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A Survey: Fundamental of EEG

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Abstract: *Recent advances in computer hardware and signal processing have made possible the use of EEG signals or "brain waves" for communication between humans and computers. Hence there is need to know about EEG signal. Electroencephalogram (EEG) is the recording of the electrical activity of the brain. The EEG signal is a representative signal containing information about the condition of the brain. The shape of the wave may contain useful information about the state of the brain. It has been known that different regions of the brain are activated according to the associated mental status, for example, emotional status, cognitive status, etc. Since the difference in activities of the brain causes the difference in characteristics of EEG, it has been attempted to investigate the brain activity through analyzing EEG.*

Keywords: *EEG, alpha, beta, gamma, theta, Hans Berger.*

I. INTRODUCTION

The group of electrobiological measurements comprises items as electrocardiography (ECG, heart), electromyography (EMG, muscular contractions), electroencephalography (EEG, brain), magnetoencephalography (MEG, brain), electrogastrography (EGG, stomach), electrooptigraphy (EOG, eye dipole field). Imaging techniques based on different physical principles include computer tomography (CT), magnetic resonance imaging (MRI), functional MRI (fMRI), positron emission tomography (PET), and single photon emission computed tomography (SPECT). So we work on the EEG signal because it directly MEASURES the electrical activity of the brain and we know that brain in main part of the body.

Electroencephalography is a medical imaging technique that reads scalp electrical activity generated by brain structures. The electroencephalogram (EEG) is defined as electrical activity of an alternating type recorded from the scalp surface after being picked up by metal electrodes and conductive media [1]. The EEG measured directly from the cortical surface is called electrocortigram while when using depth probes it is called electro gram. Thus electroencephalographic reading is a completely non-invasive procedure that can be applied repeatedly to patients, normal adults, and children with virtually no risk or limitation. When brain cells (neurons) are activated, local current flows are produced. EEG measures mostly the currents that flow during synaptic excitations of the dendrites of many pyramidal neurons in the cerebral cortex. Differences of electrical potentials are caused by summed postsynaptic graded potentials from pyramidal cells that create electrical dipoles between soma (body of neuron) and apical dendrites (neural branches). Brain electrical current consists mostly of Na⁺, K⁺, Ca⁺⁺, and Cl⁻ ions that are pumped through channels in neuron membranes in the direction governed by membrane potential [2]. Only large populations of active neurons can generate electrical activity recordable on the head surface. Between electrode and neuronal layers current penetrates through skin, skull and several other layers. Weak electrical signals detected by the scalp

electrodes are massively amplified, and then displayed on paper or stored to computer memory [3]. Due to capability to reflect both the normal and abnormal electrical activity of the brain, EEG has been found to be a very powerful tool in the field of neurology and clinical neurophysiology. The human brain electric activity starts around the 17-23 week of prenatal development.

II. EEG HISTORY

During more than 100 years of its history, encephalography has undergone massive progress. The existence of electrical currents in the brain was discovered in 1875 by an English physician Richard Caton. Caton observed the EEG from the exposed brains of rabbits and monkeys.



Hans Berger

In 1924 Hans Berger, a German neurologist, used his ordinary radio equipment to amplify the brain's electrical activity measured on the human scalp. He announced that weak electric currents generated in the brain can be recorded without opening the skull, and depicted graphically on a strip of paper. The activity that he observed changed according to the functional status of the brain, such as in sleep, anaesthesia, lack of oxygen and in certain neural diseases, such as in epilepsy. Berger laid the foundations for many of the present applications of electroencephalography. He also used the word electroencephalogram as the first for describing brain electric potentials in humans. He was right with his suggestion that brain activity changes in a consistent and recognizable way when the general status of the subject changes, as from relaxation to alertness. Later in 1934 Adrian and Matthews published the paper verifying concept of "human brain waves" and identified regular oscillations around 10 to 12 Hz which they termed "alpha rhythm" [4].

III. BRAIN WAVES CLASSIFICATION

For obtaining basic brain patterns of individuals, subjects are instructed to close their eyes and relax. Brain patterns form wave shapes that are commonly sinusoidal. Usually, they are measured from peak to peak and normally range from 0.5 to 100 μ V in amplitude, which is about 100 times lower than ECG signals. By means of Fourier transform power spectrum from the raw EEG signal is derived. In power spectrum contribution of sine waves with different frequencies are visible. Although the spectrum is continuous, ranging from 0 Hz up to one half of sampling frequency, the brain state of the individual may make certain frequencies more dominant. Brain waves have been categorized basic groups (Fig. 1) [5].

