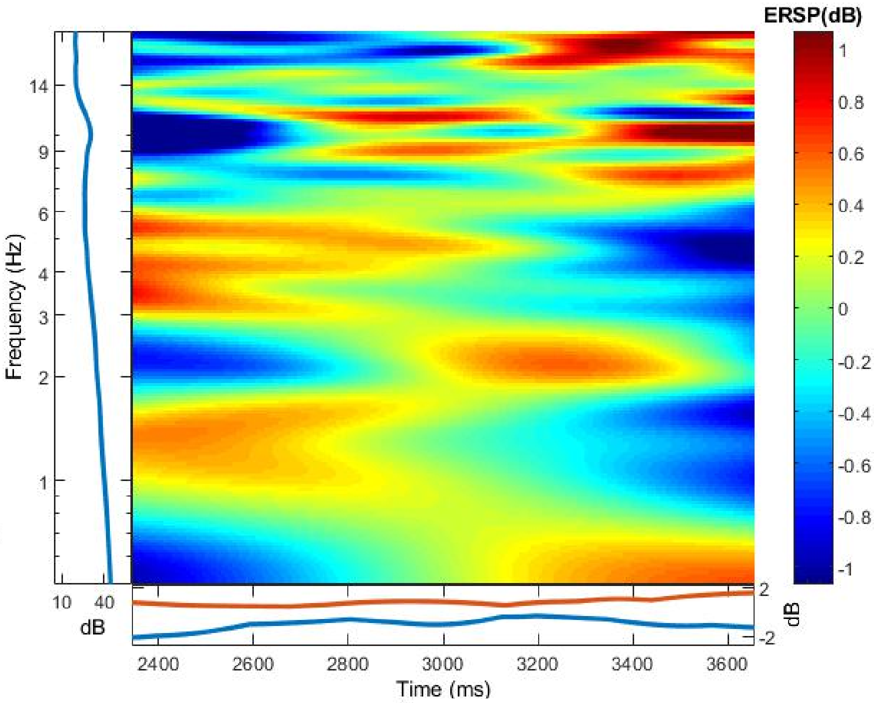

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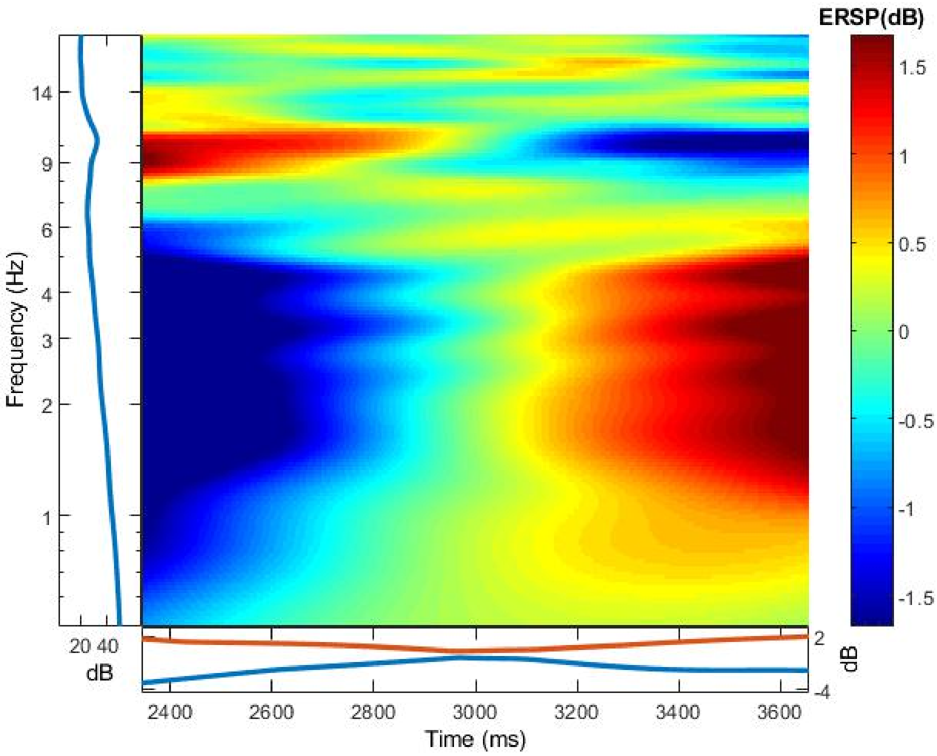
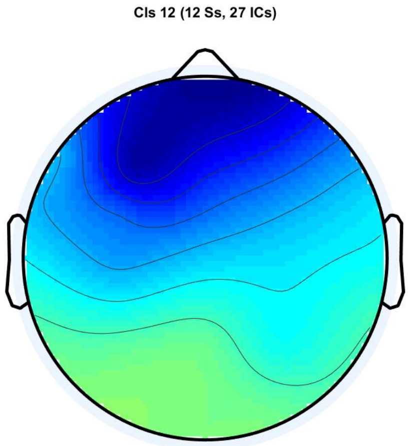


