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| The electroencephalogram (EEG) is a recording of the electrical activity of the brain from the scalp. The recorded waveforms reflect the cortical electrical activity. Signal intensity: EEG activity is quite small, measured in microvolts (V). Signal frequency: the main frequencies of the human EEG waves are:   * **Delta**: has a frequency of 3 Hz or below. It tends to be the highest in amplitude and the slowest waves. It is normal as the dominant rhythm in infants up to one year and in stages 3 and 4 of sleep. It may occur focally with subcortical lesions and in general distribution with diffuse lesions, metabolic encephalopathy hydrocephalus or deep midline lesions. It is usually most prominent frontally in adults (e.g. FIRDA - Frontal Intermittent Rhythmic Delta) and posteriorly in children e.g. OIRDA - Occipital Intermittent Rhythmic Delta). * **Theta**: has a frequency of 3.5 to 7.5 Hz and is classified as "slow" activity. It is perfectly normal in children up to 13 years and in sleep but abnormal in awake adults. It can be seen as a manifestation of focal subcortical lesions; it can also be seen in generalized distribution in diffuse disorders such as metabolic encephalopathy or some instances of hydrocephalus. * **Alpha**: has a frequency between 7.5 and 13 Hz. Is usually best seen in the posterior regions of the head on each side, being higher in amplitude on the dominant side. It appears when closing the eyes and relaxing, and disappears when opening the eyes or alerting by any mechanism (thinking, calculating). It is the major rhythm seen in normal relaxed adults. It is present during most of life especially after the thirteenth year. * **Beta**: beta activity is "fast" activity. It has a frequency of 14 and greater Hz. It is usually seen on both sides in symmetrical distribution and is most evident frontally. It is accentuated by sedative-hypnotic drugs especially the benzodiazepines and the barbiturates. It may be absent or reduced in areas of cortical damage. It is generally regarded as a normal rhythm. It is the dominant rhythm in patients who are alert or anxious or have their eyes open. | |
| https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/eeGtrace.gif | |
| |  | | --- | | **Variables used in the classification of EEG activity** | | |
| |  | | --- | | **Frequency** | | |
| Frequency refers to rhythmic repetitive activity (in Hz). The frequency of EEG activity can have different properties including:   * **Rhythmic**. EEG activity consisting in waves of approximately constant frequency. * **Arrhythmic**. EEG activity in which no stable rhythms are present. * **Dysrhythmic**. Rhythms and/or patterns of EEG activity that characteristically appear in patient groups or rarely or seen in healthy subjects. | |
| |  | | --- | | **Voltage** | | |
| Voltage refers to the average voltage or peak voltage of EEG activity. Values are dependent, in part, on the recording technique. Descriptive terms associated with EEG voltage include: | |
| |  | | --- | | 1. **Attenuation** (synonyms: suppression, depression). Reduction of amplitude of EEG activity resulting from decreased voltage. When activity is attenuated by stimulation, it is said to have been "blocked" or to show "blocking". 2. **Hypersynchrony**. Seen as an increase in voltage and regularity of rhythmic activity, or within the alpha, beta, or theta range. The term implies an increase in the number of neural elements contributing to the rhythm. (Note: term is used in interpretative sense but as a descriptor of change in the EEG). 3. **Paroxysmal**. Activity that emerges from background with a rapid onset, reaching (usually) quite high voltage and ending with an abrupt return to lower voltage activity. Though the term does not directly imply abnormality, much abnormal activity is paroxysmal. | | |
| |  | | --- | | **Morphology** | | |
| Morphology refers to the shape of the waveform. The shape of a wave or an EEG pattern is determined by the frequencies that combine to make up the waveform and by their phase and voltage relationships. Wave patterns can be described as being:   * **Monomorphic**. Distinct EEG activity appearing to be composed of one dominant activity * **Polymorphic**. distinct EEG activity composed of multiple frequencies that combine to form a complex waveform. * **Sinusoidal**. Waves resembling sine waves. Monomorphic activity usually is sinusoidal. * **Transient**. An isolated wave or pattern that is distinctly different from background activity.  |  | | --- | | a) Spike: a transient with a pointed peak and a duration from 20 to under 70 msec. | | b) Sharp wave: a transient with a pointed peak and duration of 70-200 msec. | | |
| |  | | --- | | **Synchrony** | | |
| Synchrony refers to the simultaneous appearance of rhythmic or morphologically distinct patterns over different regions of the head, either on the same side (unilateral) or both sides (bilateral). | |
| |  | | --- | | **Periodicity** | | |
| Periodicity refers to the distribution of patterns or elements in time (e.g., the appearance of a particular EEG activity at more or less regular intervals). The activity may be generalized, focal or lateralized. | |
| |  | | --- | | **Recording the EEG** | | |
| |  | | --- | | **EEG electrodes** | | |
| Small metal discs usually made of stainless steel, tin, gold or silver **covered with a silver chloride coating**. They are placed on the scalp in special positions. These positions are specified using the International 10/20 system. Each electrode site is labeled with a letter and a number. The letter refers to the area of brain underlying the electrode e.g. F- Frontal lobe and T - Temporal lobe. Even numbers denote the right side of the head and odd numbers the left side of the head. | |
| https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/cables.jpg **Copyright ADInstruments.  All rights reserved.** | EEG cables showing the disc electrodes to which electrode gel is applied and applied to the subject's scalp. |
| EEG cap Many recording systems use a cap into which electrodes are embedded; this facilitates recordings when high density arrays of electrodes are needed or when comparing recording sites. The image to the right shows the inside of such a cap. | https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/img2013Cap/inside_cap-web.jpg |
| |  | | --- | | **Electrode gel** | | |
