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Electroencephalogram (EEG) and its interpretation in dogs

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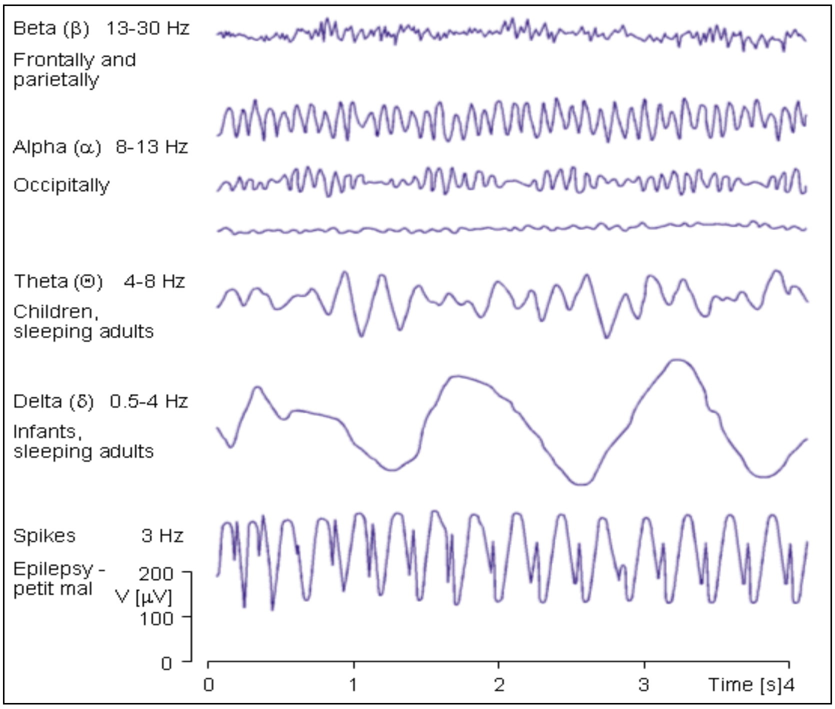
Abstract
Electro-enchaphalography is the main diagnostic technique in neurology recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neuron of the brain. This technique has been proved as a boon for diagnosis of various neurological diseases such as epilepsy, coma, encephalopathies, and brain death. EEG works on the principle of recording of electrical activity of brain through the help of electrodes. The EEG signal is closely related to the level of consciousness of the person. A routine clinical EEG recording typically lasts 20–30 minutes. Quantitative EEG is a powerful and sensitive tool for identifying maladaptive brain activity patterns that is, bad brain habits. Electroencephalogram is one of the best method to differentiate between tumours and epilepsy. Electroencephalography belongs to electrobiological imaging tools which is widely used in medical and research areas.

Keywords: EEG**,** electrical activity, electrode, Epilepsy, seizures, coma and brain

Introduction
Electroenchaphalography is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neuron of the brain [2]. EEG refers to the recording of the brain's spontaneous electrical activity over a short period of time, usually 20–40 minutes, as recorded from multiple electrods placed on the scalp. In neurology, the main diagnostic application of EEG is in the case of epilepsy, as epileptic activity can create clear abnormalities on a standard EEG study [4]. A secondary clinical use of EEG is in the diagnosis of coma, encephalopathies, and brain death. EEG used to be a first-line method for the diagnosis of tumors, stroke and other focal brain disorders, but this use has decreased with the advent of anatomical imaging techniques with high (<1 mm) spatial resolution such as MRI and CT. Despite limited spatial resolution, EEG continues to be a valuable tool for research and diagnosis, especially when millisecond-range temporal resolution (not possible with CT or MRI) is required. Derivatives of the EEG technique include evoked potentials(EP), which involves averaging the EEG activity time-locked to the presentation of a stimulus of some sort (visual, somatosensory, or auditory).Event-related potentials (ERPs) refer to averaged EEG responses that are time-locked to more complex processing of stimuli; this technique is used in cognitive science, cognitive psychology, and psychophysiological research.

