Temporal relationships between independent EEG frequency modulations

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Mean power spectra of scalp EEG signals exhibit distinct peaks emerging from the general decrease in power with increasing frequency, suggesting the existence of characteristic oscillatory modes in cortical field potentials. The interactions between peaks in different frequency bands, within and between cortical EEG sources, are not well understood. The present analysis was designed to separate second-to-second changes in the power spectra of EEG source domains into distinct modes.

EEG data from an emotional imagery task were first decomposed by independent component analysis (ICA) to isolate independent EEG activities from the signal mixtures recorded at each scalp electrode. Each independent component (IC) was determined to be artifact or plausibly brain-derived by examining its scalp projection, power spectrum, and task-related activation time course. IC activations were then decomposed in one-second sliding time windows (with half-second overlap) over the entire session by fast Fourier transform. The mean log power spectrum over all time windows was removed for each IC, leaving spectral fluctuations from the mean in each 1-sec time window.

The log spectral differences for all brain ICs were concatenated into a large matrix of size (windows by ICs*frequencies). This matrix was reduced by principal component analysis (PCA), and then decomposed by infomax ICA into maximally independent spectral modulators (IMs). Here, ICA separated the log spectral fluctuations into the multiplicative effects of frequency templates with maximally distinct profiles across frequencies and ICs. The resulting IM templates were clustered across subjects according to modulatory effects with narrow or wide band changes in the canonical frequency ranges: delta, theta, alpha (with harmonics), beta, and non-oscillatory broadband gamma (roughly 35-128 Hz or higher). Each IM template was associated with a weight in each time window giving the strength of its effect on the mean log power spectrum of the affected IC process. Since ICA, as applied here, did not constrain the IM time courses to be independent, relationships between IM weight series within-subject were assessed by correlation. A weak mean negative correlation was found across subjects between all lower frequency modulations (delta, theta, alpha, and beta) and the broadband gamma modulations, suggesting that within single cortical source domains, when low-frequency power was below average, broadband high-frequency power was high. While the mean correlations were significant according to permutation statistics, the correlation was relatively low over the entire time course of the experiment (near -0.1). These results suggest that opposite regulation of high and low frequency power may be one characteristic mode of cortical processing, though the relationship is by no means constant over time.

Acknowledgments
This work was supported by the Swartz Foundation (Old Field, NY) and the National Science Foundation