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FUNDAMENTAL CONCEPTS OF EEG. ITS PROCESSING AND PROPERTIES IN BRAIN FUNCTIONING

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ABSTRACT:

Electroencephalography (EEG) is a form of non-invasive brain imaging that records electrical activity (EEG). It's an overview of where EEG came from, briefly. In this article, we also detail the various brain imaging methods now in use. The human brain's anatomy and physiology are the next topics covered, with the intention of defining some terms. It provides context for understanding its anatomy and functionality. In this section, we'll discuss how the electrochemical currents that are recorded by scalp electrodes actually form in the brain. The techniques, potential problems, and necessary tools for EEG acquisition are discussed in this work. In modern times, the term "Electroencephalogram" (EEG) has come to mean "a recording of electrical activity of the alternating kind generated by brain regions and made at the scalp surface using metal electrodes and conductive medium". EEG recorded with electrodes placed on the brain's surface is called an electrocorticogram (ECoG), while EEG recorded with a depth probe is called an electro gramme.

1. INTRODUCTION

When it comes to medicine and philosophy, the human brain has always been the most intriguing part of the human body. Human autopsies were used to learn about the brain's anatomy, and later, a number of live brain experiments were devised to learn more about the brain's behaviour and its various functions. First used on animals, these procedures were eventually applied to humans with terminal conditions or serious skull fractures. Slowly, via trial and error, experts learned more about how the human brain works. Philosophers, psychologists, and surgeons were all captivated by it. The evolution of EEG signals is detailed in this work.

2. INTRODUCTION TO THE HUMAN BRAIN

Here, we break down the inner workings of the brain to show you how it all fits together. The study looks into how electrical activity in the brain may be detected and recorded. The neuron is the building block of the brain and understanding how electricity is generated begins there.

2.1 The neuron

The electrical potentials of several neurons in the brain are added together to create the waves shown in an electroencephalogram. About 100 billion (1011) neurons, with a density of about 104 per cubic mm, are present in a newborn human brain. An ageing brain has fewer neurons. While neurons are similar to and comprise the same parts as other cells, their electrochemical nature allows them to communicate across great distances via electrical signals. There are three primary components of a neuron.

Cell body - Included in this central region are the DNA-containing nucleus, the protein-synthesising endoplasmic reticulum and ribosome, and the energy-generating mitochondria (for supplying energy). When a neuron's cell body dies, the neuron itself is destroyed.

Axon - The action potential (AP) travels the length of the cell on this long, cable-like protrusion of the cell.

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Dendrites - Essentially tiny branches, these projections extend out from the cell to establish contacts with neighbouring cells and facilitate communication between neurons. Dendrites may extend from either the leading or trailing edge of the cell.
Depending on their role, different types of neurons can take on a variety of shapes.