The behaviour of the EEG signal
From the EEG signal it is possible to differentiate alpha (α), beta (β), delta (δ), and theta (Θ) waves as well as spikes associated with epilepsy. An example of each waveform is given
The alpha waves have the frequency spectrum of 8-13 Hz and can be measured from the occipital region in an awake person when the eyes are closed. The frequency band of the beta waves is 13-30 Hz; these are detectable over the parietal and frontal lobes. The delta waves have the frequency range of 0.5-4 Hz and are detectable in infants and sleeping adults. The theta waves have the frequency range of 4-8 Hz and are obtained from children and sleeping adults.



Principle of EEG diagnosis

EEG signal consist of different brain waves reflecting brain electrical activity according to electrode placement and functioning in the adjacent brain regions. For using EEG techniques.

The following recording system component are necessary

- Electrode cap with conductive jelly.
- Amplifiers with over all amplification gain between 100-100,000 with impedance at least 100 M ohms and common mode rejection ratio at least 100 db.
- Sufficient quick PC for taking over data for recording and eventually for on line analysis, with adequate volume of hard disc.
- Digital high pass FIR filter with similar cut-off frequency as analog high pass.

The EEG signal is closely related to the level of consciousness of the person. As the activity increases, the EEG shifts to higher dominating frequency and lower amplitude. When the eyes are closed, the alpha waves begin to dominate the EEG. When the person falls asleep, the dominant EEG frequency decreases. In a certain phase of sleep, rapid eye movement called (REM) sleep, the person dreams and has active movements of the eyes, which can be seen as a characteristic EEG signal. In deep sleep, the EEG has large and slow deflections called delta waves. No cerebral activity can be detected from a patient with complete cerebral death. Examples of the above-mentioned waveforms are given.