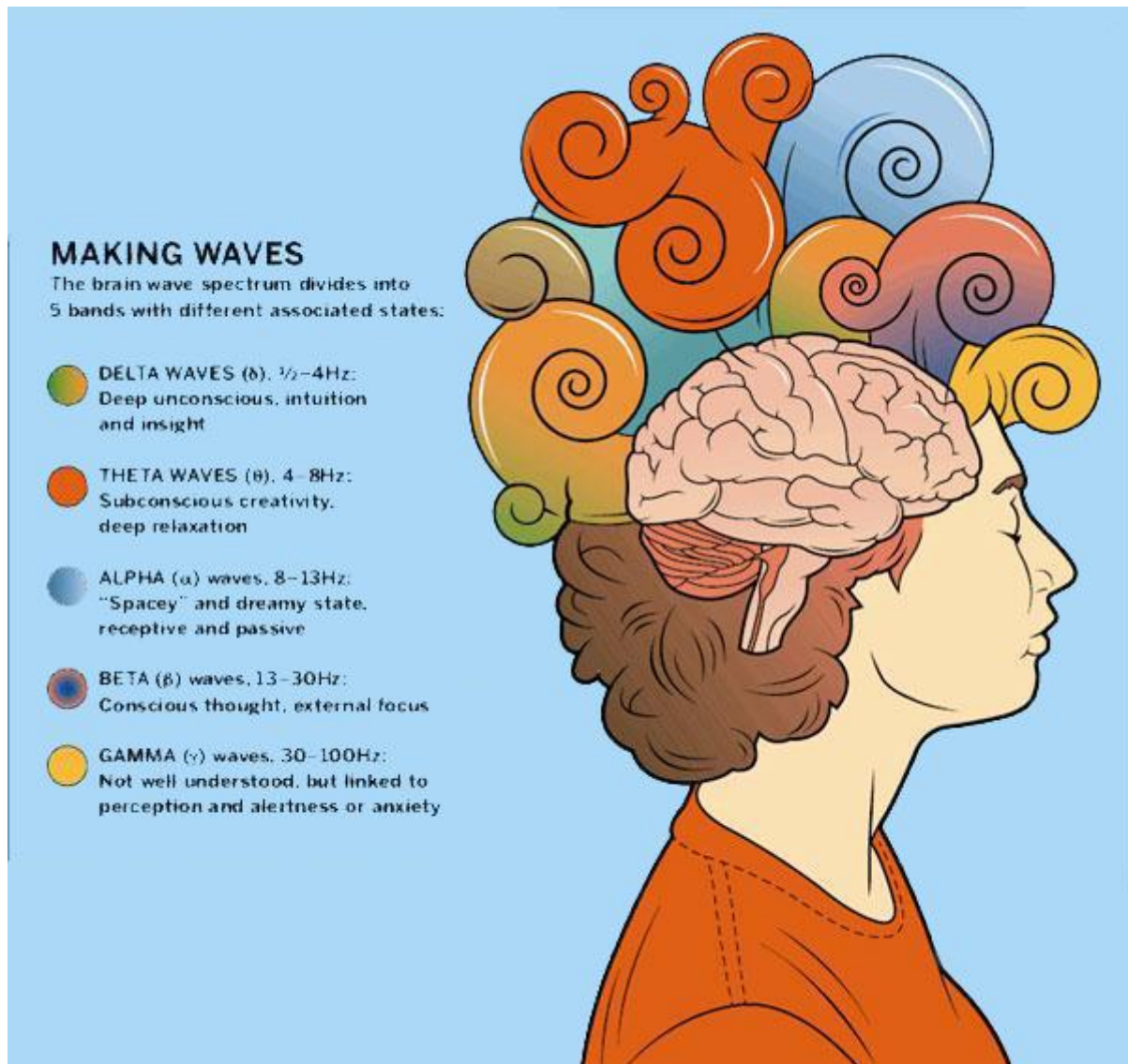


Fig. 1 Brain wave samples.

The best-known and most extensively studied rhythm of the human brain is the normal alpha rhythm. Alpha can be usually observed better in the posterior and occipital regions with typical amplitude about 50 μV (peak-peak). According to our experiences alpha was also significant between posterior and central regions in comparison to other regions. Alpha activity is induced by closing the eyes and by relaxation, and abolished by eye opening or alerting by any mechanism (thinking, calculating). Most of the people are remarkably sensitive to the phenomenon of “eye closing”, i.e. when they close their eyes their wave pattern significantly changes from beta into alpha waves. EEG is sensitive to a continuum of states ranging from stress state, alertness to resting state, hypnosis, and sleep. During normal state of wakefulness with open eyes beta waves are dominant. In relaxation or drowsiness alpha activity rises and if sleep appears power of lower frequency bands increase. Sleep is generally divided into two broad types: nonrapid eye movement sleep (NREM) and REM sleep. NREM and REM occur in alternating cycles. NREM is further divided into stage I, stage II, stage III and stage IV. The last two stages correspond to deeper sleep, where slow delta waves show higher proportions, with slower dominant frequencies responsiveness to stimuli decreases. Various regions of the brain do not emit the same brain wave frequency simultaneously. An EEG signal between electrodes placed on the scalp consists of many waves with different characteristics. A large amount of data received from even one single EEG recording presents a difficulty for interpretation. Individual’s brain wave patterns are unique. In some cases, it is possible to distinguish persons only according to their typical brain activity. For example, subjects who regard themselves as

rational types or as holistic/intuitive types may demonstrate certain higher activity in their frontal left and frontal right hemisphere respectively.

