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INSTITUTING NON-EPIPHENOMINAL EEG BRAIN WAVESAS A CONSCIOUSNESS PARAMETER TO DISCERN MENTAL/MEDITATIVE STATES USING REALTIME FEEDBACK

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ABSTRACT

This paper leverages theoretical considerations and review of empirical data from previous researches to develop a hypothesis that confirms neuronal excitations as a manifestation of neuroplasticity in various stimulated environments. In this paper, we discuss the methodology to visualize various brain waves and understand the effect of dominant role play of brain signals in defining the philosophical underpinnings of consciousness during various cognitive and meditative states. The use of non-invasive Brain Computer Interfacing (BCI) is used as a monitor for real-time feedback to support the above hypothesis. If validated, this hypothesis has the potential of providing therapeutic advantages and unifying insights into multiple aspects of mindfulness and other consciousness studies. The paper reviews state-of-the-art Electroencephalography (EEG) as a criterion to define human sentience.

Keywords: EEG, Neuroplasticity, Brain Computer Interfacing, Consciousness, NFB

I. INTRODUCTION

The encephalon (or more commonly Brain) is the commingle, gen processing and hegemony centre of an individual. It integrates the various sensations (visual, tactile, acoustic, etc.), thereby contriving an appearance of the outdoors and superintending the muscular movements to facilitate actions such as seeing, moving, and speaking in order to interact with the milieu. Cognitive accounts of mental process which are practiced again and again are said to account for neuroplastic changes in our brain. Observable inferences are drawn as a result of input-output contingencies based on "third-person" observations in most of previous researches. Alternatively, "first person" (phenomenal) consciousness would, in essence, suffice to illustrate the functions involved during conscious state of mind/brain. This paper considers two situations with close examination and convergent analysis to develop a hypothesis of neuronal excitation. First situation is where recent research at MRC Centre of Developmental Neurobiology uses Optigenesis to demonstrate two types of neuroplasticity as a consequence of balanced neuronal excitation. The second situation builds a concrete evolutionary theory from the previous studies of consciousness and implicates similar neuroplastic changes in experienced meditators as seen in the former situation. Perhaps, one beneficial outcome of this work will be to get a closer glimpse of both the worlds of neuroscientists and philosophers.

This paper presents basic EEG terminologies providing a familiarity to those not belonging to a neuroscience background. It also presents the hypothesis of neuronal excitation. The study highlights a special recognition between the balanced neuronal excitation in a stimulated environment to that of an altered state of brain observed in experienced meditators owing to the neuroplastic changes as a result of excitations in certain regions of the brain. On experimental ground, our paper talks about setting up a 3-electrode EEG setup with an insight to types of waves observed during a meditation experiment. Then we discuss about Brain physiological electric waves as a consciousness parameter in order to deduce to a logical conjecture by quoting the respective similarities between our hypothesis and results from previous researches.

II. HYPOTHESIS FOR BALANCED NEURONAL EXCITABILITY IN STIMULATED ENVIRONMENT

Different areas of our brain are charged with electrical impulses and neurochemicals which are excited in different situations and in different ways. Multi-modal sensory inputs are responsible for developing brain signatures in the form of rhythmic activity patterns. Closing our eyes in meditative state reduces the neuronal activities in the occipital region of our brain responsible for vision modality. Alternatively, intrinsic brain changes after the mindfulness training owes to the impact of increased gamma activation in the same region of the brain [1]. Even though, not all studies absolutely agree on the regions that are active during meditation because findings depend upon the type of practice and methodology used for the research, yet a reasonable amount of similarities can be accumulated with attentional focus ranging from visual/auditory stimulus to somatosensory(e.g.- breath) objects in various contemplative traditions [9].

Recent research at MRC Centre of Developmental Neurobiology shows that using ‘Optigenetics’, neuronal activities can be precisely altered using light. As a result of which AIS (Axon Initial Segment) of neuron in hippocampal region can be shortened by 25% (approx.) in 3 hours which is surprisingly quick method for Neuronal-AIS-Plasticity given the big and complex structure like AIS which is mainly responsible for developing and regularizing action potential between neurons [15].Surprisingly, after 3 hours of stimulated-neuronal activation in the brain, action potential was in fact increased the action potential despite the reduction in size of neurons. This lead to a discovery and understanding of a new level of plasticity along with Neuronal-AIS-Plasticity (NAP), which is responsible for alteration in molecular structure of proteins that drive action potential (Molecular Protein Plasticity). Thus, modulation in these voltage generating sodium channels tries to balance out the AIS-shortening factor of neuronal plasticity. The ability neurons to balance its levels of excitability can be regarded as an interplay between AIS-shortening (Axon Initial Segment) and sodium channel modulation which may also be seen in ruminative environment of mindfulness [15].Theoretical motivation for the hypothesis that the neuronal excitation in both types of stimulated environments may be associated with the repeated engagement in specific brain networks responsible for inducing Neuronal-AIS (Axon Initial Segment) as well as Molecular Protein Plasticity. Such identification of neuro-plastic changes are known to mediate various positive outcomes such as increased cognitive abilities.

