

# Impact of Emotion in Human Brain-A Lobe-based Activity on Strength of Signals Analyzed in Two Frequency Bands

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**Abstract---** Emotion analysis is an emerging field among current researchers. Emotion plays an important role in forming behavioural patterns in the human brain. A study was conducted in objective time space evolution of emotions. For emotion recognition, an EEG (electroencephalogram) data base was created from equal number of male and female subjects and named Amrita-emote database (ADB). The subjects were shown videos of various emotions and simultaneously the output EEG signals were recorded into ADB, which contained 500 samples of data. Our study had focused into 5 basic emotions, viz. neutral, happy, disgust, sad and fear. The ADB was split into two different frequency bands of 12-35 Hz as high frequency band (HFB) and 1-8Hz as low frequency band (LFB) for time localized responses. The time and space evolutions were studied by segmenting and K-mean clustering. For each emotion, the frequency distribution contributes from four regions in the brain. The statistical analysis was done to find the average contribution for each emotion.

**Keywords---** Emotion, ICA, K-mean, Unsupervised Learning Technique, Brain Lobes.

## I. INTRODUCTION

Emotion is a strong feeling based on physical and mental conditions of a person in his subjective experiences. Human beings are familiar to emotions affecting physical activity in their life for example, stress and anxiety can increase your physical sicknesses. Emotions have an objective and subjective element and as researchers in objective science, in this work the measurable part of the emotions were considered as focus. Professor Paul Ekman was one of the leading scientists who pioneered the classification of emotions into six groups: happy, sad, fear, disgust, surprise and anger [1]. After his groundbreaking innovation, additional shades of emotions were added [2].

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Image processing methods were used widely in emotion analysis, in which facial expressions were captured for recognizing each emotion [3]. Enacted emotions can mislead the results, so here brain signals or EEG signals are being used in emotion analysis.

The concepts of emotions in physiology and psychology had given different opinions. The James-Lange theory, Cannon-Bard theory, Stanley Schachter's and Jerome Singer's two factor theory were proposed with different theories of emotions [46]. Emotions activate the nervous system that ensue in physiological, and behavioral changes such as facial expressions [4]. According to James-Lange's theory, people do not cry because they feel sad. Rather, people feel sad because they cry, and likewise, they feel happy because they smile.

There is disagreement in the connection between physiological reaction and emotion. Stanley Schachter and Jerome Singer [7] proposed that physiological arousal, and the cognitive interpretation of that arousal, caused emotional responses. Even though emotions are universal, they are influenced by culture and customs followed by the ancestors, feedback from the memory of a person influence emotions. In this study, truthfulness of the manifested emotions was assumed, while enacted emotions were avoided in analysis. Mainly five of these basic emotions viz. neutral, happy, disgust, sad and fear in the work done are presented here.

## **II. METHODOLOGY**

A virtual reality (VR) head set, a fully adjustable headset with 3-D glasses supported in bringing virtual reality was used to show the recorded videos, the corresponding EEG waveforms were recorded. The EEG data for each emotion was taken separately at intervals of ten minutes while the subjects were allowed to sit comfortably. Each emotion was recorded as continuous episode and the comments of the group of subjects were considered to segregate the data for analysis. So, emotions had an influence of vision and audio stimuli from the video input shown. Emotion remained in the brain for tens to hundreds of milliseconds and then faded away. The raw data of all emotions collected from each subject were taken separately through various signal-processing techniques, for spatial and temporal localization of the emotional centers at the brain. The preprocessing was done followed by the analysis. For which the data collection, types of data used in this study, the structure of the brain and block of operation are described in the subsequent sections.

### **A. Data collection and Recording**

The raw EEG data was collected with an Emotive EPOC wireless EEG neuro headset of 14-bit resolution [12]. The data was sampled at 128 samples per second with a bandwidth of 0.1 Hz to 45.0 Hz. The montage, distribution of electrodes on the scalp, used 10-20 system of electrodes. This is an internationally accepted system of placement of electrodes. P3 and P4 pins were used as references in the electrode set AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8 and AF4 were the available electrodes, and its name indicates the location of the electrodes in the brain as shown in Fig.1. The collected EEG data were digitized and sent via a Bluetooth (BT) channel to a PC-based data acquisition system. The BT receiver decodes the data and stores it in files of European data formats (EDF). The data was collected from socially active subjects by showing them video of various emotions in a closed room. The emotion EEG data, from 10 test participants of which five females and five males, in the age group between 19 years and 24 years, is made available in this ADB. This data base consists of five major emotions namely neutral,

happy, sad, disgust, and fear. In this study, the emotion anger was not considered due to the difficulty in evoking the same. ADB was created by showing the video which evoked the emotions excluding anger for the analysis. Emotion anger was avoided in the data collection process by taking the feedback from the subject that anger was a derived emotion of disgust and was not evidently coming with the shown instances.

