DOCTORAL THESIS

Study of the variability in brain potentials and responses: development of a new method for electroencephalography (EEG) analysis - residue iteration decomposition (RIDE)

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Study of the Variability in Brain Potentials and Responses: Development of a New Method for Electroencephalography (EEG) Analysis – Residue Iteration Decomposition (RIDE)

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Abstract

Brain responses display a large extent of variability even in the circumstance of identical stimulus input, as revealed by the broad distribution of reaction time (RT) from a simple task. The variability in the final output of brain responses could further be originated from the dynamical sequential cognitive processing. As a self-organized complex dynamic system, the brain continuously generates ongoing activities even without processing a particular signal input. The interaction between the background ongoing activity and the signal input thus become a possible mechanism partially accounting for brain response variability (BRV) to identical stimuli. So far, the role that the brain background activity plays in BRV is still very unclear.

In cognitive neuroscience, the event-related potential (ERP) method opened a window for studying the brain response activity associated with specific external stimulus. The ERP is the average waveform of EEG (electroencephalography) trials that are time-locked to the stimuli. Obviously, two limitations of ERP method are 1) it discards the residual signal which contains the background activity that is crucially related to BRV; 2) the waveform of ERP is a deformed representation of neural response to the stimulus due to the trial-to-trial latency variability of its internal components.

The method we developed – RIDE (Residue Iteration Decomposition) – opened a new door for ERP and variability analysis. RIDE decomposes ERPs into different sub-component clusters associated with different psychologically relevant events. The variations of each component cluster as well as their interactions associated with experimental manipulations can be analyzed, respectively, which therefore brings ERP component analysis into a deeper level for understanding the mechanism of sequential cognitive processing. Another advantage of RIDE is that it can estimate the amplitude and latency of each component on the single trial level. When being combined with the study of the interactions between different components and background noise, the variability information of amplitude and latency provides an opportunity of studying the neurocognitive mechanism of the BRV.

By applying RIDE we have unraveled a new landscape of ERP. Specifically, we have applied RIDE to 1) retrieve ERP components with special waveforms that are totally hidden in conventional ERP; 2) disentangle latency and amplitude variation from the mixed condition-related variations in ERP; 3) disentangle different cognitive components; 4) attribute the conditional effects to specific components; 5) obtain the information of trial-to-trial variability for each separated component cluster.

Basing on its strengths in component decomposition and variability analysis, the method RIDE has great potential in the study of brain dynamic mechanisms, individual differences, brain diseases, aging, and in clinical applications.

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