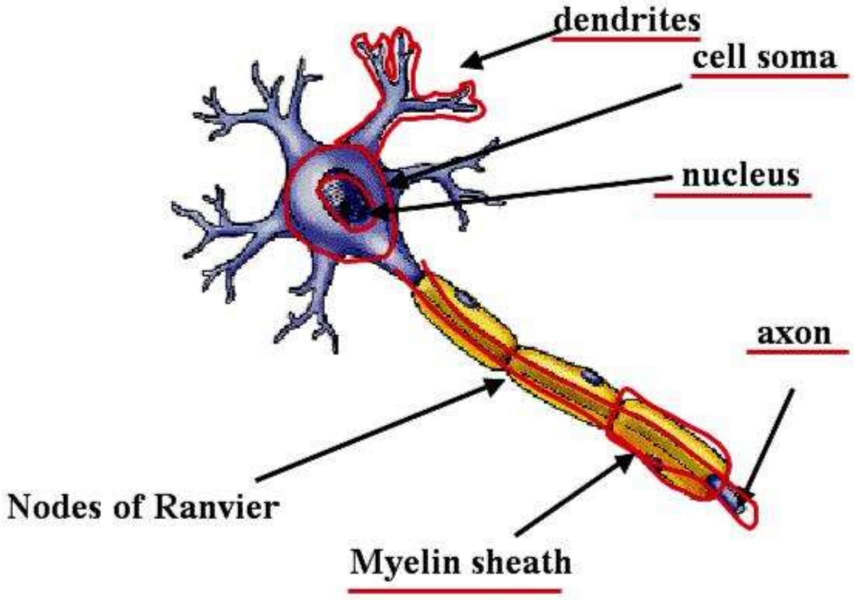

Figure 1 General Structure of Neuron

2.2 Functioning of Brain

Approximately 1.4 kg is the typical weight of an adult human brain. Figure 2-3 depicts the terminology for its orientation with relation to the body. Cerebrospinal fluid surrounds the brain and helps keep it in place within the skull while also functioning as a shock absorber to prevent damage. Carlson divides the brain into three regions, the forebrain, the midbrain, and the hindbrain, according to how far along each region is in its development. The brain has three major parts—the brain stem (or hindbrain), the cerebrum, and the cerebellum (forebrain). Figure 2-3 shows this in action. Here's a quick rundown of what these buildings are for:

- Reflexes and autonomic nerve functions are regulated by the brainstem (respiration, heart rate, blood pressure).
- Cerebral structures include the superficial cortex, the deep white matter, and the vast fibre tracts that connect the two (basal ganglia, amygdala, hippocampus). It analyses sensory data, initiates movement, regulates mood, and stores information necessary for long-term memory and abstract reasoning.
- The cerebellum uses position and movement information received from the vestibular system to coordinate limb motions and keep the body upright and steady.
- The hypothalamus and pituitary gland regulate core physiological processes like eating, drinking, arousal, aggression, and pleasure as well as body temperature.
- Rhythmic cortical activity is generated and modulated by the thalamus, notably the thalamic sensory nuclei.

Separate regions of the brain can be found in physical space. separated first into left and right hemispheres that are linked via the corpus callosum. The right one is responsible for left-side movement control and sensing. To a similar extent, the left hemisphere of the brain is linked to the right side of the physical body.

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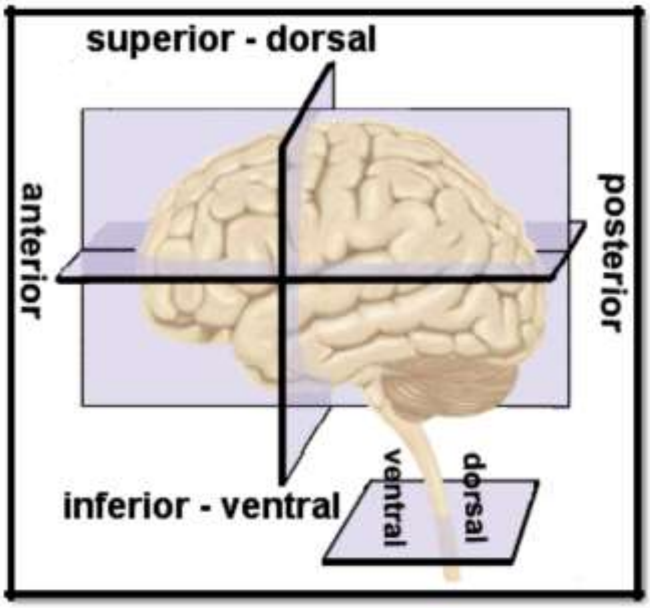

Figure 2 Orientation of Brian with respect to rest of body.

