

What is EEG?

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The language of communication with the nervous system is electric. Electroencephalography (EEG) is a tool for measuring electrical activity generated in the brain, which opens a window for exploring neural activity and brain functioning. The EEG signal is measured using electrodes placed on the scalp, which record the electrical field generated by the nerve cells.

Advantages and Disadvantages of the Method
EEG has two clear advantages for brain research. The first is characteristic of any electrical recording system—high precision time measurements. Changes in the brain's electrical activity occur very quickly, and extremely high time resolution is required to determine the precise moments at which these electrical events take place. Today's EEG technology can accurately detect brain activity at a resolution of a single millisecond (and even less). Unlike other electrical recording devices that require inserting electrodes into the brain, EEG electrodes are simply stuck onto the scalp. It is therefore a non-invasive procedure that allows researchers clear access to a healthy human brain (which they would not probe inside to explore, of course). In addition, EEG equipment is relatively inexpensive compared with other devices and simple to operate.

The main disadvantage of EEG recording is poor spatial resolution. Since measurements are taken at the scalp, the received signal is, essentially, the sum of the electric field (in the direction perpendicular to the scalp) that is produced by a large population of neurons. The spatial resolution of a single electrode is in the order of one centimeter of the cortex, which contains hundreds of thousands of neurons. Particularly strong electrical activity can be picked up by several neighboring electrodes. The EEG signal, therefore, is not useful for pinpointing the exact source of the activity, and it does not allow researchers to distinguish between activities originating in different but closely adjacent locations. That said, today there are more advanced techniques available for analyzing EEG which allow for more accurate estimates of the signal source.

Illustration 1: An electrode placed on the scalp records the electrical field generated by the voltage patterns of cortical neurons' membrane. A single electrode receives the sum of the electric fields from approximately one-centimeter area of the cortex.



Use of the EEG signal in research
Typically, a subject is fitted with several dozen electrodes placed all over the scalp in order to record activity from different locations in the brain. Researchers have two primary methods for using the EEG signals to learn about brain activity. One is to study the characteristics of brain activity in different cognitive situations. EEG, for example, can reveal different stages of sleep and levels of alertness; the EEG reading of a subject at rest is different from that of a subject engaged in cognitive activity (learning, remembering, etc.). EEG can also indicate the effects of medication, drugs, or fatigue on brain activity.

Illustration 2: A subject wearing an EEG cap fitted with 128 electrodes.

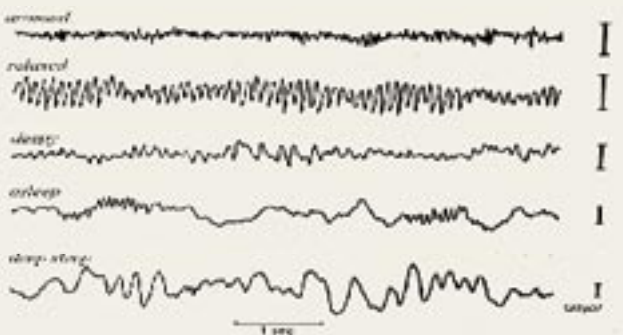


Illustration 3: EEG readings at various levels of alertness.

Another way that researchers use EEG signals for studying the brain is to examine responses to stimuli and other events. This method is based on the assumption that when a particular event occurs (we see a familiar face, for instance), something changes in the brain's regular activity. A series of particular responses to a stimulus can indicate the time course of various neural processes invoked in order to process the stimulus, understand it, and decide on the appropriate reaction. In this way, researchers can compare the brain's responses to various types of stimuli, or its activities as we perform certain tasks, and then draw conclusions about the different brain processes involved in each of these situations.

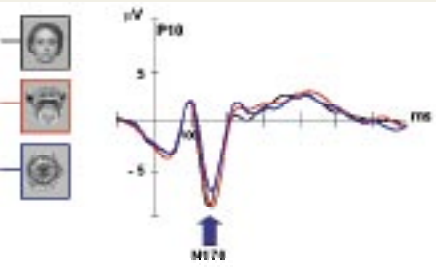


Illustration 4: EEG activity in response to different types of images. About 170 milliseconds after the appearance of the stimulus, differences are apparent in the brain's response to human monkey faces, compared to watches. This phenomenon is called the “N170” response, and indicates a neural process specific for face processing.

EEG also has an important clinical use in diagnosing and treating patients with epilepsy. Epileptic seizures are characterized by a burst of electrical activity usually originating from a particular area within the brain. By monitoring EEG signals, researchers can determine whether an epileptic seizure is taking place, and, if so, identify its type. This information is crucial for physicians in order to provide the appropriate treatment. EEG can also prove informative in determining the focus of the epileptic seizure.





Illustration 5: The EEG signal of a patient with epilepsy. When a seizure begins—about two seconds after the start of the recording—the changes in the EEG signal are quiet noticeable, as are the changes when the situation returns to “normal” at the end of the seizure.

The Origin of EEG Activity in the Brain
The brain generates two types of electrical activity. Nerve cells (neurons) communicate with each other through quick pulses of electrical current called “action potentials”. These are fleeting bursts of electricity that pass along a neuron's nerve fiber. They bring about the release of chemical substances called “neurotransmitters,” which are absorbed by adjacent neurons. Action potentials occur at a rate of over 200 Hertz and are highly localized (since they are generated by a single neuron), which makes them impossible to pick up by electrodes placed on the scalp.

Another type of neural electrical activity, that makes up the EEG signal, is the post-synaptic potential. (A synapse is the point of connection between two neurons.) Once a neuron receives an action potential from a neighboring neuron and chemical neurotransmitters have been released, this generates a current of ions inside the cell. The ion current then causes a build-up in electrical potential in the extracellular region of neuron. This is the postsynaptic potential. If the postsynaptic potential reaches a certain level, it will cause action potential to be released from the neuron.

