Modeling of trial-to-trial temporal heterogeneity in electrophysiological signals using the mixed- effects model: application to the classification of errors and correct trials

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Abstract

EEG and MEG normally require averaging across repetitions to obtain reliable results. This prevents single-trial analysis and classification. Furthermore, inter-trial variability, which may contain meaningful information, is lost. Here we propose a method that is both descriptive and discriminant using Mixed-Effects Models (MEM) to statistically model multi-sensor EEG signals and classify single-trial events. For a fixed subject, this parametric modeling allows decomposing trials into two distinct but complementary parts: a general trend defined over all trials of its class membership, plus an individual random effect that models the temporal deviation of the current trial from the common tendency (Huang et al. 2008). To make the problem more tractable with high density data, we reduced spatial and temporal data dimensionality in a discriminant fashion to classify errors and correct trials in a RT task. First, a linear discriminant analysis permits to identify the most discriminating electrode linear combinations, onto which the signals are projected. Second, a discrete wavelet transform is performed on time courses, followed by a selection of the most relevant wavelet coefficients. Dimension reduction leads to an optimization of the modeling through a synthesis of the EEG signal from the most relevant information. The classification of the EEG single-trial between two classes can be then achieved using a likelihood ratio test.
The method was tested on a problem of error-negativities detection in a cognitive task. On six subjects, the proposed method equals or outperforms the Mahalanobis distance-based classifier, with a smaller dataset to train the MEM classifier.

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