■ Why EEG?

The motivation to develop an electroencephalographic (EEG) biofeedback system that can be easily used by any person comes from the fact that the brain is one of the most important and interesting biological structure in the human body but still, its processes and functioning are not available for everyone to acknowledge [6]. When this possibility was offered, it was observed that people could modify certain aspects of their brain functioning for short periods of time and, when this was done in a methodological way, some changes could become permanent. The most interesting fact is that this type of biofeedback never showed undesirable effects and has been used to treat neurological conditions, sometimes with better results than with medication, or to improve some cognitive processes. However, more research in this area needs to be done to improve its visibility [7].

■ EEG: Anatomy of the Brain:

The brain consists of 1010-1011 neurons that are very closely interconnected via axons and dendrites [8]. The neurons are in charge of communicating information to and from the brain. According to Malmivuo and Plonsey[8], the brain has 5 main parts: a) the interbrain (diencephalon), b) the midbrain, c) the pons Varolii and cerebellum, d) the medulla oblongata and e) the cerebrum, including the two cerebral hemispheres, as shown in Fig 2.

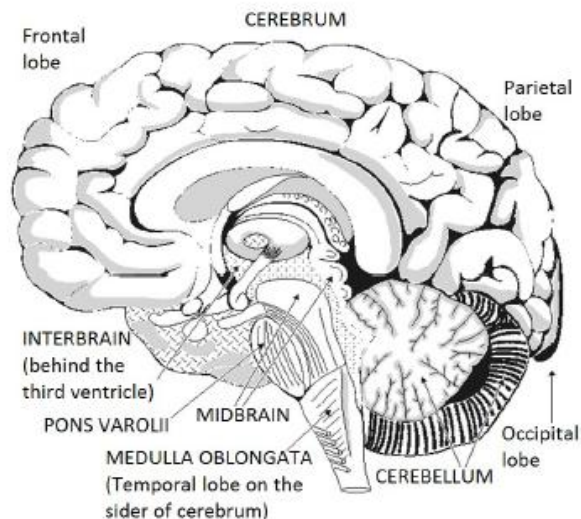


Fig. 2 Anatomy of Brain

Malmivuo and Plonsey [8] explain that the interbrain or diencephalon includes the thalamus and the hypothalamus. The Thalamus is a bridge connecting the sensory paths, while the hypothalamus is important for the regulation of the autonomic (involuntary) functions; together with the hypothesis, it regulates hormonal secretions, the midbrains a small part of the brain. The pons Varoliis an interconnection of neural tracts; while the cerebellum controls fine movement. On the other hand, the medulla oblongata resembles the spinal cord to which it is immediately connected. Many reflex centers, such as the vasomotor center and the breathing center, are located in the medulla oblongata. Finally, the cerebrum, which is the largest area of the brain, includes the higher cerebral functions, accurate sensations and the voluntary motor control of muscles. It consists of two hemispheres, the right and left cerebral hemispheres. The right cerebral hemisphere controls the left side of the body and the left cerebral hemisphere the right. The outer layer of the cerebrum, called the cerebral cortex, is made up of grey matter. The inner portion of the cerebrum is white matter. Grey matter is composed of nerve cells; these cells control brain activity; while white matter is composed of nerve cell axons that carry information between nerve cells in the brain and spinal cord. Deep indentations called fissures divide each hemisphere of the cerebrum into four lobes: a) frontal lobe, b) parietal lobe, c) temporal lobe and d) occipital lobe, Nov'ak [9]. Penfield and Rasmussen [10] state that in the cerebral cortex are located many different

areas of specialized brain function; the higher brain functions occur in the frontal lobe, the visual center is located in the occipital lobe, and the sensory area and motor area are located on both sides of the central fissure. There are specific areas in the sensory and motor cortex whose elements correspond to certain parts of the body. Based on Malmivuo and Plonsey [8], Sormo and Laguna [11], and Novák [8], there are several waves that can be differentiated from the EEG signal as follows:

Alpha waves - have the frequency spectrum of 8- 13 Hz; they can be measured from the occipital region in an awake person when the eyes are closed; alpha activity disappears normally with attention (e.g., mental arithmetic, stress, opening eyes).