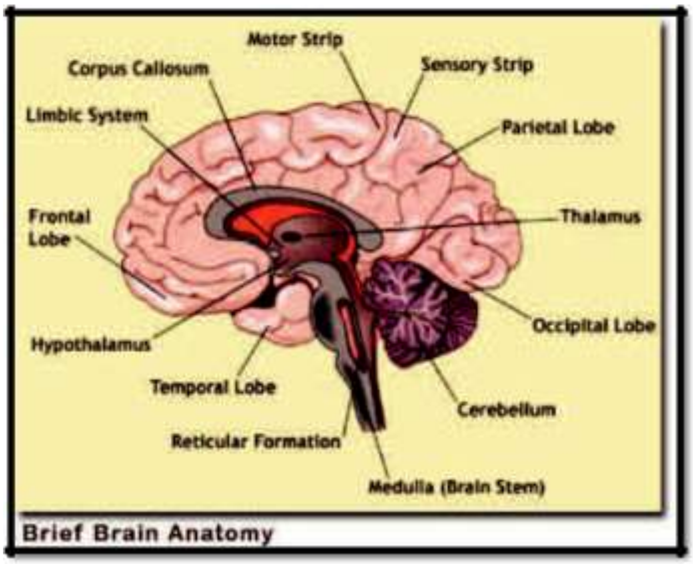

Figure 3 Anatomy of Brain

Brain function is quite regionally specific. This allows for the cerebral cortex to be segmented into many regions that can each be responsible for a certain set of mental processes. In the table below, you'll find details about these places:

Table 1 Functional Areas of Brain

Cortical Area	Function
Auditory association area	Complex processing of auditory information
Auditory cortex	Detection of sound quality (loudness, tone)
Broca's area (speech centre)	Speech production and articulation
Prefrontal cortex	Problem solving, emotion, complex thought
Premotor cortex	Coordination of complex movement

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Gustatory area	Processing of taste information
Wernicke's area	Language comprehension
Primary Visual Cortex	Complex processing of visual information

The EEG can be different depending on the position of the recording electrodes because the brain's architecture is not uniform and the cortex is functionally organised. Now that we have a basic understanding of how EEG is created physiologically, we can examine the methods used to acquire, analyse, and interpret EEG data recorded from different sites on the scalp.

3. BASICS OF EEG (ELECTROENCEPHALOGRAPHY)

A visual record of the heightened electrical activity produced by neurons in the brain, an electroencephalogram (EEG) is possible. The ancient Greek roots of the term "electroencephalogram" can be traced back to the words for "electrical brain" and "image" (encephalo and gramme, respectively).

Electrodes are attached to the scalp, and the resulting electrical activity is recorded and presented either graphically (using a computerised acquisition system) or manually (using a piece of moving paper). The ensuing fluctuations in electrochemical potentials are what we call brain waves. The amplitude and frequency of brain waves can also change. The amplitude of a voltage signal is a measure of how powerful the signal is. The EEG's voltage ranges from 20 to 200 micro volts, which is exceedingly low (pv).

The EEG measures the electrical activity of the brain by positioning electrode endpoints all over the scalp. The cumulative response of a significant population of cortical neurons, at a depth of a few millimetres, generates an electric signal that is sufficiently robust to be measured from the human skull. The electrode connections are usually arranged in an universally acknowledged "10-20" pattern. Electrodes are placed all over the surface of the scalp in the "10-20" pattern. The distance between neighbouring electrode endpoints is shown by the digits "10" and "20." The activity aspect of cerebrums is represented by signal frequency.

