EVENT-RELATED POTENTIALS SOURCE SEPARATION BASED ON A WEAK EXCLUSION PRINCIPLE

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Abstract

•Standard **event-related potentials (ERP)** technique consists in averaging many on-going EEG trials using the same stimuli. We introduce a novel **Blind Source Separation (BSS) approach based on a weak exclusion principle (WEP)** to solve the problems. The results show that our BSS algorithm can effectively extract ERPs **using fewer average times** than the traditional methods.

•We can isolate two main ERP components, which are respectively related to **an exogenous process** and **a cognitive process**, and can discriminate between the occipital lobe and the frontal lobe responses from the brain, agreeing with the classical component modeling in ERPs.

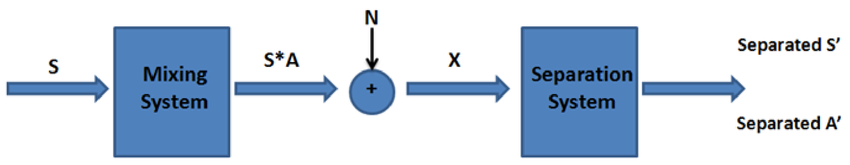
•**Single-trial** ERP separation results have demonstrated the consistency of these two main ERP components.

Blind Source Separation

Blind Source Separation (BSS):

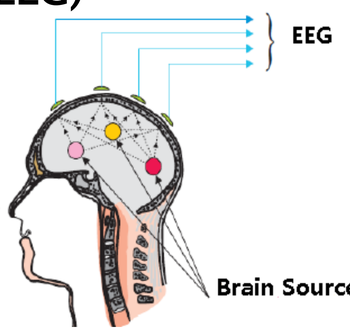
- **Blind**:No prior knowledge of the measurement.

$\mathbf{X} = \mathbf{SA}$; or, more visually, $\overset{\leftarrow K \rightarrow}{\underset{N}{\boxed{\mathbf{X}}}} = \overset{\leftarrow K \rightarrow}{\underset{N}{\boxed{\mathbf{S}}}} \times \underset{K}{\overset{\leftarrow K \rightarrow}{\boxed{\mathbf{A}}}}$



Electroencephalography (EEG)

- non-invasively measures voltage fluctuations resulting from ionic current within the neurons of the brain with very high temporal resolution.



Previous BSS Methods' Hypothesis

- The signals are **statistically independent.**
- Representative Algorithm: **Independent Component Analysis (ICA).**

✕ When considering the source signals as stochastic processes, the requirement of stationarity is necessary to guarantee the existence of a representative (non-Gaussian) distribution of the sources.

✕ However, the **non-stationarity of EEG signals** is well documented.

The Proposed BSS Method's Hypothesis

- Based on a **deterministic principle**, **Weak Exclusion Principle.**
- **Exclusion Principle (EP)**: The Sources are exclusive from each other.
- **Weak Exclusion Principle (WEP)**: at each time instance, the EEG signal is dominated by one source which is significantly (e.g. by a factor of 2) larger than the others.

