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A Study of Emotive Brain Mapping using EEG

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Abstract: Electroencephalography (EEG) is an electrophysiological observing technique to record electrical bustle of the brain. It is classically non-invasive, with the probes placed laterally along the scalp, although invasive electrodes are occasionally used in precise requests. EEG processes voltage fluctuations ensuing from ionic current inside the neurons of the brain.

Emotion is ubiquitous and a significant factor in human life in interacting and communicating with people. Although emotion is instinctively known to everybody, it is hard to define. Scientists consider human brain as the main source of all emotions. And therefore, brain signal is captured in order to study emotion. However, the precise role of brain is not so clear. Brain activity can vary person to person but is the most accurate measure of stress.

This paper proposes a new emotive stress recognition scheme using multi-modal bio-signals. Since electroencephalogram (EEG) is the replication of brain movement and is broadly used in clinical analysis and biomedical study, it is used as the main signal. In order to choose the proper EEG channel, we use the cerebral model of the brain under expressive strain. We design an efficient acquisition protocol to obtain the EEG and psychophysiological signals under photographic stimulation for participants. Qualitative and quantitative assessment of psychophysiological signals is tried for selecting suitable segments of EEG signal for refining competence and performance of emotional stress recognition system. After pre-processing the signals, both Linear and nonlinear features are employed to extract the EEG parameters.

1. OBJECTIVE

The use of EEG gestures as a vector of message between men and machineries denotes one of the existing experiments in signal theory research. The crucial component of such a communication scheme, more known as "Brain Computer Interface", is the understanding of the EEG indications related to the typical limitations of brain electrical activity.

An electroencephalogram (EEG) is an examination that procedures and records the electrical commotion of your brain. Special sensors are committed to the head of the examinee and bowed by wires to a mainframe computer. The computer records the brain's electrical activity on the monitor or on broadsheet as wavy lines. Certain situations, such as seizures, can be understood by the changes in the usual outline of the brain's electrical action.

An electroencephalogram (EEG) may be done to:

- Analyze epilepsy and see what kind of seizures are happening. EEG is the most beneficial and important trial in confirming an analysis of epilepsy.
- Check for difficulties with damage of consciousness or dementia.
- Helps in finding out a person's chances of retrieval after an alteration in consciousness.
- Find if a person in coma is brain-dead.

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- Read sleep disorders, like narcolepsy.
- Read the brain signals at the time of certain emotional conditions and figure an algorithm to read a person's mind.
- Develop a better Human Computer Interaction by connecting human thoughts and stress levels for certain tasks to the computer.

Principles of Electroencephalography

The Nature of EEG Signals: The electrical environment of the nervous system has been renowned for more than a hundred years. It is known that the dissimilarity of the surface potential circulation on the scalp reproduces practical activities developing from the brain. The output that we get on reading the brain signals is a little complicated for layman understanding. The surface potential dissimilarity can be chronicled by fastening an array of electrodes to the scalp, and calculating the current between these electrodes, which are then clarified and filtered, improved, and recorded. The resulting data is called the EEG.

A. The 10-20 System of Electrode Placement

The 10-20 system of electrode placement is a recognized method to define and apply the position of scalp electrodes in the perspective of an EEG test or experimentation. This structure is based on the connection between the position of a probe and the area underlying the cerebral cortex. The "10" and "20" denote the fact that the distances between neighboring electrodes are whichever; 10% or 20% of the entire front–back or right–left expanse of the skull.