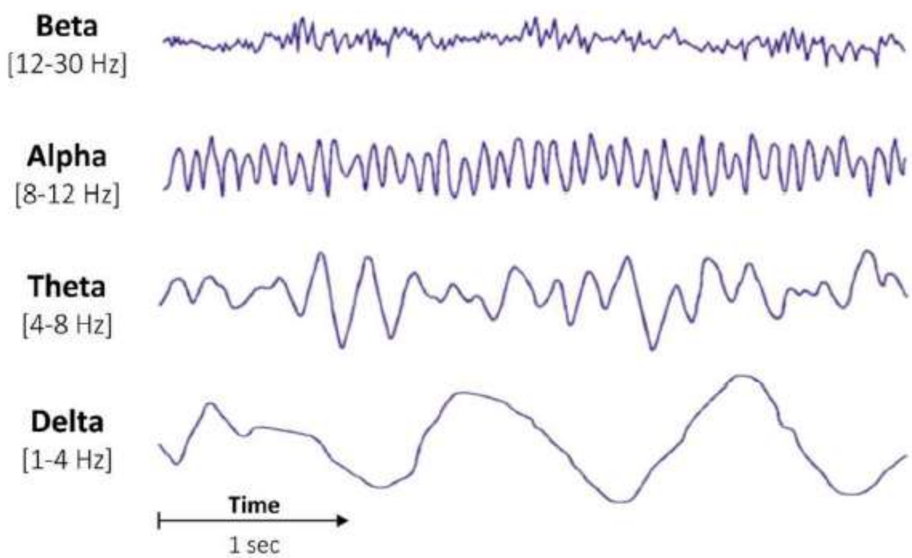

Fig 4: Human EEG Signal Main Frequencies [14]

Delta Wave: It has a frequency of fewer than 3 Hz and has the maximum amplitude that moves at the lowest latency. This is common in newborns under the age of one year, as well as sleep phases three and four. It might be focal with sub cortical lesions or disseminated with diffuse lesions, biochemical encephalopathy hyperinflation or profound bilateral lesions. The frontal lobes of adults are usually the relatively pronounced.

Theta Wave: It is classified as "slow" activity since its frequency ranges from 4 to 8 Hz. It's frequent among youngsters less than the age of thirteen and when they're asleep, however, it is rare in conscious grownups. It can be seen as a sign of isolated sub-cortical lesions, including in more widespread disorders such metabolic dementia and some forms of hypertension, when it appears as a widespread occurrence.

Alpha Wave: The frequency is between 7.5 and 13 Hz. On either area of the head, it is more typically evident at the rear, with the dominant part having larger amplitude. When eyes are closed and calm, it emerges, and when eyes are awake or alerted by any process such as thinking, calculating, it disappears. It is the pattern that most people have when they are at ease. It lasts the majority of a person's life, especially beyond the age of thirteen.

Beta Wave: The word "beta" means "quick." It oscillates at a frequency of 14 Hz or higher. It is frequently displayed in a symmetrical pattern on both sides and is more noticeable in the front. Sedative-hypnotic drugs, particularly benzodiazepines and barbiturates, exacerbate this effect. In areas where cortical trauma has occurred, it may be lacking or decreased. It's supposed to be a distinctive beat. When a patient is attentive, anxious, or has their eyes open, this is the dominant rhythm.

he normal range of EEG signal amplitude in the 0 to 100 Hz frequency range is around 40 and 100 micro-volts. The EEG signal is shown as a graph or chart that plots the voltage or potential difference against time. The intentional voltage is calculated as the potential difference between two terminal locations on the scalp. The EEG is a diagnostic and research tool used to diagnose and investigate neurological disorders such as epilepsy. The EEG measurements can be used to assess the nature of subjects' rest and examine various periods of rest. Furthermore, the brain signal or cerebrum signature can be used to monitor a pharmaceutical effect, such as the right amount of dosage during anaesthesia.

5. BASIC STEPS OF EEG SIGNAL PROCESSING

The basic signal processing steps that are involved in EEG evaluation is shown in Figure 1.10.