EEG activity is dependent on the level of consciousness

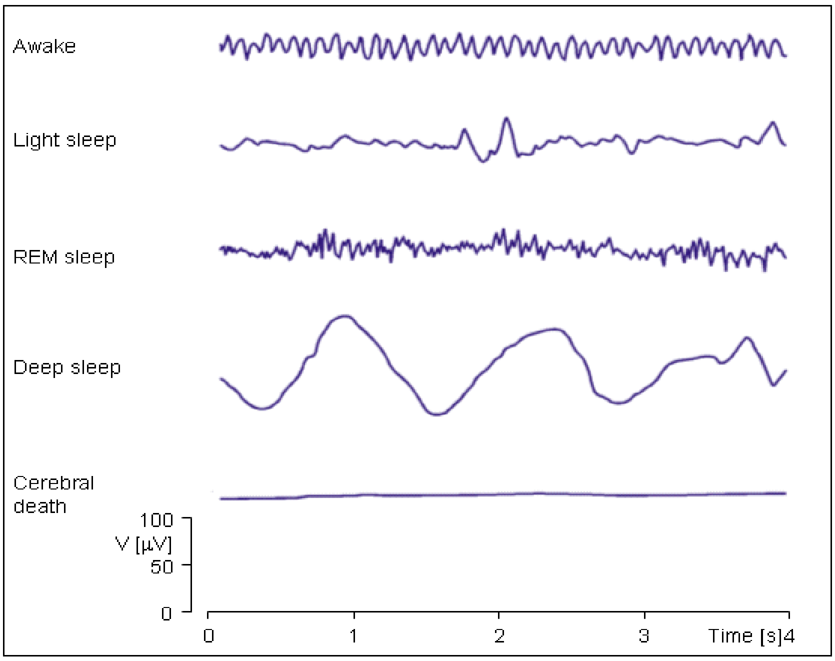


Table 1: Interpretation Comparison of EEG bands

Type	Frequency (Hz)	Location	Normally	Pathologically
delta	up to 4	frontally in adults, posteriorly in children; high amplitude waves	▪ adults slow wave sleep ▪ in babies ▪ Has been found during some continuous attention tasks [5] ▪ young children ▪ drowsiness or arousal in older children and adults ▪ idling	▪ subcortical lesions ▪ diffuse lesions ▪ metabolic encephalopathy hydrocephalus ▪ deep midli ne lesions ▪ focal subcortical lesions
Theta	4 – 8	Found in locations not related to task at hand	▪ Associated with inhibition of elicited responses (has been found to spike in situations where a person is actively trying to repress a response or action) [5] ▪ relaxed/reflecting ▪ closing the eyes	▪ metabolic encephalopathy ▪ deep midline disorders some instances of hydrocephalus
Alpha	8 – 13	posterior regions of head, both sides, higher in amplitude on dominant side. Central sites (c3-c4) at rest	▪ Also associated with inhibition control, seemingly with the purpose of timing inhibitory activity in different locations across the brain. ▪ alert/working	▪ Coma
Beta	>13 – 30	both sides, symmetrical distribution, most evident frontally; low amplitude waves	▪ active, busy or anxious thinking, active concentration ▪ Displays during cross-modal sensory processing (perception that combines two different senses, such as sound and sight) [4, 6]	▪ benzodiazepines
Gamma	30 – 100+	Somatosensory cortex	▪ Also is shown during short term memory matching of recognized objects, sounds, or tactile sensations	A decrease in gamma band activity may be associated with cognitive decline, especially when related the theta band; however, this has not been proven for use as a clinical diagnostic measurement yet
Mu	8 – 13	Sensorimotor cortex	▪ Shows rest state motor neurons [1].	▪ Mu suppression could be indicative for motor mirror neurons working, and deficits in Mu suppression, and thus in mirror neurons, might play a role in autism.[3].

Clinical use

A routine clinical EEG recording typically lasts 20–30 minutes (plus preparation time) and usually involves recording from scalp electrodes. Routine EEG is typically used in the following clinical circumstances:

- to distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants.
- to differentiate "organic" encephalopathy or delirium from primary psychiatric syndromes such as catatonia.
- to serve as an adjunct test of brain death.
- to prognosticate, in certain instances, in patients with coma.
- to determine whether to wean anti-epileptic medications

At times, a routine EEG is not sufficient, particularly when it is necessary to record a patient while he/she is having a seizure. In this case, the patient may be admitted to the hospital for days or even weeks, while EEG is constantly being recorded (along with time-synchronized video and audio recording). A recording of an actual seizure (i.e. anictal recording, rather than an inter-ictal recording of a possibly epileptic patient at some period between seizures) can give significantly better information about whether or not a spell is an epileptic seizure and the focus in the brain from which the seizure activity emanates.

Epilepsy monitoring is typically done

- to distinguish epileptic seizures from other types of spells, such as psychogenic non-epileptic seizures, syncope (fainting), sub-cortical movement disorders and migraine variants.
- To characterize seizures for the purposes of treatment
- to localize the region of brain from which a seizure originates for work-up of possible seizure surgery

Additionally, EEG may be used to monitor certain procedures

- to monitor the depth of anesthesia.
- as an indirect indicator of cerebral perfusion in carotid endarterectomy.
- to monitor amobarbital effect during the Wada test.

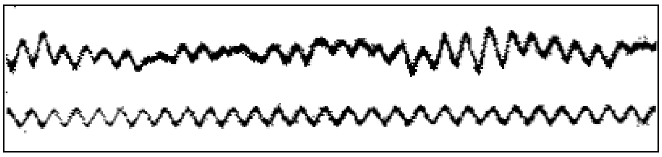
EEG can also be used in intensive care units for brain function monitoring

- to monitor for non-convulsive seizures/non-convulsive status epilepticus

- to monitor the effect of sedative/anesthesia in patients in medically induced coma (for treatment of refractory seizures or increased intracranial pressure)
- to monitor for secondary brain damage in conditions such as subarachnoid hemorrhage (currently a research method)

