Electroencephalography

Electroencephalography (EEG) is the recording of electrical activity along the scalp. EEG measures voltage fluctuations resulting from ionic current flows within the neurons of the brain.

In clinical contexts, 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 electrodes placed on the scalp. Diagnostic applications generally focus on the spectral content of EEG, that is, the type of neural oscillations that can be observed in EEG signals.

see Continuous EEG monitoring.

see Intracranial electroencephalography.

Mullen et al., [1)] designed a dry, wearable, and wireless EEG acquisition system with dynamic, real-time signal processing and data analysis software. In their article, they review the design of the device, providing a detailed description of the mathematical methods of artifact reduction and their methods for reconstructing EEG data to analyze underlying neuronal electric activity. They tested their analytic methods in simulated 64-channel EEG data and in recordings from their wearable EEG device. Their analysis of cognitive states demonstrates that wearable EEG may be a potential tool for human cortical recording with broad applications.The mobile EEG system supports 64 channels of high-density recordings. The headset contains an internal Faraday cage to filter external interference and a wireless transducer to transfer data. The cage conforms to the shape of the patient’s head and provides tension to maintain sensors on the scalp. The contact sensors used have durable, high recording quality. One type of sensor has conductive “feet” that better contact the scalp through hair. The other sensor is a wet/dry hybrid, using an ion-permeable membrane to contain the conductive gel. Although these dry and hybrid electrodes may be less accurate at higher frequencies, they generally produce recordings similar in quality to those of standard wet electrodes. This EEG system is complemented by a software analysis pipeline that removes artifacts, performs source localization and functional connectivity analyses, determines cognitive and behavioral states, and generates images of the data in real-time. The software removes high-amplitude artifacts from online data using artifact subspace reconstruction. Next, EEG data can be used to localize activity sources, to define regions of interest, and then to analyze features of neural activity such as spectral power and functional connectivity within and between regions of interest. The connectivity analysis is then used to classify activity into cognitive and behavioral states using a novel method, ProxConn. ProxConn allows learning of flexible, predictive models of cognitive and behavioral states with just a few experimental trials, making EEG data processed in this manner accessible for brain-computer interface use. Finally, this system can generate 2-dimensional plots of EEG data and project spatiotemporal features of neural activity features on a 3-dimensional model brain.This EEG data acquisition and analysis system was successfully validated in a study of 8 subjects performing the Eriksen flanker task. The task requires subjects to identify when visual stimuli surrounding or flanking the target stimulus are congruent, incongruent, or neutral with respect to the target stimulus; thus, the subjects must suppress certain responses on the basis of the flanking context. Performance of this task has been shown to activate the anterior cingulate cortex (ACC) and to lead to characteristic patterns of event-related potential (ERP) detected over the caudal ACC when target and flanking stimuli are incongruent. Data collected and analyzed through the hardware and analysis system replicated the ERP pattern localized to the same region corresponding to the ACC for incongruent target and flanking stimuli. The area under a receiver-operating characteristic curve was used to classify performance and was calculated for the data analyzed using the current gold standard for ERP classification analysis, dual-spectral regularized logistic regression (DSLR), and ProxConn. The 2 methods yielded similar performance in subjects, although the ProxConn method produced lower between-subject variance, a larger percentage of subjects performed above chance level than with DSLR method, and the group mean for performance was higher with DSLR.Mullen et al have designed a wearable EEG system that can be used to ascertain cognitive states in human subjects. The group used the BCILAB + SIFT system, from the EEGLAB toolbox in MATLAB data, for real-time analysis, which is not yet available in alternative methods of connectivity analysis. They were able to ascertain cognitive states from mobile EEG data in subjects, suggesting that their methods could be used in alternative settings to ascertain cognitive states in ambulatory situations [2].

Recommended Books

Niedermeyer's Electroencephalography: Basic Principles, Clinical Applications, and Related Fields

[1]
Mullen TR, Kothe CA, Chi YM, et al. Real-time neuroimaging and cognitive monitoring using wearable dry EEG. IEEE Trans Biomed Eng. 2015;62(11):2553–2567.
[2]
Boone C, Wojtasiewicz T, Anderson WS. Characterization of a Wearable Dry Electroencephalography System. Neurosurgery. 2016 Oct;79(4):N10-1. doi: 10.1227/01.neu.0000499703.35843.82. PubMed PMID: 27635965.