### ***B. Types of data used in analysis***

An array of electrodes and an electronic data gathering system, to record the temporal and spatial distribution of impact of emotions in the brain, and the records thus obtained are known as electroencephalograms (EEG). EEG signals are classified as Delta (1 Hz-3 Hz), Theta (4 Hz-7 Hz), Alpha (8 Hz-13 Hz), Beta (14 Hz-30 Hz) and Gamma (31 Hz-50 Hz) [11]. Delta waves are usually associated with the slow-waves like sleep. Theta waves are generated when one is sleeping, drowsy, or in deep meditation. Alpha waves are generated in the states of wakefulness or relaxation. The amplitude of alpha waves decreases with opening of eyes and in sleep states. Beta waves are generated when the person is involved in problem solving, judgment, decision making, and focused mental activity. Gamma waves indicate extreme cognitive functions and the peak of concentration [11]. EEGs of healthy individuals were collected and analyzed from the scalp electrodes with 14-bit resolution. Signal processing methods were applied to filter and process the data. EEG is mainly used in various Brain Computer Interfacing (BCI) applications [9]. EEG is the signal directly taken from the scalp of the brain. This study is done with this non-invasive data analysis of human brain in localizing emotional centers.

### ***C. Brain structure and Origin of emotions***

The brain is comprised of the cerebrum, cerebellum and brain stem. The cerebral cortex is the largest and occupy top most part of the brain, this comprises of frontal, temporal, parietal and occipital lobes. Left hemisphere of the brain communicates with the right hemisphere, through a fibril tack called corpus callosum. The corpus callosum integrates the motor and sensory regions in the left and right hemispheres of the brain. The functions of right side of the brain is responsible for controlling awareness, creativity, imagination and intuition. The left side of the brain is responsible in logic reasoning, language, and analytical thoughts. The deepest layer of the cerebrum is the Limbic system, which is comprised of hippocampus, corpus callosum amygdala and thalamus (HAT). Thalamus is considered as the sensory relay station. Thalamus handles hear, touch, vision, and taste. Among the senses, smell can bypass thalamus, and directly affect the brain. Hippocampus is responsible in the creation of long-term memory [10]. Cerebellum acts as an intermediary, to all sensory information, between the cerebral cortex and the spinal cord. Emotions are from deep inside the cerebral cortex. This will not give an individual location for each individual emotion, but the combination of all peripheral lobes of the cerebral cortex constitutes all emotions.

### ***D. Experimental setup***

Our analysis includes the pre-processing steps, feature extraction and classification of every individual data of the ADB. The scalp cap includes the non-invasive surface electrodes, which capture the electrical activity of the brain. This scalp electrode, with 14-bit resolution, follows reference montage of 10-20 system of electrode placements, to ensure true scalp recording [11]. The digitizer converts the electrical impulses into 16-bit digital signals with the analog to digital converter (ADC). Thus, the data was encoded and send via a BT channel to a PC

based data acquisition system. The BT receiver decodes the data and stores it as EDF files. The recording of data could be done manually for a specific period. To remove the artefacts, in pre-processing stage the ADB is filtered with a Butterworth bandpass filter of order 3000, with a cut off frequency 0.1 Hz-45 Hz in the signal range processing. The filtered data of 10 subjects consists of 5 emotions each, and data associated with each emotion was captured for a duration of 500 seconds. The blinking eye artefact, and the visible artefact, due to muscle movements, influenced the entire channel, at a random duration of time. By inspection, they were removed before the preprocessing step. The obtained duration of each emotion after preprocessing and removal of artifacts were different in time duration as described here. For neutral emotion, it was 4 min 42s, happiness: 12 min 3 s, sad: 8 min 40 s, disgust: 4 minutes 5 s and fear-10 min 12 s. This data was segmented with a non-overlapping window of 50 seconds. From these 10 segments of data, the dc offset values are removed, and passed through two *bandpass*FIR filters with the frequency band from 12 Hz to 35 Hz, HFB, and from 1 Hz to 8 Hz, LFB, respectively, as shown in Fig.1. The feature extraction of the pre-processed data was done using ICA, to separate them into independent spatial sources in the brain.

