New methods for analyzing trial-to-trial EEG spectral variability

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INTRODUCTION
A basic feature of both scalp and intracranial EEG records is its marked second-to-second spectral variability. Known causes of this abundant spectral modulation include central brain arousal systems. Methods are needed to identify independently acting spectral modes and modulations directly from the data, and to identify actions of these modulator processes that are linked to features of the shifting behavioral context.

1) Weights/Template (WT) spectral decomposition

**PURPOSE** – find independent modes of frequency modulation within and/or across independent component processes

**ICs** × freqs or (times × freqs) activations

**WEIGHTS**

**TEMPLATES**

WT decomposition including scalp muscle processes:

A sample decomposition that included muscle components confirms that high-frequency activity in brain ICs is not the result of muscle activity since brain and muscle high-frequency activity appear in separate independent modulations (IMs). At right, the same IMs are shown relative to their respective mass power spectra to show a more intuitive representation of how the shape of the power spectrum changes with variations in IM weights. Note the intriguing mode of broadband modulation (left) in which brain IC high-frequency power increases (or, in some occipital IC) while alpha-band activity of muscle ICs (near the left axis) decreases. Brain/muscle interactions might also be better understood using this decomposition.

2) Template/Weights (TW) spectral decomposition

**PURPOSE** – find independent, task-related spectral perturbation patterns

Across-subject template weights

Across-subject spectral decomposition (TW):

**TEMPLATES**

**WEIGHTS**

Three modes of spectral perturbation time-locked to letter presentations in a Sternberg working memory task: (A) Modulated increase in High-Freq. alpha occurs midtrial and is followed by a decrease in IM 8. (B) Beta/Theta transitory activity increases in IM 12 (midtrial) and is followed by a decrease in IM 4. (C) Increased power in IM 22 is followed by a decrease in IM 14. These are independent modulator processes of unspecified origin that act multiplicatively on the spectra of independent EEG component processes.

3) Context ICA (xICA): Special case of TW decomposition

**PURPOSE** – find independent, task-related spectral perturbations associated with particular behavioral contexts

Understanding single-trial dynamics is essential for discovering the physiological significance of EEG activity. While past research has treated trial-to-trial variability as ‘noise’, results illustrated here demonstrate ways in which discrete modes of spectral variability may play more specific roles.

Here we present data-driven methods for identifying:

1) Modes of spectral modulation (WT)

2) Modes of spectral reactivity in single trials or time windows (TW)