

# Brain Signals and Alcoholism

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**Abstract-** Electroencephalogram (EEG) is the recording of electrical activity through various electrode sensors placed on the scalp. The electrical signal is recorded as waves that can be classified as normal or abnormal. Different types of normal waves can indicate various states or activity levels of the functioning of the brain. Abnormal electricity of the brain may represent many brain disorders, which can be detected by analyzing EEG signal pattern. However, it is very difficult to get useful information from these signals directly in the time domain just by observing them. They are basically non-linear and non-stationary in nature. Hence, their important features can be extracted for the diagnosis of different diseases using advanced techniques in engineering. The measurement of the brain signals involves the use of Electroencephalogram (EEG) at rest and Evoked Potentials (EPs). Brain activity of alcoholics and non-alcoholics differs in many ways. These differences prevail in alcoholics along with imbalance in excitation and inhibition processes in their brains. There are two ways in which the activity of the brains of the alcoholics can be revealed, analysing the images of the brain and the electrophysiological mapping of the brain. Magnetic resonance imaging (MRI) and positron emission tomography (PET) are the examples of the techniques that produce the images of the brain structure, where as EEG and EPs are included in the other method of measurement. This paper summarizes the techniques of mapping of brain signals, which can best reveal the brain activity of alcoholic subjects as it occurs in time.

**Keywords :** Electroencephalogram, Evoked Potentials, Event Related Potentials, Alcoholism.

## I. INTRODUCTION

Consumption of alcohol results in many economical and social losses to human beings. It is also harmful on the health related issues of a person. Various effects of alcohol on evoked responses have been reported [1,7]. Health weaknesses and disorders resulting from the alcohol abuse will remain for a long period of time after quitting alcohol [2]. Moreover, It can cause serious accidents on road, while driving the vehicles or operating machines where active presence and proper judgement of a person is required. So, there is a definite need to devise the methods which can discriminate alcoholic from normal people, and suggest the preventive measures.

Each neuron (nerve cell) in the brain produces a small electrical voltage. When many neurons become active, the sum of these tiny electrical voltages can be detected on the surface of the scalp with the help of the suitably placed electrodes over it. This very small electrical signal is amplified and gets recorded as brain waves. These signals represent the activity of the brain as it takes place inside the various areas of the brain. These waves are randomly active in a purely resting state.

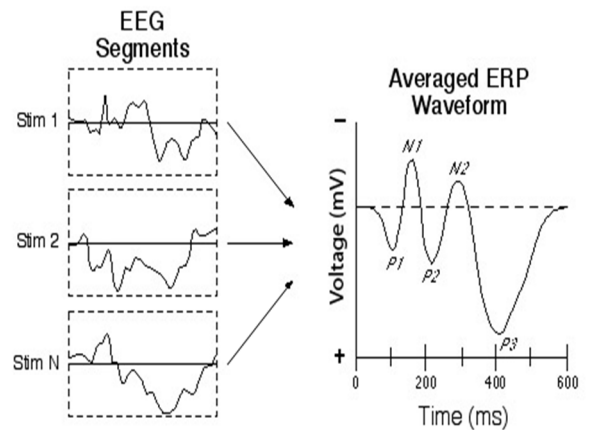


Fig. 1 [51]

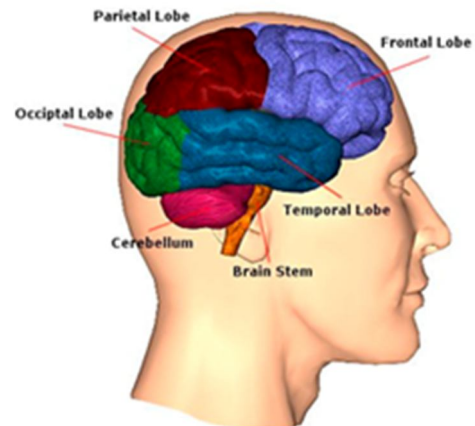


Fig. 2 [52]

The response of a person to sensory or cognitive stimulus generates event related (evoked) potentials embedded in background random EEG that is not related to the stimulus processing. Multiple identical trials are carried out and then EEG is averaged to see this small event related activity. The waveform produced after averaging across identical trials is called an event-related potential (ERP), one such wave form is shown in figure 1. Early fast activity on the recording graph is related to sensory reception which occurs in the visual cortex i.e. occipital lobe of the brain area. Various lobes of brain are depicted in figure 2. It is then followed by the slower activity related to the cognitive function of the brain which involves parietal and frontal lobe. These fast and slow neural oscillations that represent sensory and cognitive functions of the brain, underlie the ERP and are called event-related oscillations (EROs). EEG, ERPs, and EROs are significantly different for alcoholics when

compared with normal ones. The paper explains these findings in the following sections.