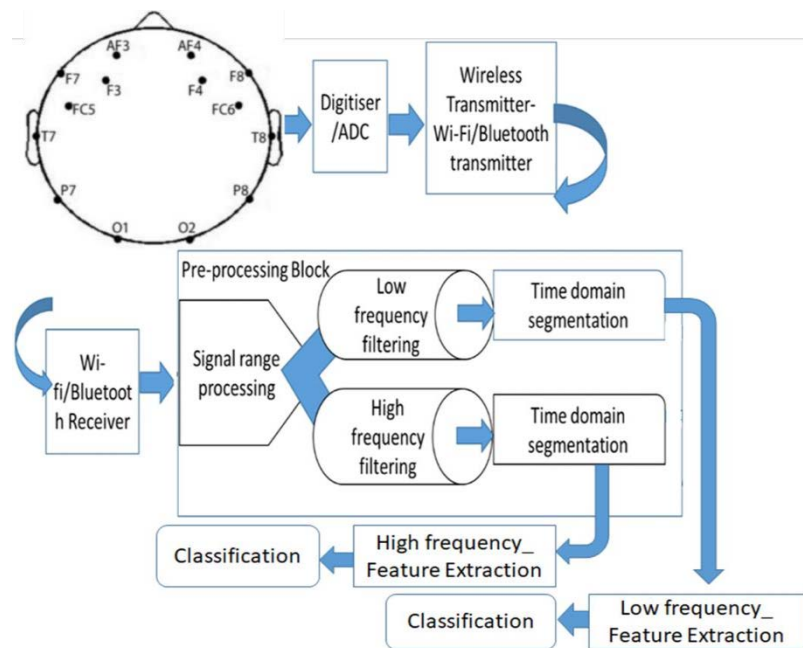


Figure 1: Block diagram of our set-up for emotion analysis with lobe-based activity based on strength of the signals in high and low frequency band (HFB and LFB)

### III. ANALYSIS

The independent component analysis (ICA) was done on the pre-processed data [14]. The different statistical nature of signals considered non-Gaussian and artefacts due to eye blink and muscle movements were separated out into different channels. The source with artifacts were removed and the remaining components were used for classification using Kmean clustering. This feature gave the local centroids and those were considered as the k-values for the classification. Equation 1 shows the unsupervised learning method of classification.

$$clustercentroids(j) = \sum_{j=1}^k \sum_{i=1}^n \|x_i - C_j\|^2 \quad (1)$$

Initially k local centroids were estimated from the ICA, and sent to the K mean clustering methods, in which local centroids were fixed and then found the Euclidian distance to each data points and clustered out into the centroids with the lowest distance. The n value is the number of cases or iterations were done, until there were no further clustering takes place. Some out layered data points are also present in the classified emotions. The emotions were separately clustered and labelled in Fig. (2-6), an intuitive finding of low and high frequency band separately (HFB and LFB) helped in this work to see the frequency specific response.

#### IV. RESULTS

The results of our study on the localization of emotional centers showed that, while for emotion disgust had the local centroids of centroids at x coordinate 229.99 and y coordinate 316.43, for neutral emotion the corresponding values were x 236.14 and, y 321.01. For fear, the local centroids were at x 272.64 and y 340.85. These values were obtained from high frequency EEG data. The corresponding analysis using low frequency data gave the response centers at the locations at x and y coordinates at 246.26 & 290.45 for happy. They were at x & y at 225.81 & 294.25 for sad, while for disgust x was at 259.17 & y was at 317.22. For neutral, the coordinates/centers were at x 230.55 & y 299.13 and for fear the centers were at x 264.79 & y 308. The standard deviation of the values in all cases were less than 5% of the maximum value The emotions also showed different time pathways while evolving in the memory. Two sets of emotion results were obtained. First section discusses the whole impact of emotions in the brain and the second section explains the emotions evolved in time.

##### A. Result1: Collective Response of emotions

There were five emotions under consideration viz. Neutral, happy, disgust, sad and fear. The local centroids and the maximum deviation from the cluster centroids are specifically shown in table.1. The centroids shown on the table 1 and 2 are the local centroids taken in K-means clustering, and the x, y values are the centroids of clusters of each emotion.