III. TERMINOLOGIES

Brain-computer interface (BCI) is a computer-based technology that allows the brain to communicate with external devices in order to restore, assist, or augment cognitive and sensory functions.

Electroencephalography (EEG) is a *modern electrophysiological method or technique* of chronicling the electrical potentials that are spontaneously generated during the physiologic activity of cells in the cerebral cortex. Electroencephalography often (not always) means scalp EEG recording. It can also be recorded intracranially (inside the skull) directly over the cortex leading to a synonymous method known as **electrocorticography (ECoG)**. EEG reflects your state of mind. Different recorded frequencies mean different states from deep sleep to excited ones with spikes indicating oddities. It can assist in calculating complex idiosyncrasies indicating whether you are thinking 'right' or 'left'.

EEG-based BCI is the most studied and perhaps the most clinically promising BCI technology offering advantages of being non-invasive, ease of use, portable, low set-up cost and a superior temporal resolution. Despite giving a pretty qualified view of recordings, it is highly susceptible to noise.

EEG Generation: The classic view is that nearly all normal EEG recorded on the scalp (scalp EEG) or on the cortex (electrocorticography or ECoG) is the extracellular summation of post-synaptic potentials of pyramidal neurons in the cerebral cortex. However, there is some evidence that non-synaptic currents, fast action potentials, calcium spikes, voltage-dependent intrinsic oscillations, intrinsic spike after hyper polarizations, ephaptic effects, and glia-generated slow potential shifts also play a role in normal EEG generation. For clinical purposes, we assume that most (if not all) normal EEG waves and most abnormal non-epileptiform EEG waves are derived from post-synaptic potentials and most abnormal epileptiform EEG waves from sustained membrane de-polarizations and action potentials of hyper excitable pyramidal cells.

Extracellular Potentials: Most clinical electrophysiological studies involve extracellular (not intracellular) recording. The extracellular potential generated by a single cell (e.g. neuron) or a cellular component (e.g. dendrite, soma, or axon) is known as single-unit extracellular potential. The sum of single-unit extracellular potentials within a recording 'field' (i.e. the space surrounding an electrode were extracellular potentials can be effectively recorded) is known as field potential. Field potentials that are recorded in the vicinity of the current sources are called local field potentials. The spatial and temporal summation of local field potentials can give rise to higher-order compound field potentials some of which are volume-conducted to the surface and recorded as surface potentials.

Field Size: The volume of neurons that contributes to the measured signal depends on the size and placement of electrodes. Thus, extracellular recording may be performed to determine the activity of an individual cell, the activity of a small group of cells, or the synchronous activity of a large population cells. Single-unit extracellular potential recording has been made possible with the invention of fine-tip microelectrodes. A tip diameter of about 1 micrometer can detect the activity of a neuron nearest the electrode tip with minimal contamination by neighbouring neurons. Single-unit action potentials are like the action potentials that are recorded intracellularily but only much smaller in amplitude (~1 mV). Multi-site single-unit recording is the simultaneous recording of several single-unit extracellular potentials; it is useful in determining the functional relationship between individual cells within an ensemble. Multi-unit recording of extracellular local field potentials requires electrodes with larger tips. Because of its size, the electrode cannot resolve the activity of individual cells; it can

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suitably record local field potentials generated by a small population of cells (e.g. muscle fibers) or cell structures (e.g. a bundle of axons) within the field of observation. Multi-site multi-unit recording is the simultaneous recording of several multi-unit local field potentials; it is useful in determining the relationship of different functional cell classes in a cell assembly.

Synchronization: A property of neuronal populations that is essential to generate EEG signals is the capacity of the neurons to work in synchrony. This depends on the connectivity between neurons that comprise a network. For EEG to occur, a population of dendrites, axons, or nerve cell bodies must be synchronously activated by appropriate stimulus. The thalamus and cerebral cortex have to be considered as a unified oscillatory apparatus under the control of brainstem and forebrain modulatory systems.