Beta waves - have the frequency band of 13 - 30 Hz, these are detectable over the parietal and frontal lobes and beta activity is generally regarded as a normal rhythm and is the dominant rhythm in patients who are alert or anxious or who have their eyes open.

Delta waves - have the frequency range of 0.5-4 Hz; they are detectable in infants and sleeping adults, and can be an indicative of cerebral damage or brain disease.

Theta waves - have the frequency range of 4-8 Hz; they are obtained from children and sleeping adults; the theta activity occurs during drowsiness and in certain stages of sleep, being abnormal in awake adults but is perfectly normal in children up to 13 years and in sleep.

Gamma waves - have the frequency spectrum of upper 30 Hz, it is related to a state of active information processing of the cortex.

IV. EEG LEAD SYSTEM

The internationally standardized 10-20 system is usually employed to record the spontaneous EEG [10]. In this system 21 electrodes are located on the surface of the scalp, as shown in Fig. 3. The positions are determined as follows: Reference points are nasion, which is the delve at the top of the nose, level with the eyes; and inion, which is the bony lump at the base of the skull on the midline at the back of the head. From these points, the skull perimeters are measured in the transverse and median planes. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals. In addition to the 21 electrodes of the international 10-20 system, intermediate 10% electrode positions are also used [13]. The locations and nomenclature of these electrodes are standardized by the American Electroencephalographic Society. In this recommendation, four electrodes have different names compared to the 10-20 system; these are T₇, T₈, P₇, and P₈.

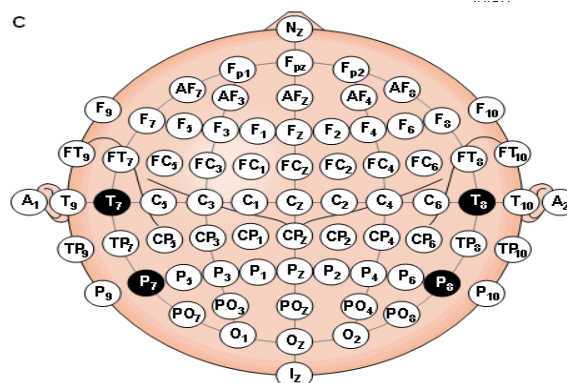


Fig. 3 10-20 System

How EEG Work?

Here, instead of a central nervous system, there are decentralized nerve nets where sensory neurons communicate with motor neurons by electric signals. This communication can be seen as a logic circuit where some action is done if signals from a certain group of input sensory neurons are present. This kind of activity, known as bioelectromagnetism, already produces a measurable electromagnetic field. In the human nervous system the electrical signal of a single neuron is too small to be measured by an electrode on the scalp therefore, the measured activity comes from the summation of the activity of hundreds of neurons on the vicinity of the electrode. If the electric field is measured, the signal is called electroencephalogram (EEG)[14]. Therefore, according to the measure location and the measured signal, it is possible to understand until a certain degree what kind of activity occurs. Sometimes, a group of neurons fire more synchronously reflecting immediately in the measured signal as it becomes stronger and more synchronous to the firing frequency. This is why these signals are seen as brainwaves and are categorized in different frequency bands. Each frequency band can correlate to a certain mental state for example; activity in the alpha frequency range (8-12Hz) is seen during relaxation whereas activity in the beta frequency range (15-20Hz) is present during high alertness and mental activity.

Besides the EEG clinical applications for diagnosis and monitoring, others exist like brain computer interfaces (BCI) and EEG fundamentals [15]. The last two rely on the fact that an individual can change certain EEG characteristics on demand. Brain computer interfaces allow its user to control a system using his EEG as an input. In EEG biofeedback a person's EEG is used as an input as well but the target is the person himself.

V. CONCLUSION

In this paper we studied different signal such that electrocardiography (ECG, heart), electromyography (EMG, muscular contractions), electroencephalography (EEG, brain), magnetoencephalography (MEG, brain), electrogastrography (EGG, stomach), electrooptigraphy (EOG, eye dipole field) but EEG is the only available investigation for recording and evaluating the paroxysmal discharges of cerebral neurons causing seizures. The appropriate evaluation of patients with epileptic disorders is often impossible without an EEG. In the majority of cases the clinical diagnosis is concordant with the EEG findings. EEG measures electric potentials EEG signals can be used in many ways: ERP, Frequency, Time/Frequency EEG are best-suited to hypotheses about time .EEG can provide spatial information. Digital EEG is the paperless recording of an EEG using computer-based instrumentation. The data are stored on electronic media, such as magnetic drives or optical disks and displayed on a monitor. There are several waves that can be differentiated from the EEG signal alpha, beta, gamma, theta etc.

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