The first two columns show the cluster centroid points of disgust emotion. The maximum deviation for each centroid is provided on the righth and side of each emotion. Table1 and 2 are centroids and maximum deviation of all emotions at HFB and LFB. Fig.2 shows the HFB and LFB of neutral emotion, in which (a) shows LFB and (b) shows HFB.

Referring Fig 2 & 3, neutral and happy emotions showed a prominent HFB than LFB distributions. These two, neutral and happy, emotions contain more high frequency waves like beta and alpha. This shows the subjects were energetic and relaxed, when they underwent tests for these two emotions. In addition, the delta wave was absent and lower frequency of alpha was present in the LFB of both these emotions. The emotions, fear and disgust, had LFB dominant than HFB, as shown in Fig. 4 & 6. In sad, there were low and high frequency waves with equal distribution as shown in Fig.6.

Table 1: K-Mean Clustering Results with the Centroid Values and the Number of Clusters Taken for K- Shown in the Table for Each Emotion in HFB

Emotion	Disgust			Happy			Sad			Neutral			Fear		
	Centroid (k-9)		Max.Deviation	Centroid(k-12)		Max.Deviation	Centroid(k-12)		Max.Deviation	Centroid(k-10)		Max.Deviation	Centroid(k-12)		Max.Deviation
	x	y		x	y		x	y		x	y		x	y	
High frequency	323.99	82.11	10.9	182.35	71.6	19.9	176.39	89.03	9.8	182.35	71.6	17.4	172.61	81.94	18.1
	301.48	544.91	15.9	193.32	540	16.7	425.3	248.79	3	193.32	540	17.7	435.36	264.87	11.2
	397.29	187.99	8.5	423.97	280.37	6.3	317.62	550	10	423.97	280.37	16.5	419.25	455.82	16.9
	395.58	452.4	15	390.87	141.96	10.2	86.87	448.46	10.23	390.87	141.96	19.7	326.45	541.18	10.6
	60	299.16	6.23	416.95	173.4	9.9	414.27	177.87	12.2	416.95	173.4	17.9	344.22	78.18	18.1
	165.4	90.93	12.6	70	294.09	17.9	340.02	81.48	8.9	70	294.09	18.35	76.37	440.85	15.64
	79.91	447.54	19.49	106.08	150.68	10.17	106.26	168.63	7.68	106.08	150.68	17.85	60	294.51	6.62
	91.27	169.06	16.33	295.49	50.14	22.6	417.43	455.97	24.1	295.49	50.14	19.6	145.4	525.91	18.1
	175.9	546	10.1	90.01	440.62	11.16	70	300.63	6.91	90.01	440.62	19.15	369.46	150.79	15.5
				385.27	477.19	16.3	442.05	319.73	2.5	385.27	477.19	12.55	423.54	175.06	12.2
				334.06	69.83	17.8	352.35	528.2	9.6				178.51	546	17.1
				94.95	196.28	19.2	172.78	539.88	18				96.2	167.16	7.7

**Neutral**

It is a state without the influence of any other emotions. The frequency of occurrence of each cluster with minimum of 6 Hz and maximum of 13 Hz is shown in the Fig.2 (b). This shows prominent alpha waves in neutral emotion. The lower component of alpha waves with an influence of theta wave is shown on both left and right occipital regions. The strength of this region was contributed by an energy of 26.51% at HFB and at LFB 25.194%. Frontal region is showing high frequency alpha waves about 13 Hz which is shown on left frontal region. The strength of this region is 25.044% and 23.492% at HFB and LFB respectively. The temporal-parietal region on the left side of the brain shows an overlapping effect of high frequency of alpha and beta as shown in the Fig. 2(b), this was shown 23.342% of energy in this region at HFB. The right temporal region is also showing a prominent activity with alpha and beta waves. This region shows a strength of 25.104% at HFB.

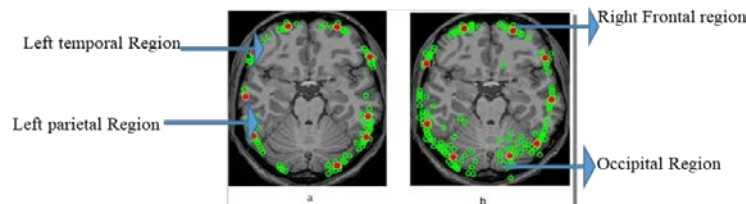


Figure 2: Emotion Neutral, a Coronal View with the Cluster Plot of Emotion Distribution-the centroids Marked in Each Cluster (a) LFB and (b) HFB

The net effect of neutral emotion consists of alpha waves with a bias of theta waves. Fig.2 (a) shows the LFB of neutral emotion. The energy distribution of temporal region had shown 25.254% and parietal region had shown 26.66%. Table 2 shows the centroid values of LFB. At HFB, occipital region shows more energy than LFB.