| It acts as a malleable extension of the electrode, so that the movement of the electrodes cables is less likely to produce artifacts. The gel maximizes skin contact and allows for a low-resistance recording through the skin. https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/img2013Cap/cap_syringe.jpg   The electrolytic gel is injected into each cavity until a small amount comes out the hole in the mount. With a moderate amount of downward pressure,the syringe with a blunt needle is rapidly rocked back and forth. | |
| |  | | --- | | **Impedance** | | |
| A measure of the impediment to the flow of alternating current, measured in ohms at a given frequency. Larger numbers mean higher resistance to current flow. The higher the impedance of the electrode, the smaller the amplitude of the EEG signal. In EEG studies, should be at lest 100 ohms or less and no more than 5 kohm. | |
| |  | | --- | | **Electrode positioning (10/20 system)** | | |
| The standardized placement of scalp electrodes for a classical EEG recording has become common since the adoption of the 10/20 system. The essence of this system is the distance in percentages of the 10/20 range between Nasion-Inion and fixed points. These points are marked as the Frontal pole (Fp), Central (C), Parietal (P), occipital (O), and Temporal (T). The midline electrodes are marked with a subscript z, which stands for zero. The odd numbers are used as subscript for points over the left hemisphere, and even numbers over the right. | |
| https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/10-20_sys.gif | https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/10-20_sysprof.gif |
| **10/20 System of electrode placement** | |
| |  | | --- | | **EEG montages** | | |
| Montage means the placement of the electrodes. The EEG can be monitored with either a bipolar montage or a referential one. Bipolar means that you have two electrodes per one channel, so you have a reference electrode for each channel. The referential montage means that you have a common reference electrode for all the channels. | |
|  | |
| |  | | --- | | **Artifacts** | | The biggest challenge with monitoring EEG is artifact recognition and elimination. There are patient related artifacts (e.g. movement, sweating, ECG, eye movements) and technical artifacts (50/60 Hz artifact, cable movements, electrode paste-related), which have to be handled differently. There are some tools for finding the artifacts. For example, FEMG and impedance measurements can be used for indicating contaminated signal. By looking at different parameters on a monitor, other interference may be found. | |  | | |
| Electrodes used in EEG recording do not discriminate the electrical signals they receive. The recorded activity which is not of cerebral origin is termed artifact and can be divided into physiologic (generated from the subject from sources other than the brain) and extraphysiologic artifacts arise from outside the body (equipment including the electrodes and the environment). | |
| **Electromyogram (EMG) activity** | |
| EMG activity are common artifacts: the myogenic potentials generated in the frontalis muscles (raising eyebrows) and the temporalis muscles (clenching of jaw muscles) are of shorter duration than those generated in the brain. These artifacts can be identified on the basis of duration, morphology and rate of firing (frequency). Particular patterns of EMG artifacts can occur in some movement disorders: essential tremor and Parkinson disease can produce rhythmic 4 to 6 Hz sinusoidal waveforms. | |
| **Eye movements** | |
| The eyeball acts as a dipole with a positive pole oriented anteriorly (cornea) and a negative pole oriented posteriorly (retina). When the globe rotates about its axis, it generates a large amplitude alternate current field detectable by any of the electrodes positioned near the eye. A blink causes the positive pole (the cornea) to move closer to frontopolar FP1, FP2 electrodes, producing symmetric downward deflections. | |
| https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/img2013Cap/rosy_blinks-web.jpg | |
| In the above example, the subject was blinking while the chart view and the recording was active (notice the four higher amplitude waves). The spectrum view window calculated and displayed a dominant frequency of 3 Hz which was the blinking frequency. | |
| **Skin artifacts** | |
| A further difficulty arises due to properties of certain layers of the skin. A significant DC potential exists between the stratum corneum and the stratum granulosum and any local deformation of the skin will alter this potential. The only reliable way to eliminate the source of artifact is to to create a low resistance pathway through the layers of skin by skin cleaning (alcohol swab). Also, sodium chloride (electrolyte) from sweating reacting with metals of the electrodes may produce a slow baseline drift. | |
| **Electrodes** | |
| Surface electrodes such as the ones used in EEG must create an interface between an ionic solution (the subject) and a metallic conductor (the electrode). This leads to a half-cell potential which can be quite large relative to the signal being recorded. To minimize this problem of polarization of the electrode, some electrodes are coated with silver chloride, but all are maintained away from the skin through an intermediate layer of conductive paste. Touching the electrodes during recording can produce artifacts. An electrode which is not contacting the skin very well acts like an antenna with resulting 60-cycle interference (see recording below). | |
| **60-Hz artifact** | |
| The problem arises when the impedance of one of the active electrodes becomes significantly large between the electrodes and the ground of the amplifier. In this situation, the ground becomes an electrode that, depending on its location, produces the 60-Hz artifact. Interference from high-frequency radiation from other electronic devices can overload EEG amplifiers. | |
| https://www.medicine.mcgill.ca/physio/vlab/biomed_signals/images/img2013Cap/rosy_60hz-web.jpg | |
| In the above recording, there was a very poor contact of the electrodes with the scalp of the subject; the spectrum view shows a dominant frequency of 60 Hz. | |
| |  | | --- | | **Differential amplifier** | | |
| It is the key to electrophysiological equipment. It magnifies the difference between two inputs. An unwanted signal that is common to the two inputs will be subtracted. | |
| |  | | --- | | **Filtering** | | |
| The standard filtering settings for routine EEG are:  Low frequency filter: 1 Hz High frequency filter: 50-70 Hz | |