(c)

Fig (a) Scalp Map of Cluster 10
(b) ERSP Plot of Cluster 10 with Reaction Time<0.5
(c) ERSP Plot of Cluster 10 with Reaction Time>3

8.6 CLUSTER 12



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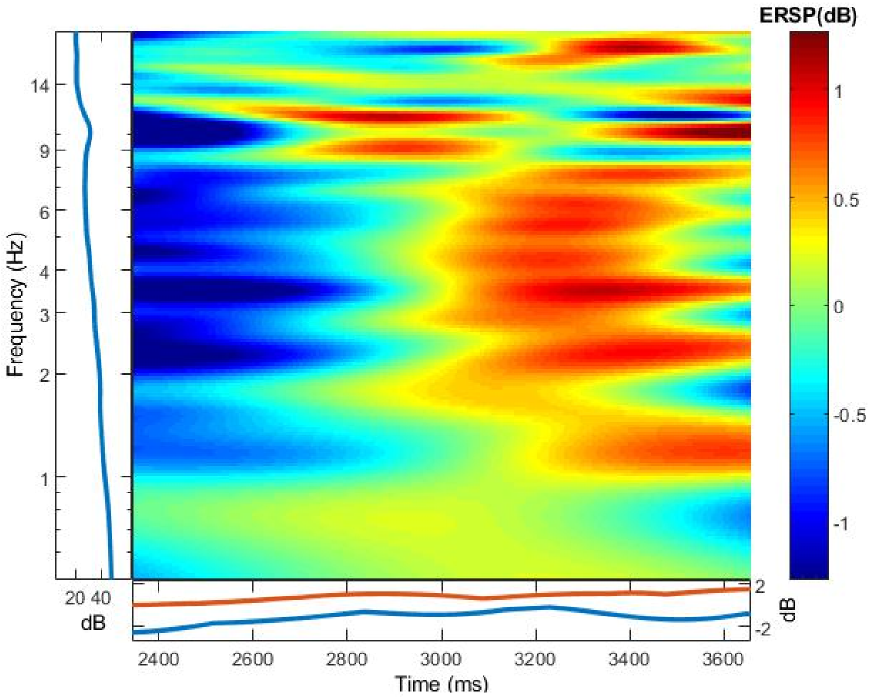
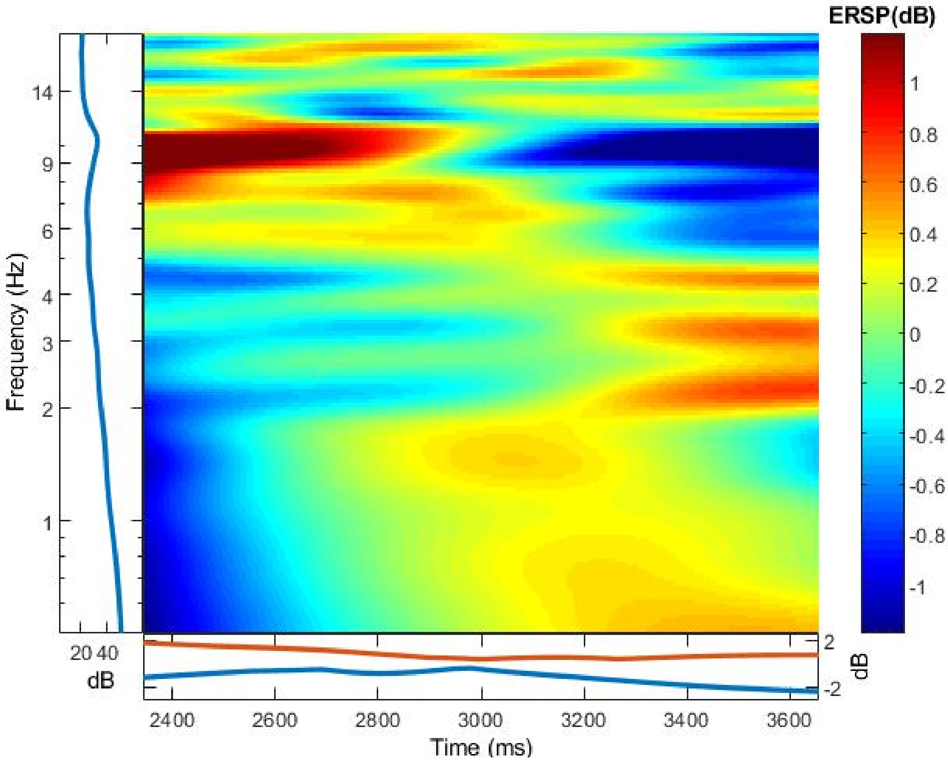