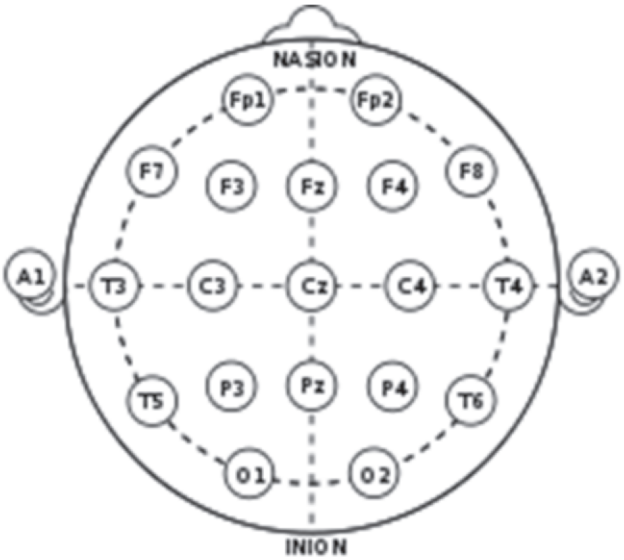

Figure 1: 10-20 electrode positioning system

Each spot has a letter to recognize the section and a numerical to identify the respective hemisphere location. The letters F, T, C, P and O are letters for frontal, temporal, central, parietal, and occipital lobes. Although there exists none central lobe; the letter "C" is used only for representational purposes. Even numbers (2,4,6,8) refer to electrode positions on the right hemisphere, whereas odd numbers (1,3,5,7) refer to those on the left hemisphere. A "*z*" (zero) refers to an electrode placed on the midline. In addition to these combinations, the letter codes A, Pg and Fp identify the earlobes, nasopharyngeal and frontal polar sites respectively. Nasion: point between the forehead and nose. Inion: Bump at back of skull.

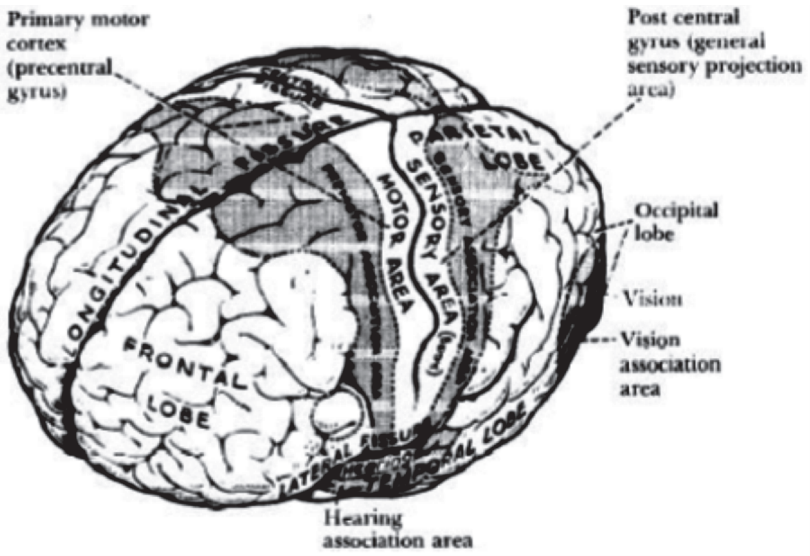

Figure 2: Cerebral hemispheres (frontal, temporal, central, parietal, and occipital lobes)

The common edifice of a Brain Computer Interface is the following:

1. Signal Acquisition: EEG signals are attained from the mind through invasive or non-invasive (EEG is a non-invasive method as it does not follow through into the skull) methods (for example, probes). After, the gesture is amplified and tested.
2. Signal Pre-Processing: Once the signals are acquired, there can be attenuations in the signal and therefore it is essential to clean them up for better reading.
3. Signal Classification: After signals are dressed and cleaned, they are treated and categorized to catch out which sort of cerebral task the subject is acting.
4. Computer Interaction: After classification, they are used by an appropriate algorithm for the development of a certain application.

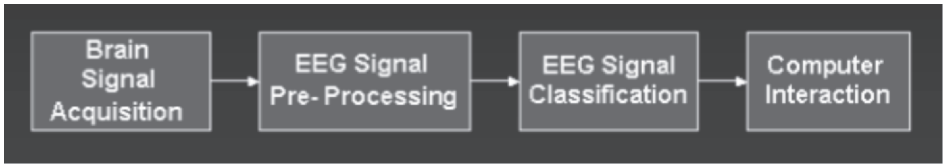

Figure 3: BCI working process

2. Eeg Wave Groups

The examination of constant EEG hints or mind waves is multifaceted, due to the massive quantity of measurements acknowledged from each and every probe. As a skill in the aforementioned, it has to be accomplished with its specific set of nomenclature. Dissimilar influences, like so voluminous broadcasting positions, are branded by the occurrence of their productions and, in roughly some valises or bags, by the figure of their waveforms. Though not any of these influences is perpetually released alone, the awareness of the individuals may make one of the frequencies array more distinct than all the others. Five sorts are chiefly important:

BETA. The frequency of variation lies amongst 13 and 30 Hz, and typically has a squat current of 5-30 μV. Beta is the mind wave allied with lively discerning or thinking, active devotion, attention on the outdoor biosphere or resolving concrete complications. It can influence incidences near 50 hertz for the duration of strong mental action.