## II. EEG FREQUENCY COMPONENTS AND ALCOHOLISM

EEG is the brain signal recorded when a person is in resting mode, with eyes open or closed. Signals recorded from the scalp have amplitudes ranging from a few micro volts to approximately 100  $\mu\text{V}$  and a frequency content ranging from 0.5 to 30-40 Hz. EEG rhythms, also referred to as backbone rhythms, are conventionally classified into following five different frequency bands: delta (0-4 Hz.), theta (4-7 Hz.), alpha (8-12 Hz.), beta (12-30 Hz.) and gamma (> 30 Hz.) [3]. These frequencies are shown in figure 3.

The frequencies between 8-13 Hz. are the main components of the signal of a normal healthy subject under the resting mode. Moreover, it remains stable throughout the life of a healthy subject and is highly heritable [4]. The delta activity is found mainly in children of ages up to 1 year and during deep sleep of normal subjects.

Theta frequencies exist in normal infants and children and also during drowsiness and sleep in normal adults. Highly active theta frequencies suggests abnormal conditions. Frequencies in alpha range with amplitudes up to 50  $\mu\text{V}$  are a major component of the signal recorded of a normal relaxed adult where as beta variations are present in alert or anxious subjects [5]. A person in the resting state exhibits largest theta band components in the back region of the brain while the movement of this signal shifts to the frontal region of the brain of a highly active mind. Tonic theta increases in abnormal neurological states such as in the patients suffering of Alzheimer disease and in the state of decreased cognitive activity of the brain [6,7].

### Comparison of EEG Bands

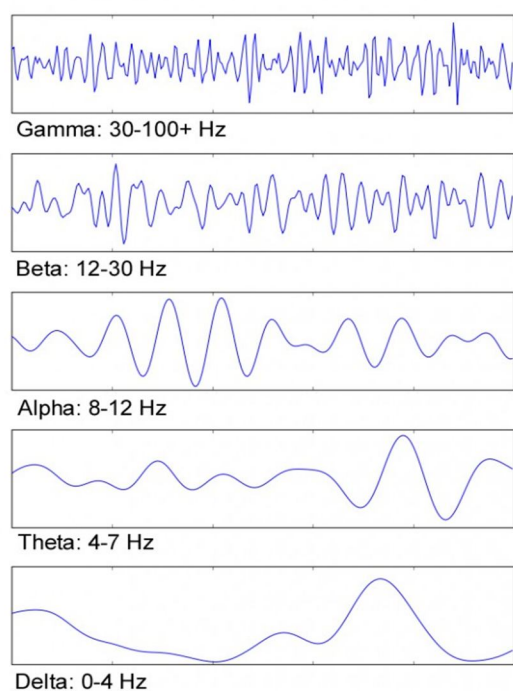


Fig. 3<sup>[53]</sup>

Resting theta power is reported to be high in alcohol dependent subjects at all the locations of the scalp. Theta waves began to appear and be gradually enhanced after consuming alcohol in the sleep state of the subjects. Results have indicated a decreased correlation between the parts of the brain. So, too much drinking may lead to decrease of balance, stability between different parts of brain and hence the increase of containment procedure [8].

Alpha rhythm is highly dominant in the occipital region in the brain of a person with closed eyes and are said to be connected with the feelings of well being [9]. Previous study of the researchers has shown that alcoholics record less prevalent and lower alpha power than normal subjects [10,11], but results from the recent studies have not been consistent with these findings [12].

