Estimating Single-Trial Responses in EEG

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Abstract

Accurate characterization of single-trial field potential responses is critical from a number of perspectives. For example, it allows differentiation of an evoked response from ongoing EEG. We previously developed the multiple component Event Related Potential (mERP) algorithm to improve resolution of the single-trial evoked response. The mERP model states that multiple components, each specified by a stereotypical waveform in latency and amplitude from trial to trial, comprise the evoked response. Application of the mERP algorithm emulates data with three independent, synthetic components has shown that the model is capable of separating these components and estimating their variability. Application of the model to single-trial, visual evoked potentials recorded simultaneously from V1, V4, and superior temporal sulcus reveals that certain local components estimated by the model were distributed in both granular and supragranular laminas. This suggests a linear coupling between the responses of thalamo-recipient neuronal ensembles and subsequent responses of supragranular neuronal ensembles, as predicted by the feedforward anatomy of V1. Our results indicate that the mERP algorithm provides a valid estimation of single-trial responses. This will enable analyses that depend on trial-to-trial variations and those that require separation of the evoked response from background EEG rhythms.

Why Single Trials?

A sensory stimulus activates multiple neuronal ensembles whose electrical activity can be measured. Activation of these ensembles exhibits trial-to-trial variability, which when characterized reveals a “higher resolution picture” of sensory processing schema. For example, the V1 feedforward circuit model states that visual input enters layer 4C at a precise latency and progresses to layers 2/3. Trial-to-trial co-variation in activity from these two layers is thus expected. Deviations in onset latency and amplitude might signal multiple activation times related to different task or subject conditions. Variability in single-trial evoked responses also prohibits accurate separation of stimulus-evoked activity from ongoing EEG rhythms. Thus single-trrial dynamics must be characterized and studied to understand processing.

Experimental Paradigm

A lines multi-electrode array was inserted acutely into macaque V1 as illustrated earlier. The subject performed a visual discrimination task during which intracranial field potential (FP) was recorded. Responses to the non-target stimulus were averaged, and current source density was calculated. The CSD profiles shovw initial activity in Layer 4C. Activity is similar across the supergranular and infragranular layers. Layer 2/3 activation is revealed in the supergranular layers.

Bimodal Activation of Layer 4C

Since the model permits trial-to-trial latency and amplitude variability, we can examine these dynamics to characterize activation patterns in different laminae. The initial activation of layer 4C illustrates a bimodal latency distribution in both experimental sessions. Furthermore, “early” activation is associated with smaller amplitude responses, and “late” activation is associated with larger responses. Note that the overall amplitude variability is small in both cases.

The mERP Model

The mERP model defines multiple components as stereotypical waveforms that have identical amplitude and latency from trial to trial. This is expressed mathematically as:

\[ x_n(t) = \sum \alpha_c x_n(t - \tau_c) + \eta_n(t) \]

Coupling between the m ERP component and n ERP channel

\[ \text{Amplitude scaling for the nth component in the m ERP channel} \]

\[ \text{Latency shift of the nth component in the m ERP channel} \]

Bayes’ theorem is applied to compute the posterior probability of the model from which maximum a posteriori (MAP) solutions are estimated using a fixed-point algorithm.

Experimental Session V2C

The mERP model was applied to single-trial FP data resulting in estimates of component waveforms and their associated spatial locations and single-trial amplitudes and latencies. Below are CSD maps of the model components.

Verifying the Model in Layer 4C

To verify the modeling results, we examined single-trial data from each session. The plots show trial-to-trial variability in layer 4C activation and illustrate that the response in some trials occurs early (arrows). The red mark to the right indicates trials in which the response is unmatched with subjective latency.

References


Please visit 506.4 for information on the validation of mERP.