ALPHA. Degree of change lies in the middle of 8 and 13 Hz, with 30 to 50 μV amplitude. Alpha waves mostly indicate an extremely relaxed state of the mind and also inattentiveness. They are sturdiest above the occipital (rear part of the head) cortex and over frontal cortex. Alpha is the utmost protuberant and maximized surge in the entire realm of mind motion and perhaps refuges a superior range than was formerly believed. It is recurrent the beta range go as high as 20 Hz, that has the physiognomies and characteristics of alpha state moderately than beta, and the situation in which such reaction seems also clues to the exact same assumption. Alpha waves alone seem to showcase an empty mind, mostly thoughtless; not even in a relaxed state. The waves disappear as soon as the thought process starts upon opening of eyes.

THETA. Theta waves lie within the range of 4 to 7 Hz, with an amplitude usually greater than 20 μV. Theta ascends from passionate stress, particularly frustration or dissatisfaction. Theta has been allied with admission to cataleptic or mostly unconscious material, imaginative stimulus or deep contemplation. The leading peak of the theta waves is 7 Hz.

DELTA. Delta waves lie inside the assortment of 0.5 to 4 Hz, with highly varying largeness. These whitecaps are chiefly allied to deep sleep, and in sudden state of wake up, are supposed to designate physical flaws in the mind. It is very informal to complicate signals produced by the strong muscles of the neckline and jawbone with the candid delta retorts. This is due to the reason that the muscles are nearby the seeming of the skin and henceforth harvest large indications while the pointer which is of curiosity initiates deep in the mind and is attenuated in fleeting via the skull. However, with an immediate investigation EEG, it is stress-free to notice when the answer is produced by extreme movement.

GAMMA. Gamma waves range initiates from 35 Hz and moves up. It is believed that this group imitates the contrivance of mindfulness or in any form consciousness - the obligatory binding together of discrete segmental mind occupations into rational percepts adept of executing in a re-entrant manner (nourishing on themselves above phase to craft a logic of consciousness).

MU. An 8 to 12 Hz impulsive EEG wave related with motor actions and outstandingly chronicled over motor cortex. They usually diminish with movement or even the intention to move physically. Mu wave and the Alpha wave share the same frequency band, but this last one is detailed about the occipital cortex.

Most efforts to regulate a workstation with constant EEG amounts toil by nursing alpha or mu waves, because people can, with time, learn to regulate these wave frequencies and as a result give enumerated outputs at different times. An individual might achieve this consequence, for example, by remembering some powerfully thought-provoking image or by hovering his or her intensity of attention.

The image from Wikipedia below displays the exact function of the waves that are located from the EEG analysis.

These wave forms might also receive some attenuation from the environment and other external entities, which has been talked about in the upcoming section.

The EEG footages can be alienated into two very chief classes: Reference recordings and scalp-to-scalp bipolar linkages. In case of reference recording apiece probe is denoted to whichever detached reference electrode, single conjoint probe on respectively both side of the skull or to joint movement of two or further probes. The reference electrode(s) necessarily be located on the portions of the physique where latent remains justly persistent. Typically reference electrodes are located on the ear sections or on the mastoid skeletons or cartilages behind the ear. In bipolar recordings variance dimensions are prepared between consecutive pairs of probes.

Table 1
Types of Wave form

Band	Frequency (Hz)	Location	Occurrences
Delta	< 4	Maximally in adults and less in children	• Adult slow-wave sleep • Has been found during some continuous-attention tasks.
Theta	4 – 7	Found in locations not related to task at hand	• Higher in young children. • Drowsiness in adults. • During idle times of deep thought, none physical work. • Normally found in people trying to repress a certain thought.
Alpha	8 – 15	Posterior regions of head, both sides, higher in amplitude on the dominant side.	• Closing the eyes • Also associated with self-consciousness control, or feeling like shyness; apparently with the persistence of scheduling inhibitory actions in different locations across the brain.
Beta	16 – 31	Symmetrical distribution on both sides of the brain, most evident frontally; low-amplitude waves	• Range: Intense -> stressed -> mild obsessive thoughts. • Active thinking, focused thoughts, being anxious.
Gamma	32 +	Somatosensory cortex	• Processes that require two different senses, such as sound and vision. • Also seen during short-term memory matching of familiar objects, resonances, or solid sensations.
Mu	8 – 12	Sensorimotor cortex	• Shows rest-state motor neurons