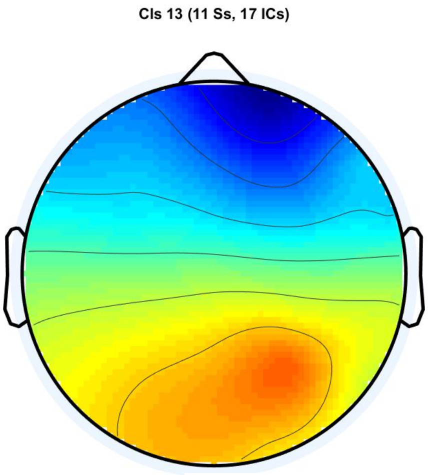
(b)



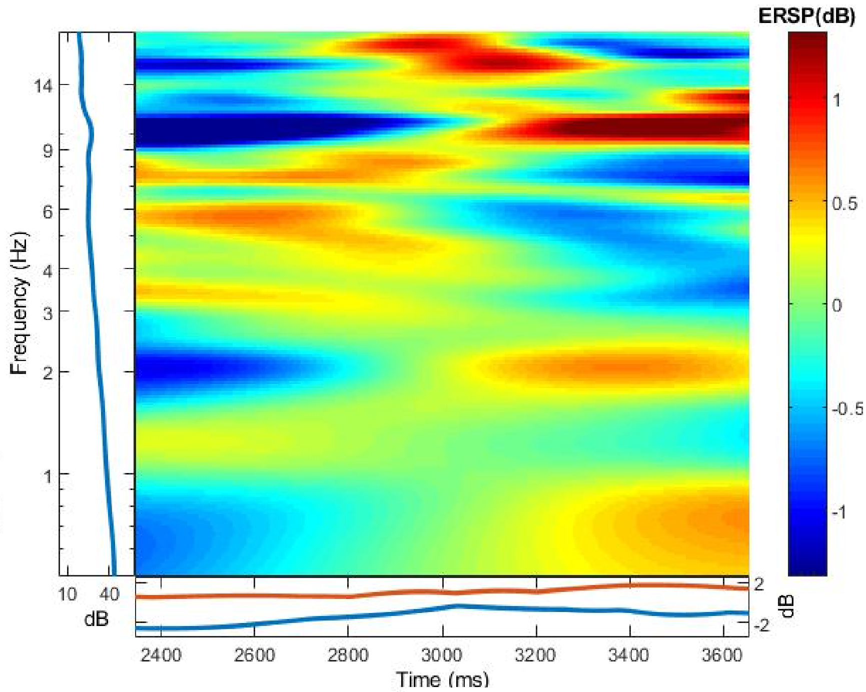
(c)