**Happy**

There are about four regions formed in LFB of the emotion happy, refer Fig3 (a). The centroid values are shown in the table 1. Right parietal and occipital region shows a significant activity in happy emotion, the energy distribution was 27.35%

Table 2: K-Mean Clustering Results with the Centroid Values and the Number of Clusters Taken for K- Shown in the Table for Each Emotion in LFB

Emotion	Disgust			Happy			Sad			Neutral			Fear		
	Centroid		Max.Deviation	Centroid		Max.Deviation	Centroid		Max.Deviation	Centroid		Max.Deviation	Centroid		Max.Deviation
	x	y		x	y		x	y		x	y		x	y	
Low Frequency	404.4	460.5	19.1	81.25	441.18	8.75	88.9	180.6	18.74	81.25	441.18	19.6	363.1	145.82	17
	328.1	85.13	12	400.44	453.76	5.8	420.02	550	2.5	400.44	453.76	18.67	173.26	546	12.1
	400.63	176.28	9.8	325.3	70.4	10.1	327.15	85.6	16.4	325.3	70.4	17.05	60	295.01	6.01
	92.81	183.58	7.98	382.11	142.52	17.5	339.57	171.84	2.8	382.11	142.52	14.75	419.94	271.92	12.6
	89.14	447.66	11.4	93.86	161.15	9.92	109.77	244.57	7.06	93.86	161.15	15	388.31	481.75	16.1
	94.84	236.72	16.98	172.95	72.57	12.4	93.92	466.24	14.8	172.95	72.57	17.45	311.38	543.12	18.8
	183.98	95.62	10.1	408.19	173.97	7.3	415.8	79.41	18.7	408.19	173.97	18.69	74.12	436.8	9.28
	178.16	550	9.9	70	269.82	6.12	182.32	244.67	14.3	70	269.82	19	409.22	446.44	17.1
	103.7	158.81	18.83	415.21	280.93	14.1	425.01	312.98	12.4	415.21	280.93	17.6	91.04	161.71	11.5
	414.52	257.31	10.1	173.87	540	19.8	70	549.23	7.34	173.87	540	13.35	177.69	69.69	14.6
	315.07	548.3	18	286.73	50.7	10.2	176.97	321.56	9.9				325.62	75.2	19.2
	70	305.43	4.51	314.23	536.66	14.9	444.86	321.56	0.3				408.57	174.33	16.4

And 26.66% in the respective regions at LFB. The left occipital region had also shown a significant activity. The frequency distribution of frontal and temporal regions is 25.74% & 25.91% respectively. High frequency of alpha is seen in left occipital region and right parietal region. In HFB, nine clusters were formed in the four regions of the brain as shown in Fig 3 (b). The centroid values are shown in the table 2. High beta – activity seen on parietal and occipital regions with 27.2% & 21.51% energy distribution. This shows that subjects get high frequency signals of beta and low frequency of alpha when they were happy. The significant contribution of happy emotion is from alpha and beta signals of frequency ranges between 12 Hz – 30 Hz. In emotion, happy frontal region is showing more activity in high frequency than in low frequency. HFB is prominent than LFB and is evident in Fig.3. The energy distribution on the frontal region constitutes 27.014% and temporal with 25.08%.

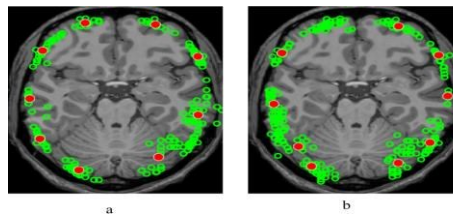


Figure 3: Emotion Happy, A Coronal View with the Cluster Plot of Emotion Distribution-the Centroids Marked in Each Cluster (a) LFB and (b) HFB

**Disgust**

Disgust is an abrupt emotion and lasts only for a few seconds. In the data the first 5 seconds shows the major part of disgust emotion. In low frequency, waves, which are around in theta frequency, are prominent specifically in Fig4 (a). Occipital and frontal region shows a small activity in the specified frequency segment with an energy distribution of 26.136 & 27% regions respectively. This indicates most of the subjects have facial expressions, which effects the frontal region. Partial region had 21.44%, which had lowest energy and temporal had 24.94% of energy

in LFB. In high frequency, the significant contribution is from right parietal and occipital regions for which, refer Fig4 (b). Left parietal is also showing a small activity. The energy distribution at HFB for frontal, temporal, parietal and occipital regions were 25.114%, 24.436%, 25.044% and 25.212 % respectively.