3. EEG SIGNAL PRE-PROCESSING

A major problem in the computerized EEG investigation is the finding of the dissimilar kinds of intrusion waveforms called artifacts, getting auxiliary to the EEG signal all through the footage recording session. These interfering waveforms, the relics, are any logged electrical potentials that have not patented out from the brain. There possibly are four major foundations of artifacts production:

1. The EEG equipment in itself.
2. Electrical interventions exterior to the subject and record system, like the intrusion from other electronic gadgets.

3. Leads and the conductors.
4. Normal electrical activity from the heart or undesired movements of other organs can also generate some unwanted waves.

These can broadly be grouped as the following groups:

- Biological Artifacts.
- Environmental Artifacts.

The next section gives an explanation about these artifacts.

The most protruding eye-induced relics are produced by the probable difference amid the cornea and retina, that is pretty huge paralleled to cerebral abilities. At the times that the eyes and eyelids are totally immobile, this cornea-retinal dipole has no effect on EEG. Though, blinks can possibly happen numerous times in a minute, the eye activities befall numerous times every second to let that blink occur. Eye actions, occurring habitually during blinking or perpendicular eye activities, provoke a huge potential perceived typically in the alteration of the signals.

ECG relics are fairly conjoint and can be misguided for barb commotion. As a result of this, contemporary EEG attainment normally includes a single-channel ECG from the extremes. This also permits the EEG to recognize cardiac arrhythmias that are a significant disparity during the diagnosis.

Glossokinetic artifacts are produced by the latent difference amongst the base and slant of the tongue. Negligible tongue movements can also pollute the EEG with attenuation of signals, especially when the person has signs of conditions like, the parkinsonian and certain tremor illnesses.

In accumulation to artifacts produced by the body, numerous artifacts instigate from exterior of the body. Physical movement by the person, or even at the time of settling of the probes, may reason *electrode pops*, barbs devising from a temporary change in impedance of a certain conductor. Meagre grounding of the presently being used EEG electrodes can source substantial 50 or 60 Hz disturbance, dependent on the indigenous power system's regularity. A secondary cause of probable interference can be the occurrence of an IV drip (infusion of liquid substances into the veins to cause required sensations); such expedients can cause periodic, fast, low-voltage eruptions, which may be muddled for spikes of attenuation.

Artifact Correction

Lately, self-governing constituent study or also known as Independent Component Analysis (ICA) methods have been castoff to accurate or eliminate EEG contaminants. These methods endeavor to "unmix" EEG signals hooked on some amount of underlying mechanisms. There are quite numerous foundation parting algorithms, frequently assuming different performances or landscapes of EEG. Irrespective, the belief behind any precise way frequently permit "remixing" only those machineries that would outcome in "unsoiled" EEG by invalidating (zeroing) the mass of unsolicited workings. Fully computerized artifact rebuff systems, which practice ICA, have also been established.

In the past few years, by associating figures commencing by the paralyzed and un-paralyzed focuses, EEG infection by influence has been exposed to be distant more predominant than had formerly been understood, chiefly in the gamma assortment overhead 20 Hz. Though, Surface Laplacian has remained to be actual in removing muscle artifact, chiefly for dominant probes, which are supplementary from the sturdiest pollutants. The mixture of Surface Laplacian with mechanical methods for eliminating muscle mechanisms using ICA showed particularly actual in a survey study.

