Brain Sychronization Events follow cognitive challenges

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Non-invasively recorded high-density EEG data contain a large amount of information about cortical synchronization in multiple frequency bands and cortical domains. Sufficient signal processing means to detect, visualize and model these phenomena are needed. The approach we present here uses independent component analysis to separate EEG information from different domains of cortical synchrony and to remove artifacts, followed by time/frequency analysis and single-trial visualization, to detect brain dynamic events occuring in response to cognitive challenges presented by external events.

Implementing intentions to actively attend and respond appears to Require dynamic tuning of cortical receptivity. Such tuning and retuning doubtless accompanies our every change of intention. For example, a soccer player kicking the ball towards the goal "concentrates on" relevant somatomotor and visual input while his brain "ignores" irrelevant parameters (such as crowd noise). Most likely, such transient refocusing of attention to maximize the chance of achieving his intention ("goal!") may affect the dynamic state of nearly every cortical area. Behavioral attention experiments demonstrate that normal subjects can change their attentional tuning rapidly if sufficiently motivated. Synchronous field activity in cortex giving rise to EEG signals at the scalp appear to accompany this top-down focusing of attention produced by changes in intention (in turn occasioned by events and their anticipated consequences).

Data from six subjects participating in a 128-channel event-related EEG experiment involving binary forced choice speeded response task (Luu et al., 2000) were analyzed using infomax independent component analysis (ICA) followed by time/frequency analysis (Makeig et al., 2002). During and immediately following response errors (late and/or incorrect responses), theta band (4-6 Hz) bursts were observed in the EEG. ICA applied to the unaveraged EEG data revealed that these bursts occurred in otherwise maximally temporally independent frontal and parietal EEG domains. Further, these bursts exhibited transient, event-related coherence which tended to proceed from anterior to posterior domains. The central midline post-response theta bursts were also partially phase reset by the motor response, giving rise to the so-called Error-Related Negativity (ERN) feature of the averaged event-related potential (ERP).

Event-related coherence between maximally independent EEG domains Was not simply a consequence of common entrainment to phase resetting by the response -- and thus was not reflected in features of the response-locked ERP. We will present an animation showing event-related changes in theta power and synchronization during correct and incorrect response trials. Similar synchronization dynamics in the theta band appear in other paradigms in response to immmediate cognitive challenges, including memory encoding and selective attention tasks.

The presence of cognitive event-related changes in the spatiotemporal pattern of synchronized macroscopic field activity across cortical (and, doubtless, subcortical) regions is a new and intriguing feature of event-related EEG dynamics. Such transient, frontal-parietal theta-band 'brainstorm' events may facilitate attentional refocusing, here occasioned by subjective (top-down) awareness of the consequences of motor errors in the context of goals and intentions.