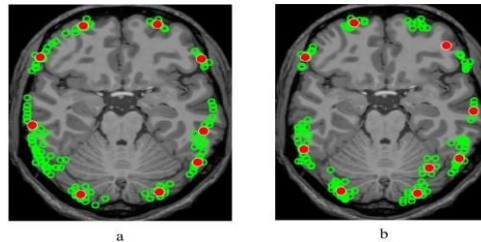


Figure 4: Emotion Disgust, A Coronal View with the Cluster Plot of Emotion Distribution-the Centroids Marked in Each Cluster (a) LFB and (b) HFB

### *Sad*

In LFB, right parietal region has more of theta waves and contributes for sad emotion as shown in Fig5 (a). Right occipital shows delta waves. The left occipital region also shows an activity this indicates that sad emotion requires lot of memory and imagination in the visual cortex and a temporal activity is more evident in sad emotion. In high frequency, the right parietal region contributes more to this emotion refer Fig.5 (b). There are four regions affected in the brain on both low and high frequency. The values are shown in table 1 and table 2 respectively. The frequency between delta and theta is seen in lower frequency of 1Hz to 7 Hz in sad emotion. Moreover, at high frequency the 13 Hz to 16 Hz has a small activity is present and shows a right parietal activity as well. In LFB 27.92, 25.15, 23.3 & 23.63% of energy for Frontal, parietal, temporal and occipital regions respectively, similarly in HFB 25.47, 27.835, 23.212, 23.48%. Here LFB had shown more emphasis on the clusters shown in Fig.5 (a) than in Fig.5 (b). This shows prominent LFB compared to HFB

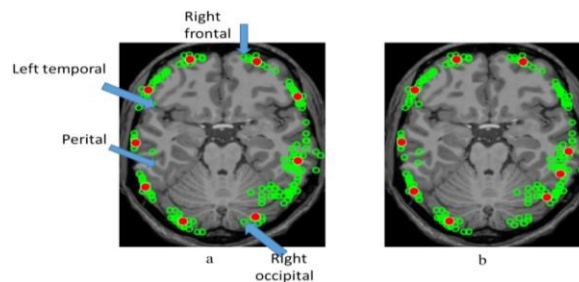


Figure 5: Emotion Sad, A Coronal View with the Cluster Plot of Emotion Distribution-the Centroids Marked in each Cluster (a) LFB and (b) HFB

### *Fear*

The activity on both LFB and HFB are similar in cluster density and there is difference in energy distribution. 24.8, 25, 23.6 and 26.6% were the energy distribution from LFB and 20.49, 19.9, 24.5 and 35.11% in HFB of frontal, parietal, temporal and occipital regions of the brain. HFB of occipital was very prominent here. This shows that fearful videos were biased with memory and they tried to visualize more while watching the video. In LFB,



there is a significant cluster seen on the left parietal region that contribute to this emotion as shown in Fig6 (a). Right parietal and left temporal region shows a small activity. In HFB, occipital region had shown more activity, that shows imagination and visualization is shown in Fig.6 (b). High frequency of beta and low frequency of gamma waves were prominent in this emotion.