Beta rhythm is a fast with low amplitude, which is distributed over the scalp area. Increased beta signal power has been reported in alcoholics when compared with non alcoholic subjects [13,14]. These differences have been reported in female alcoholics compared with female non-alcoholics, but not in male alcoholics compared with male non-alcoholics [15]. The subjects with alcohol dependency had increased power in beta 1 band (12-16 Hz.) and beta 2 (16-20Hz.) frequency band over the scalp area, compared with non alcoholic subjects. This difference was most prominent in the region between parietal and frontal areas of the brain. The alcoholic group also had increased power in the beta 3 (20-28Hz.) frequency band in the frontal region [16]. Variations in the beta signal of the alcoholic subjects have been more random and desynchronized in the frontal region of the scalp as compared to the non alcoholic subjects. It pertains to functional disturbance in the area of the brain just behind the forehead (prefrontal area). Fast beta power is an effective measure to differentiate alcoholics from non alcoholics [13,14]. Excess beta power is reported to be related with genetic predisposition of the alcoholic subjects and not to the use of alcohol in any other sense [16]. It conforms to the statement that an imbalance between excitatory and inhibitory neurons is involved in a predisposition to develop alcohol dependence [17] as well as a proneness to relapse [13]. Beta rhythm represents a balance between networks of nerve cells projecting from the cortex to other parts of the brain and spinal cord (i.e., pyramidal cells), which are excitatory and neurons that carry signals between other neurons, which are inhibitory.  $\text{GABA}_A$  the receptor (also called as binding molecule), for the neurotransmitter Gamma-Amino Butyric Acid (GABA), is thought to regulate this rhythm [18]. Researchers working on the COGA (Collaborative Study on the Genetics of Alcoholism) project have devised a genetic linkage (within families) and linkage disequilibrium (across families) between the beta frequency of the EEG and a  $\text{GABA}_A$  receptor gene [19]. Neuro-image analysis of alcoholic subjects have indicated deficits in the GABA receptors for the chemical benzodiazepine, which facilitates inhibitory GABAergic transmission [20,21]. Neuronal loss or shrinkage has been reported in the superior frontal and motor cortices of alcoholics [22]. These results suggest that the deficit in GABA receptors in the brain of alcoholics may lead to the lack of CNS (central nervous

system) inhibition i.e. hyper excitability. The association of GABA<sub>A</sub> receptor gene and beta frequency is further associated with the diagnosis of alcohol dependence [23].

### III. EVOKED POTENTIALS OF ALCOHOLIC SUBJECTS

Evoked potentials (EPs) constitute an event related activity which occurs as an electrical response from the brain to various types of sensory stimulation of nervous tissues. Auditory and visual stimulations are commonly used. It is a non-invasive testing procedure and provides information on sensory pathways abnormalities and disorders related to language and speech of a person. These voltage potentials are generally transients whose nature depend upon the type and strength of the stimulus and the electrode position on the scalp. EPs have a very low amplitude, ranging from 0.1 to 10  $\mu$ V, and are hidden in the ongoing EEG background activity [3]. Evoked potentials are better known as Event Related Potentials (ERPs). The series of peaks in the waveform are designated as P (positive) and N (Negative). These peaks carry their name as P (or N) and is followed by the time of observation of this peak after the application of stimulus, such as P300, here 300 is in milli-seconds (ms). It is also represented as P3 i.e. third positive peak. The components, occurring within 100 ms of the application of stimulus, reflect responses to the physical characteristics of the stimulus, whereas later components are influenced by more cognitive factors. P300 or P3 component has been mainly focussed characteristic in case of investigating alcoholic subjects. It is a large positive peak component which takes place between 300 to 700 ms after the stimulus (auditory or visual) has been applied. Further the characteristics of this component does not depend on the physical features of the stimulus such as the brightness and shape for visual stimuli and loudness or pitch for auditory stimuli. P3 represents the functioning of working memory i.e. the temporary storage of information required for complex processing of cognitive tasks. P3 may reflect attention seeking allocation and updating processes [24]. It is also thought to reflect the cognitive closure i.e. the termination of mental process [25,26]. It is a result of inhibition over widespread cortical areas [25,26,27,28,29]. The voltage level of the P3 signal reflects the prohibition of active responses to irrelevant stimuli that the subject must ignore in order to respond effectively to the relevant targets [25,28,30]. The processing speed of brain is reflected by the time of occurrence of P3, earlier and larger it appears, the easier is the processing [24]. "Oddball task" is commonly used to elicit P3 signal in which rare "oddball" stimuli are embedded in a series of standard or non target stimuli. When the subject is asked to respond to these rare stimuli, it is called as target. These P3s are recorded mainly over the parietal region of the scalp and designated as P3b components. P3s recorded to the unattended rare non-target stimuli are called as P3a components. Frequent non targets usually do not elicit any P3s. It has been found that the amplitude of P3b is significantly lower in alcoholics than in non-alcoholics [31,32,33,34,35]. The effect of both auditory and visual task appears in P3 components. Female alcoholic subjects have been shown to produce low P3 amplitudes as compared to male subjects [36,37,38]. It is clear that alcoholics have a