Surface Recording: Most clinical electrophysiological studies involve recording on the surface of biological structures. The spatial and temporal summation of local field potentials generated by a large population of cells gives rise to higher-order field potentials. These potentials are volume conducted towards the surface and can be recorded non-invasively over the skin (most routine studies) or invasively over the surface of an internal structure (e.g. electrocorticography or ECoG). The electrodes used to record surface potentials are sensitive only to certain types of synchronous activity within populations of cells numbering in the millions, spatially integrating over larger populations of cells (e.g. volumes of nervous or muscular tissue).

Volume Conduction Effects: This is the reason why scalp-recorded potentials have very little similarities to potentials recorded near the neural generators. A scalp electrode "sees" a smoothed version of the local field potentials generated from approximately 10 cm2 of cortical surface. Scalp electrodes also sample mostly the potentials generated in the superficial layers of the cortex; the contribution of deeper layers is scaled down substantially, and the contribution of neuronal activity from below the cortex is virtually negligible. Another issue is that extracellular potentials display frequency-dependent attenuation due to in-homogeneities in the volume conductor (brain, CSF, meninges, skull, scalp tissue).

Recording Parameters: These are selected to emphasize certain characteristics of the field potentials (EEG) being recorded. For example, the time constant of typical high-pass filters used in clinical EEG recording do not allow recording of very slow potential change (DC shifts) [13].

IV. EEG EXPERIMENT

The EEG pilot was developed using basic amplification components mounted over a standard breadboard with an aid of disposable EEG-Electrodes used as an input to the circuit. For convenience and understanding purposes, a 3-electrode configuration was adopted with one of the electrodes connected just above and right to the NASION in the frontal region while the other connected in similar manner to the INION in the occipital region. The third electrode provided a means to ground the entire configuration by choosing a suitable reference (Mastoid Bone, in this case.)

The electrode input was fed to an instrumentation amplifier which provided the requisite gain to amplify the brain waves to an extent suitable for visualization. The frequency range was limited to Alpha and Beta waves because the circuit posed a great challenge to even an exiguous amount of noise owing to which smaller frequency signals could not be studied effectively. To achieve this, a low pass and a high pass filter were adjunct to the original amplifier.

Two notch filters (one right at the beginning and the other towards the end) provided for some respite from noise due to power line interference. The final output was visualized using an Oscilloscope with help of a regular Arduino such that it directed the entire output for better result. Furthermore, the data was analyzed and studied using SimPlot.

The circuit served as a visualization pilot and although didn't prose a great accuracy, it did a fair job in understanding and implementing the overall concept.

The SimPlot implementation in terms of Time x- axis(Sec) and Potential Difference y-Axis (μV) has been portrayed during a slight meditative state in Figure 1. The plot tacit falling alpha waves on account of frequency band displacement.

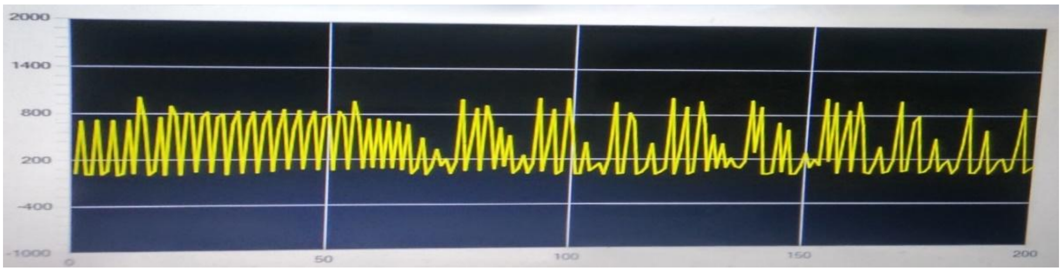

Figure 1: Swithering Alpha Waves on account of light meditation

EEG measures brainwaves of different frequencies present within the brain. Fourier Transform study implementing various decomposition bands has been the most widely used EEG analysis technique. Four basic components of EEG are:-

- Delta - 0.5-4 Hz - implies deep sleep
- Theta - 4-8 Hz - implies drowsiness
- Alpha - 8-12 Hz - implies relaxed, alert state of consciousness
- Beta - 14-30 - implies active, busy or anxious thinking

Although none of these waves is ever emitted alone, the state of consciousness of the individuals may make one frequency range more pronounced than other.