If a patient with epilepsy is being considered for respective surgery, it is often necessary to localize the focus (source) of the epileptic brain activity with a resolution greater than what is provided by scalp EEG. This is because the cerebrospinal fluid, skull and scalp *smear* the electrical potentials recorded by scalp EEG. In these cases, neurosurgeons typically implant strips and grids of electrodes (or penetrating depth electrodes) under the dura mater, through either acraniotomy or a burr hole. The recording of these signals is referred to as electrocorticography (ECoG), subdural EEG (sdEEG) or intracranial EEG (icEEG)--all terms for the same thing. The signal recorded from ECoG is on a different scale of activity than the brain activity recorded from scalp EEG. Low voltage, high frequency components that cannot be seen easily (or at all) in scalp EEG can be seen clearly in ECoG. Further, smaller electrodes (which cover a smaller parcel of brain surface) allow even lower voltage, faster components of brain activity to be seen. Some clinical sites record from penetrating microelectrodes [2].

Research use



The first human EEG recording obtained by Hans Berger in 1924. The upper tracing is EEG, and the lower is a 10 Hz timing signal.

EE, and the related study of ERPs are used extensively in neuroscience, cognitive science, cognitive psychology, and psycho-physiological research. Many EEG techniques used in research are not standardized sufficiently for clinical use.

A different method to study brain function is functional magnetic resonance imaging (FMRI). Some advantages of EEG over FMRI include:

- Hardware costs are significantly lower
- EEG sensors can be used in more places than a bulky, immobile fMRI machine can
- EEG has higher temporal resolution - milliseconds, rather than seconds
- EEG is relatively tolerant of subject movement (in fMRI the subject must remain completely still)
- EEG is silent, which allows for better study of the responses to auditory stimuli
- EEG does not aggravate claustrophobia
- EEG does not involve exposure to high-intensity (>1 Tesla) magnetic fields (as in MRI)

In addition, EEG does not involve exposure to radioligands (unlike positron emission tomography)

Disadvantages of EEG relative to FMRI include

- Significantly lower spatial resolution
- ERP studies require relatively simple paradigms, compared with block-design fMRI studies

Simultaneous EEG recordings and fMRI scans have been obtained successfully, though successful simultaneous recording requires that several technical difficulties be overcome, such as the presence of ballistocardiographic artifact, MRI pulse artifact and the induction of electrical currents in EEG wires that move within the strong magnetic fields of the MRI.

EEG also has some characteristics that compare favorably with behavioral testing

- EEG can detect covert processing (i.e., processing that does not require a response)
- EEG can be used in subjects who are incapable of making a motor response
- Some ERP components can be detected even when the subject is not attending to the stimuli.

Limitations

EEG has several limitations. Most important is its poor spatial resolution. EEG is most sensitive to a particular set of post-synaptic potentials: those generated in superficial layers of the cortex, on the crests of gyri directly abutting the skull and radial to the skull. Dendrites, which are deeper in the cortex, inside sulci, in midline or deep structures (such as the cingulate gyrus or hippocampus), or producing currents that are tangential to the skull, have far less contribution to the EEG signal.

The meninges, cerebrospinal fluid and skull "smear" the EEG signal, obscuring its intracranial source.

It is mathematically impossible to reconstruct a unique intracranial current source for a given EEG signal [2] as some currents produce potentials that cancel each other out. This is referred to as the inverse problem. However, much work has been done to produce remarkably good estimates of, at least, a localized electric dipole that represents the recorded currents.

Conclusion

Quantitative EEG is a powerful and sensitive tool for identifying maladaptive brain activity patterns that is, bad brain habits. Electroencephalogram is one of the best method to differentiate between tumours and epilepsy. This introduction has touched on the multitude of issues surrounding this technology and its clinical application in neuro feedback. Electroencephalogrphy belongs to electrobiological imaging tools widely used in medical and research areas. EEG measures changes in electric potential caused by a large number of electric dipoles formed during neural excitation which makes it a reliable tool for neurological diagnosis.

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