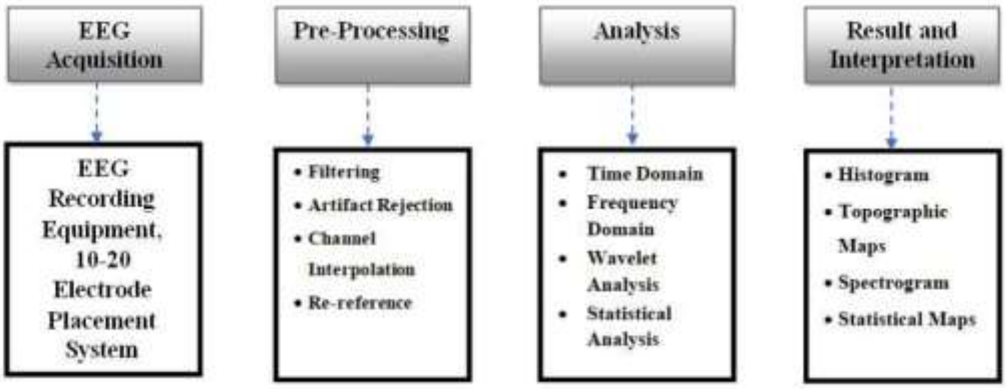

Fig. 5: Basic Steps of EEG Signal Processing

EEG signals are acquired through RMS 32 channel and 64 channel EEG machine. 10-20 electrode system is used for acquiring the data. The EEG data can be of any form like EEGLAB, EDF, and EGI. This EEG data is to be converted into some other form which can be used for further analysis.

Raw EEG signal that is collected is contaminated with noise and artifacts. To obtain "clean" EEG data, preprocessing is required to enlarge the SNR (signal to noise ratio). The signal in addition to

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noise are constantly mixed together in EEG signal. Some artifact can be easily recognized and removed while performing this step.
The next step is of channel location assignment and interpolation. This is implemented to scatter the coordinate data for every electrode (channel) in the dataset. There are many electrodes connected to the headsets, it is necessary to re-reference the electrodes so that noise from adjacent electrodes does not affect the electrodes which are of interest.
After pre-processing, EEG analysis is performed in which its time domain and frequency domain parameters are studied. This will provide the idea about the patient classification, level of dementia, trauma etc. The proper classification of the patients according to the age, gender and severity etc. is done using wavelet transform. Finally, the results of EEG are obtained with topograhps, histograms and statistics. To process all EEG signals, analyze all the EEG frequencies; EEG spectral density is calculated for all the subjects.

6. EEG RECORDING ELECTRODES

For the purpose of collecting high-quality data for interpretation, the EEG recording electrodes and their correct operation are essential. There are many distinct electrode kinds, often with unique properties. The basic categories of electrodes are as follows.

6.1 Stick on Cup or Disc Electrodes

Electrodes in the form of shallow cups or discs are widely used in clinical and research applications. They are made up of chloride silver, diameter is 9 to 11 mm and thickness is 0.25 mm.

6.2 Floating Electrodes

These types of electrodes are designed to avoid direct contact between skin and metal. The electrolyte paste or jelly acts as a conductor between metal and skin. They range in resistance from 3 to 20 kQ. They have two-sided sticky collars that cling to the skin.

6.3 Pressure Contact or Pad Electrodes

In essence, they are made up of a piece of chloride silver that has been padded with sponge and gauze, supported by a plastic foot, and held in place by some type of cap made of flat rubber band or narrow rubber tubing. They are susceptible to artefact and have a high touch resistance and relative mobility to skin.

6.4 Insersion Scalp Electrodes

They are frequently made of platinum, iridium, or stainless steel. The needle is inserted into the skin at a minimum depth of 5mm and at an angle of 30° to the scalp. They are particularly appropriate for emergency reports from patients who are profoundly unconscious.

7. CONCLUSION

The many cognitive research and clinical uses of EEG are discussed in this section. Most of the therapeutic applications of EEG today may be traced back to the groundwork that Hans Berger set forth in his early papers. EEG's quickness and low cost make it a preferable method for brain imaging. Millisecond-accurate recordings of brain activity may now capture even the most intricate patterns. In contrast to MRI and PET, which offer a spatial resolution of just 1mm and 3mm, respectively, EEG has a far lower resolution of 1cm. For this reason, it is common practise to compare MRI scans from a similar but independently executed trial with EEG inverse solution images for a better understanding of the basis of neuronal activity.

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