Fig (a) Scalp Map of Cluster 12
(b) ERSP Plot of Cluster 12 with Reaction Time<0.5
(c) ERSP Plot of Cluster 12 with Reaction Time>3

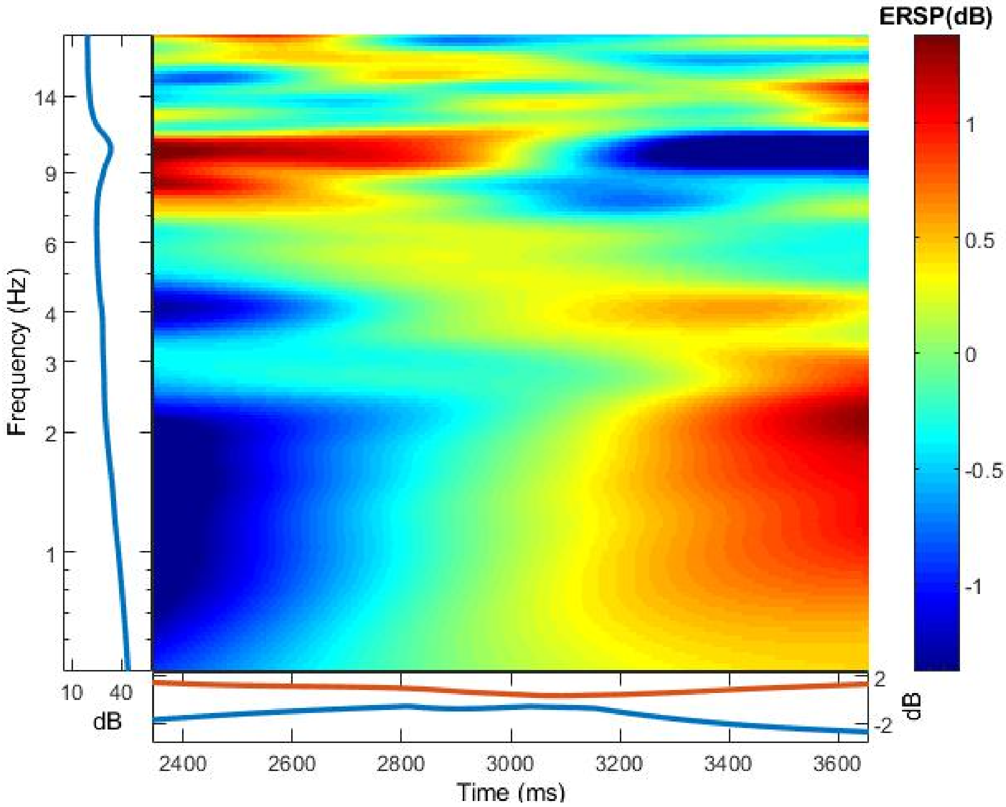
8.7 CLUSTER 13



(a)



(b)



(c)

Fig (a) Scalp Map of Cluster 13
(b) ERSP Plot of Cluster 13 with Reaction Time<0.5
(c) ERSP Plot of Cluster 13 with Reaction Time>3