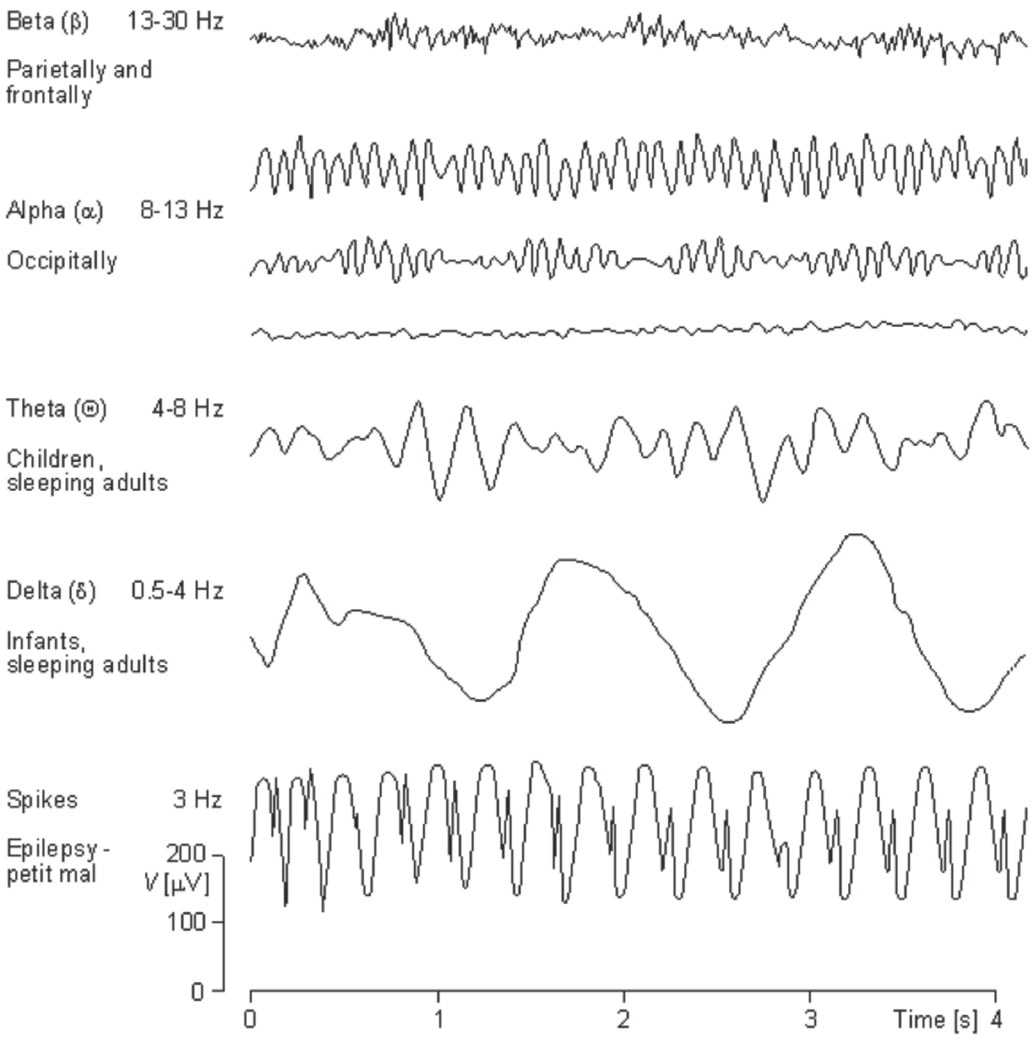

Figure 4: Different frequency wave

Dimensions of Correctness in BCIs

There have been many dissimilar measurements. One technique of recording correctness is to stretch a precise classification degree. This stricture tells the proportion of the classifications within the BCI system correctly. It ensures not to take into version that discrete modules typically have diverse classification proportions and that more or less of the EEG statistics may just be rejected.

More inclusive mode to testimony precision is to contemporary a confusion matrix. This matrix, the confusion matrix tells the exact classification proportions of apiece class, but also it specifies those classes in which the false classifications were classified. In case, rejection was castoff, it displays the fraction of the classifications that were forbidden or rejected.

Inappropriately, confusion matrices are exhibited only in limited BCI documents. The precise classification degree is created in most documents, but occasionally only hit rates are reported. The hit rate expresses how sundry times the consumer succeeded to hit the mark with a cursor. The hit rate is apparently told as; not a decent method to account results because the total of the cursor periods mandatory to range the goal influences the hit frequency. Hence, two hit charges are only equivalent if the numeral of the phases is equivalent. Moreover, the hit rate states very miniature around what the real classification correctness of the BCI is. It is conceivable, for instance, that the hit rate is nearby to 100 %, but indeed the classification rate shows it to be below 60 %.

Rejection is castoff in more or less BCIs. It is linked to the classification technique used. The impression is that indeterminate classifications are disallowed. If rejection is of a specified class, the mistaken classification can be named false positive (FP). The numeral of false positives must be reserved negligible or absent, if a healthy working of a BCI is desired. Rejection can upsurge BCI routine.