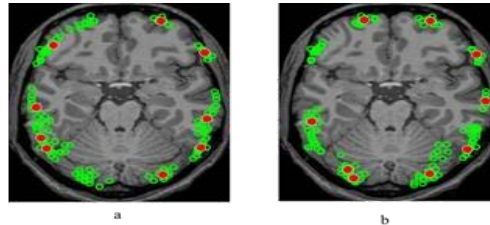


Figure 6: Emotion Fear, A Coronal View with the Cluster Plot of Emotion Distribution-the Centroids Marked in each Cluster (a) LFB and (b) HFB

### ***B. Result 2: Temporal Response of emotions***

The time evolution of emotions, in the brain, is shown in this section, on both LFB and HFB. The data of each emotion is analyzed, separately in time segments, to see the drift in activity, over the brain lobes. Result 1 had shown the collective impact of emotion over four to five segments. Result2 discusses the localization of emotion in segment 1, and then segment 2 then segment 3 extended over the duration of emotion data. The Fig.7 shows HFB, containing four cluster plots; first one corresponds to 0 to 60 seconds, 122 to182, 190-250 and 251 to 311seconds. Due to pick-ups, over entire channels, due to eye blinking, artefacts were removed from the data. Initially the frontal activity was seen more on the left most plot of Fig.7, this shows the subjects were slowly evolving into the emotion. The visualization, in combination with memory, contributes to the next segment, which is 122 seconds to 182 seconds showed a significant right occipital activity with a low left occipital activity.

Here the 60 to 121 seconds was showing similar activity so skipped that segment and taken the next plot. In the Third and fourth segment subjects with sad emotion shows, prominent right parietal and significant left occipital activity was evident in the last segment. Fourth segment of the Fig.7 is the completely evolved sad emotion. Fig.8 shows the LFB emotion shift in the brain, this starts with lower activity in frontal and occipital region and in the second segment shows parietal and temporal activity. In the third and fourth segment of low frequency had prominent temporal activity.

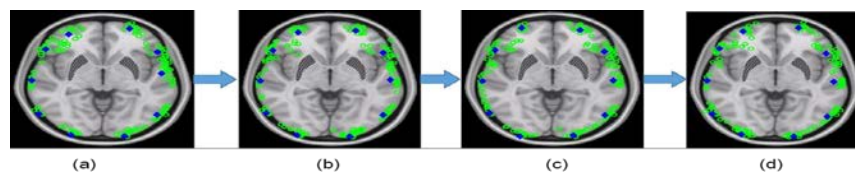


Figure 7: The time evolution of sad emotion at HFB of the segmented data processed separately (a) time segment 1duration 0 to 60 seconds (b) time segment 2-duration: 122 seconds to 182 seconds (c) time segment 3-duration: 190 seconds to 250 seconds , (d) Time segment 4-duration: 251 seconds to 311 seconds

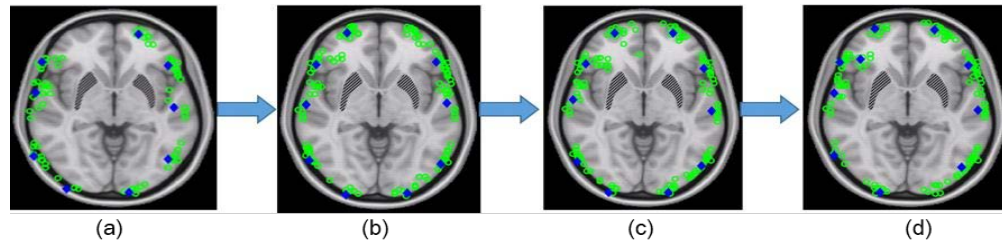


Figure 8: The time evolution in sad emotion at LFB the segmented data processed separately (a) time segment 1 duration 0 to 60 seconds (b) Time segment 2-duration: 122 seconds to 182 seconds (c) time segment 3-duration: 190 seconds to 250 seconds (d) Time segment 4-duration: 251 seconds to 311 seconds

## V. CONCLUSION AND FUTURE WORK

Our study discussed about the steps involved in emotion recognition from the EEG signals from ADB. The results were shown with different frequency distribution in four regions of the brain at two bands of frequencies. HFB and LFB were the two bands with 12Hz -35 Hz and 1Hz -8Hz respectively. The cluster with large number of data points were considered with high activity. The frequency of each data points decided the mental state of the subject at that emotion. The emotions happy and neutral had shown more activity in HFB. Disgust and fear shown prominent LFB. Emotion sad had shown activity both on HFB and LFB. In result 2 the gradual change in the brain while evolving the emotion had discussed and had seen both had same impact at the end, but in the initial stages the frontal area was affected more in HFB than LFB. This classified data can be used for generation of the required control signals, for various applications, including emotive robots. Recognition of emotions can be used to assess the psychological strength of a person. The emotional quotient (EQ) is important when you deal with corporate world or leading a good family life. Brain mapping can lead to the application of robotics. Emotional responses are incorporated in robots to make interactive robots with emotions.

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