9. DISCUSSION

Git hub link containing the scripts used:
https://github.com/grewaldarshvir/Sustained-Attention-Driving
The ERSP measures average dynamic changes in amplitude of the broad band EEG frequency spectrum as a function of time relative to an experimental event. That is, the ERSP measures the average time course of relative changes in the spontaneous EEG amplitude spectrum induced by a set of similar experimental events. To compute an ERSP, baseline spectra are calculated from the EEG immediately preceding each event. The epoch is divided into brief, overlapping data windows, and a moving average of the amplitude spectra of these is created. Each of these spectral transforms of individual response epochs are then normalized by dividing by their respective mean baseline spectra. Normalized response transforms for many trials are then averaged to produce an average ERSP, plotted below as relative spectral log amplitude on a time-by-frequency plane.
Using ERSP plots of different clusters following inferences were drawn:
Cluster 2: In parietal cluster initially power in delta and theta is relatively greater than in alpha and beta band when reaction time is less than 0.5 seconds but as the time progresses power in alpha and beta bands is relatively greater. ERSP plot for reaction time greater than 3 seconds depicts that initially relative power in alpha band is greater than theta and delta bands. In later parts relative power of delta band increases. When reaction time is greater than 3 seconds there was no significant change observed in beta band.
Cluster 3: It depicts information about posterior parietal lobe.It is important to note that power in posterior parietal lobe is relatively less as depicted by scalp map. In epochs in which reaction time was less than 0.5 seconds relative power was greater in theta band when compared to alpha and beta bands near time of deviation onset but in later part relative power of alpha and beta band increased. There was no significant change in the delta band power when reaction time was less than 0.5 seconds. ERSP plot containing information of epochs with reaction time greater than 3 seconds depicts high relative power in alpha band when compared to other bands initially but as time progressed relative power also increased in delta and theta bands. However, there was no change in relative power of beta band.
Cluster 5: It contains the information about parietal posterior and some part of occipital.When reaction time was less than 0.5 seconds it was observed that relative power between delta and theta band was relatively high than alpha band initially but as we move away from deviation onset event relative power of alpha band increased. When reaction was greater than 3 seconds, initially relative power of alpha band was highest and relative power of theta band was lowest, on moving away from deviation onset relative power of delta band increased significantly and power of alpha band decreased. There was no significant change in beta and theta band observed in this cluster.
Cluster 7: In frontal lobe when reaction time was less than 0.5 seconds relative power of alpha band was lower initially but in later part relative power of alpha band was highest. There was no significant change observed in other bands. ERSP plot containing information of epochs with reaction time greater than 3 seconds depicts that in initial stages relative power in alpha band was greater and in delta band was lowest. As we move away from deviation onset relative power of delta and theta increased but on the other hand relative power in alpha band dropped.
Cluster 10: In middle frontal and major temporal lobe (of left hemisphere) when reaction time was less than 0.5 seconds relative power was highest in theta band but in later part relative power increased in alpha and beta bands. When reaction time was greater than 3 seconds relative power was lowest in delta and theta bands and highest in alpha band but for later part relative power in alpha band decreased on the other hand it increased in delta and theta band. When reaction time was greater than 3 seconds there was no significant change in beta band.
Cluster 12: This cluster contains information about superior frontal lobe when relative power of this part is lowest. When reaction time as less than 0.5 seconds relative power was lower in initial parts

but it increased in later parts. When reaction time was greater than 3 seconds relative power in alpha band was highest and relative power was lowest in delta and theta band initially in later part relative power in alpha band was lowest.

Cluster 13: In superior frontal lobe (right hemisphere), when reaction time was less than 0.5 seconds the relative power was lowest in alpha band in later part the relative power in alpha band was the highest. In intermediate time period the relative power of beta band increased too. When reaction time was greater than 3 seconds initially relative power in alpha band was the highest which dropped in latter part. Initially relative power of delta and theta was lowest which increased in the latter part. There was no significant change observed in beta band.

10. REFERENCES

For entire documentation related to dataset-
https://www.nature.com/articles/s41597-019-0027-4#Sec12
Introduction to EEGLAB
https://sccn.ucsd.edu/eeglab/index.php
Preprocessing of data in EEGLAB
http://learn.neurotechedu.com/preprocessing/
For Artifact Removal, ICA decomposition, Dipole Fitting, Clustering and Time Frequency Analysis
https://sccn.ucsd.edu/wiki/Main_Page
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Video Lectures by Prof. Arnaud Delorme on EEGLAB
https://www.youtube.com/channel/UCK8x1bdiHWmT0yCNEjTcEvA