Emerging technologies help advance the understanding, detection and control of epilepsy

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A smartphone-induced EEG waveform and an intelligent algorithm for seizure detection are among the emerging technologies to be unveiled at the American Epilepsy Society's (AES) 69th Annual Meeting. Four innovative studies presented at the meeting promise to reshape current paradigms for seizure detection and epilepsy management.

In the first study, (abstract 3.277) researchers from Brighton and Sussex Medical School demonstrate that electrodermal (EDA) biofeedback - a technique that uses electrodes to detect changes in the skin's electrical activity - is an effective method for reducing seizure frequency in patients with drug-resistant epilepsy.

The authors' prior work showed that increased skin conductance in patients with epilepsy can calm over excitability in the motor cortex, and that skin conductance is associated with regional changes in brain activity.

In the current study, the authors explored whether EDA biofeedback restores normalcy to the complex networks of neural tasks that often run amuck in patients with epilepsy. They examined clinical trial data from eight patients with temporal lobe epilepsy who received EDA biofeedback training three times a week for four weeks and fMRI scans at the first and last sessions.

One month of biofeedback training reduced seizure frequency by an average of 40 percent in all patients, the authors report. Increased network connectivity was noted in regions of the brain responsible for emotional arousal and control of the motor cortex.

"Our findings suggest that EDA biofeedback is an accessible, non-pharmacological, and side effect-free treatment for patients with drug-resistant epilepsy," says Yoko Nagai, Ph.D., a Wellcome Trust Research Fellow at the Brighton and Sussex Medical School.

A second study (abstract 3.114) uncovers a previously unknown waveform associated with smartphone use. Researchers from the Mayo Clinic in conjunction with colleagues at Rush University Medical Center have identified the waveform during video EEG monitoring of 129 patients evaluated for epilepsy at institutions in Florida and Illinois.

Dubbed the 'texting rhythm,' the waveform is induced by active text messaging and produces a reproducible, stimulus-evoked, generalized frontocentral monomorphic burst of 5-6 Hz theta. The waveform was not observed during voice calls or during non-texting activities involving cognition, speech/language or movement in one arm of the study. According to the authors, the waveform may reflect the neural coding observed during non-auditory communication, and its significance should be assessed in further studies.

"These findings provide objective evidence that the use of smartphones is capable of altering neurophysiologic function. This feature of the EEG could represent a unique brain-technology interface that could further our understanding of the way in which some people communicate without verbal expression or visual cues. From a practical standpoint it provides an objective measure in the brain that could potentially interfere with tasks that require full attention, such as driving," says William Tatum, D.O., a neurologist at the Mayo Clinic in Florida.

In a third study, (abstract 3.092) researchers from Johns Hopkins University use data acquired in real time to train a machine learning algorithm for seizure detection. Few technologies can reliably warn patients of an impending seizure due to wide variations in seizure onset patterns and the locations where seizures originate and spread in the brain. Modern seizure detection technologies rely on machine learning algorithms to sort EEG features into seizure or non-seizure events, but the clinical data needed to build reliable, patient-specific algorithms can be hard to come by.

The researchers circumvent this challenge by constantly retraining the machine learning algorithm with the patient's own brain patterns. Using intracranial recordings from patients with focal epilepsy who were undergoing presurgical evaluation, they describe an algorithm capable of detecting previously unnoticed seizures between 0 to 4 seconds after onset, even when those seizures had novel ictal signatures. The ability of the algorithm to adapt to changing brain activity often allows for the detection of seizure onset before clinical symptoms appear.

"The use of a dynamically adaptive algorithm is a promising strategy for detecting seizures with characteristics that are unknown at the time of the patient's admission," says Daniel Ehrens, a Ph.D. candidate and Howard Hughes Medical Institute Gilliam Fellow in the laboratory of Christophe Jouny, M.S.,Ph.D., at the Johns Hopkins Hospital.

A fourth study (abstract 2.084) describes a carbon nanotube-based strategy for enhancing the power of the Responsive Neurostimulation System (RNS), the only FDA-approved intracerebral neuromodulation therapy to date for patients with drug-resistant focal epilepsy. The electrodes used in the RNS act locally, activating neurons within 4 mm of the electrode's surface. Carbon nanotubes could potentially expand this area of influence by enhancing the conductivity of the brain near the electrode.

The authors performed cytotoxicity testing on human brain cells to confirm the safety of functionalized carbon nanotubes. Computational and experimental modeling experiments demonstrated that the nanotubes indeed expand the area of activation.

"Functionalized metallic-type carbon nanotubes are biocompatible within the brain and could enhance the volume of activation by an electrode via direct neurostimulation. This could allow the electrode to interface with and activate a greater extent of the epileptogenic circuit," says Marvin Rossi, M.D., Ph.D., an associate professor of neurology at Rush University Medical Center.

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