tendency for reduced P3 amplitudes to both target and non-target stimuli. Moreover, alcoholics manifest less differentiation between these two types of responses. The amplitude of P3 is supposed to reflect CNS inhibition [25,26,27,28,30]. So, it can be said that, low amplitude P3 components of alcoholics indicate that they have less CNS inhibition than control subjects. The lower amplitude P3 components and weaker and less well organized sources in alcoholics, suggest disorganized and inefficient brain functioning.

Event Related Oscillations (EROs) are the neural oscillations that underlie ERPs. These are measured in the same frequency bands as resting EEG signal but they are functionally different from them. EROs are related to the sensory and cognitive processing of stimuli [39]. Sensory signal reception involves the gamma range signals and it results due to the firing of group of neurons that are close together where as cognitive processing involves communication between regions separated apart in the brain. Cognitive processing involves the frequencies in alpha and beta range. Higher cognitive processing involves slow synchronization in the theta or delta frequency range [40]. It implies that faster frequencies represent synchronization of groups of neurons in more local areas, whereas slower frequencies are involved in synchronization over longer distances [41,42]. P3 component has multiple sources of its generation, with contribution from frontal cortex and hippocampus. P3 has higher delta oscillations from posterior regions and less theta occurring in the frontal and central regions [39,43,44,45]. Synchronization of theta range frequencies occurs between hippocampus, frontal and parietal regions of brain during attention seeking tasks. Cholinergic receptor genes of the brain are involved in theta and delta frequency production and are also associated with alcohol dependence [46]. The theta and delta rhythm involves interactions between GABA and cholinergic neurotransmitter systems. The frequency of theta is controlled by the GABA system and power being controlled by cholinergic system [47,48]. Evoked delta and theta power is significantly decreased in alcoholic, which indicates that reduction in P3 is accompanied by deficits in theta and delta waves. Decreased delta and theta power has been reported in target and rare non-target scenario, particularly in non-target situation [49]. The deficit in inhibitory theta waves which underlie P3 in alcoholic indicates deficient inhibitory control while processing the information i.e. tasks related to attention and memory in alcoholics. It further suggests that the CNS disinhibition is caused due to alcoholism [17]. Alcoholics record lower gamma signal power during target processing up to 150 ms in a visual oddball situation than normal subjects [39,50]. Non-alcoholics appeared with significantly higher gamma power in the processing of the target as compared to the processing of the non-target stimulus. Whereas gamma power of alcoholics was not higher during target processing. This fact that the gamma deficits in response to target stimuli in alcoholics, proves the deficiency in cognitive processing in those subjects.

IV. CONCLUSIONS

Male and female subjects record low amplitude of their P3 component but female alcoholics manifest this result to a lesser extent than males. It is also found that reduced amplitude of P3 components is accompanied by deficient neural oscillations (evoked delta and theta oscillations) underlying P3 waves in alcoholic subjects. It implies abnormal functioning of cognition process of the brain. Delta oscillations relate to event related signal detection while theta waves are associated with cognitive functioning of brain such as attention, alertness and processing of memory. Alcoholics produce smaller gamma signal amplitudes during the processing of target stimuli. Because gamma waves are related to selective attention processes and working memory, so it indicates that alcoholics manifest deficits in cognitive functions associated with these oscillatory processes. So, it can be stated that alcoholic subjects produce increased theta and beta oscillations and decreased active oscillations in the same frequency bands during cognitive tasks.

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