Experimentation and Analysis

A. Experimentation

Mind Workstation software from the Transparent Corporation was castoff for mining the indications from the subjects. The EEG signals used in this work were recorded using the Emotiv Insight device for 4-5 mins on different subjects. A pleasing photograph was displayed for 30 seconds and the subject was asked to distillate on it. Response to pleasing photographs, a coherent waveform of higher frequency and lower amplitude in the frontal regions were seen, which proves that alpha wave was generated. It is apparent that the subject was moving into a relaxed state by reducing the stress and strain. The next was a stage of wars and killings shown to the subject and there was a change in the frequency of the outcome

Table 2
The Results of the experiment

Time(mm:ss)	*Activity*	*Outcome*
00:00	Start EEG recording	Acquisition started
00:15	Wave signal analyzed	Presence of line noise
00:30	Wave signal analyzed	Line noise fixed. Presence of low frequency beta waves inferred which are related to tensed/excited state.
01:00 to 03:30	Pleasant photographs of scenery.	Very low frequency alpha waves were detected linked to a state of a little cavernous thought.
03:30 to 04:00	Picture changed to a war state photograph with killings.	High frequency high beta waves were detected which is showed a certain display of stress.

4. OTHER WAYS OF MAPPING BRAIN SIGNALS

Invasive and Non-Invasive Techniques of mapping brain activity.

There are two ways of gathering data about brain signals, namely, invasive and non-invasive techniques.

Invasive Techniques

Deep Brain Stimulation: **Deep brain stimulation** (**DBS**) is a neurosurgical method that involves the imbedding of a therapeutic device called neurostimulator (also referred to as ‘brain pacemaker’), which directs electrical instincts, through rooted probes, to precise portions of the brain (the nucleus) for the cure of movement and emotional conditions. DBS in select brain sections has given salutary assistances for diseases that were otherwise resistant to treatments, such as Parkinson’s disease, tremor, dystonia, chronic pain, major depression and obsessive–compulsive disorder (OCD). Notwithstanding the elongated history of DBS, its primary ideologies and mechanisms are still not clear.

The deep brain stimulation structure contains three constituents: the implanted pulse generator (IPG), the lead, and an extension. The IPG is a battery-operated neurostimulator wrapped in a titanium body, which conducts electrical rhythms to the brain to inhibit with the neural motion at the objective site. Lead is a twisted cable shielded in polyurethane by four platinum iridium rods and is positioned in one or two

dissimilar nuclei of mind. The lead is linked to IPG by an extension, a sequestered cable that turns beneath the skin, from head, downcast the sideways of the neck, behindhand the ear to the IPG, which is sited dermatologically underneath the clavicleor, or in certain cases, the abdomen.

Non-Invasive Methods

Transcranial Magnetic Stimulation: **Transcranial magnetic stimulation** (**TMS**) is a non-invasive technique castoff to kindle slight regions of the mind. During a TMS process, a magnetic pitch creator, or "helix", is positioned adjacent to the skull of the individual getting the cure. The coil harvests minor electric fluxes in the area of the mind just below the loop by electromagnetic stimulation. The curl is associated to a pulsation producer, or stimulator, that carries electric current into the helix. TMS is cast-off diagnostically to ration the assembly among the mind and a muscle to assess impairment from thump, several scleroses, amyotrophic adjacent sclerosis, crusade syndromes, motorized neuron syndrome and damages and other conditions distressing the facemask and further cranial nerves and spinal cord.

Future Research and Suggestions

The EEG has been recycled and exploited for numerous resolutions further the conservative uses of scientific analysis and conservative reasoning neuroscience. An initial usage was throughout World War II done by the U.S. Army Air Corps to shade out aviators in risk of partaking seizures; lasting EEG footages in epilepsy subjects are still cast-off till date for capture forecast. Neurofeedback residues a significant postponement, and in its greatest progressive procedure is also endeavored as the base of mind mainframe interfaces. The EEG is used quite widely in the ground of neuro-marketing. In modern years, academics have been dependent on EEG to recognize the neural root of swallowing.

The EEG is rehabilitated by medicines that affect mind occupations, the compounds that are foundation for psychopharmacology. At the present date, the science of pharmaco-electroencephalography has technologically advanced procedures to detect materials that methodically alter mind functions for beneficial and frivolous or recreational use.

Honda is struggling to ripen a system to allow an operative to switch its Asimo automaton using EEG, an expertise it ultimately hopes to integrate into its vehicles.

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