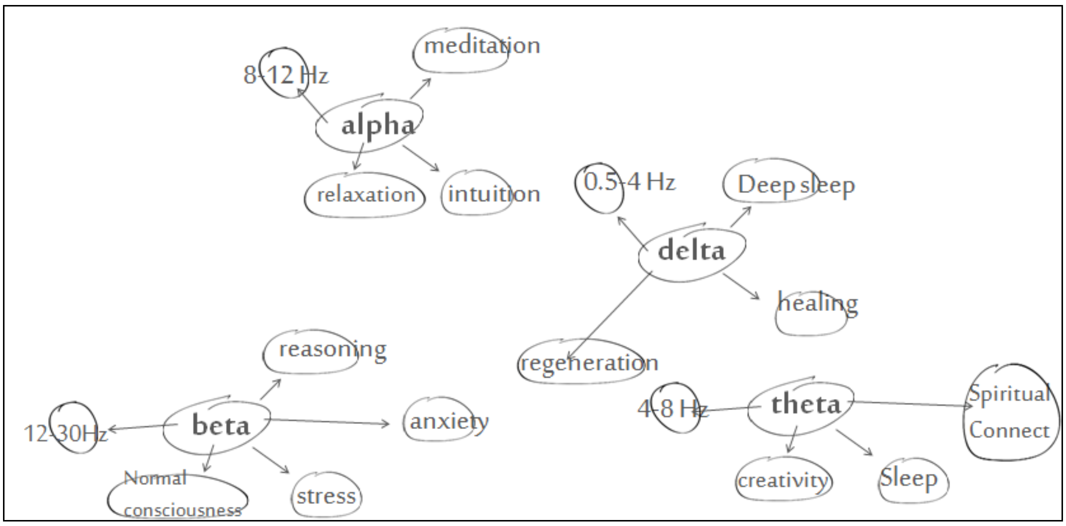

Figure 2: Classification of Different Brainwaves

V. WHAT IS CONSCIOUSNESS?

According to Cole's Paradox, we cannot actually perceive a physical reality that does not reflect a specific brain state. In other words, all the experiences can be broken down in terms of physical modalities like taste, vision, smell etc. – they are empirical reflections of our brain. It can clearly be defined as a vantage point between the outer reality and one's focus of consciousness.

In the realm of space-time illusion, existence of beginning and end can be defined and measured as an illusionary perspective of time. Existence cannot go away or come back, it can only change. Say, a glass plate fell down and is broken. The next existential state of that glass plate is that it is melted and moulded. So the glass plate did not go away or destroy. It is just changed into a glass sphere. Thus existence is the one and only experience of consciousness, experiencing itself because of existence [14].

The idea of touching the philosophical aspect of consciousness is to provide a reasonable support to the above mentioned hypothesis of experiencing the mindfulness as a state of consciousness which is non-epiphenomenal in nature [15]. Thus, neuronal excitation ascribe neuroplasticity in individuals as a result ofrepeated meditation practice in a similar stimulated environment involving the use of 'Optigenetics'. In both the cases there is a reduction of alpha rhythm in the highlighted area of figure 3. *In Transcendental Meditation*, there is a state of keen mental discernment when all the parts of the brain are tied together often due to neuroplasticity. When the frontal lobe, back lobe and the two hemispherical (analytical and intuitive) parts of the brain work cohesively, alpha brain waves start to disappear from the back of the brain and appear in front (shown in Figure 3) which is often regarded as a state of restful awareness in meditative terms [1-3], [8-10]. This state is observed during meditation which is often guided by inward concentration and quieter level of the mind [10], [12-14].

Figure 3: Remoulding Alpha Rhythm in Occipital Region

Perception of brain in different sensory modality can influence consciousness parameter which in turn influences physiological electrical activities in our brain. Thus using brain signatures as interpretations of context stimulus enables us to recognize patterns in various stimulated environments [4]. Studies have found various contrastive and attractive context for stimuli of various complexities. Bayesian models do provide computational principles to study these contexts in terms of neuronal activities in cerebral cortex through neuroimaging [5-7].

VI. CONCLUSION

There is an extensive research that studies the functional analysis of "conscious" and "non- conscious" processing to reveal the causal interactions between the brain and consciousness. Meditative states are likely to correlate with higher order physical states of the brain which in turn alters brain's micro-operations. Such parametric differences may help resolve some prevailing philosophical positions which needs to be re-examined and resolved using empirical research. Based on past literature and theoretical considerations, we believe that our hypothesis for neuronal excitation may be a way to conceptualize consciousness as a product of causal affect after neuroanatomical and neurochemical changes, shared by most experienced meditators. It is important to remember that the hypothesis be verified in a larger population and it is possible to observe overwhelming similarities given the heterogeneity of the practitioners in terms of methodology used and other ontological aspects. It is encouraging, however, to know that there is a preserved commonality which helps us detect the core traits for therapeutic assessments, suggesting consistent neural affects after meditation.

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