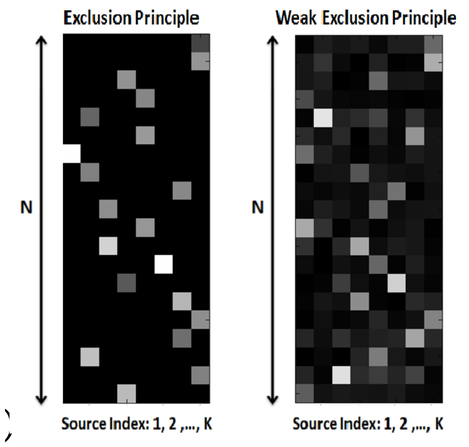


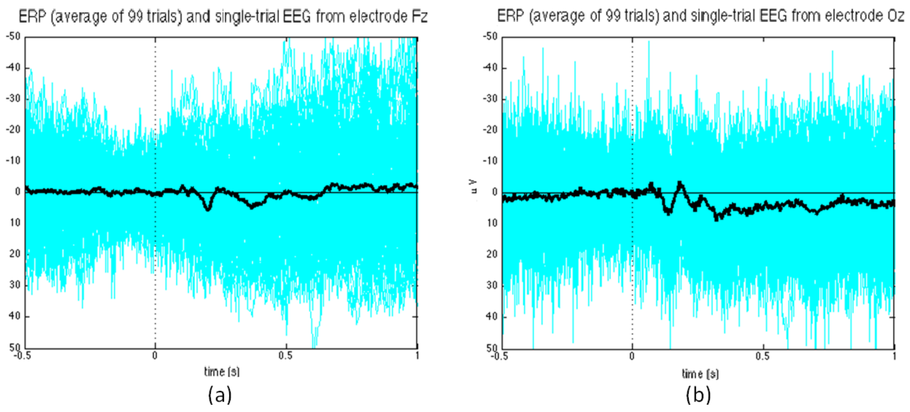
Illustration of Sources which satisfy EP and WEP requirements

Event-Related Potentials (ERP)

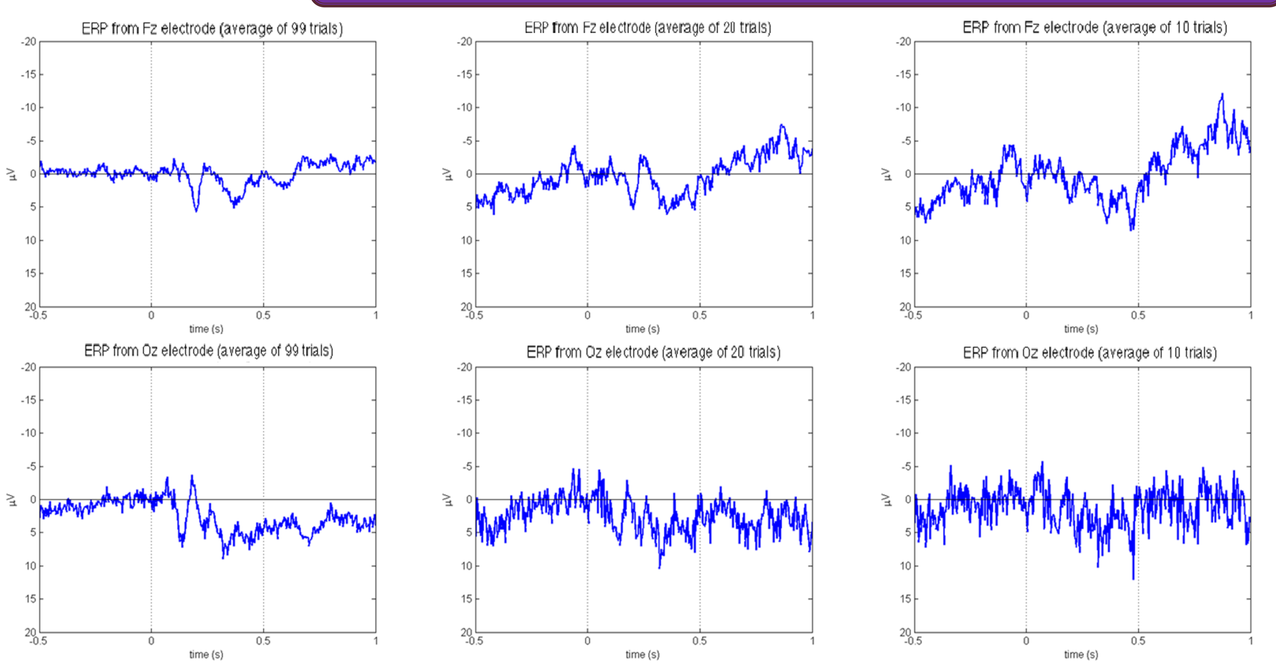
Standard ERP technique

✕ Tens or even hundreds of trials are necessary to obtain a reliable ERP average waveform.

✕ Different electrodes have different ERP waveforms. The standard ERP plots **cannot integrate the global information**.



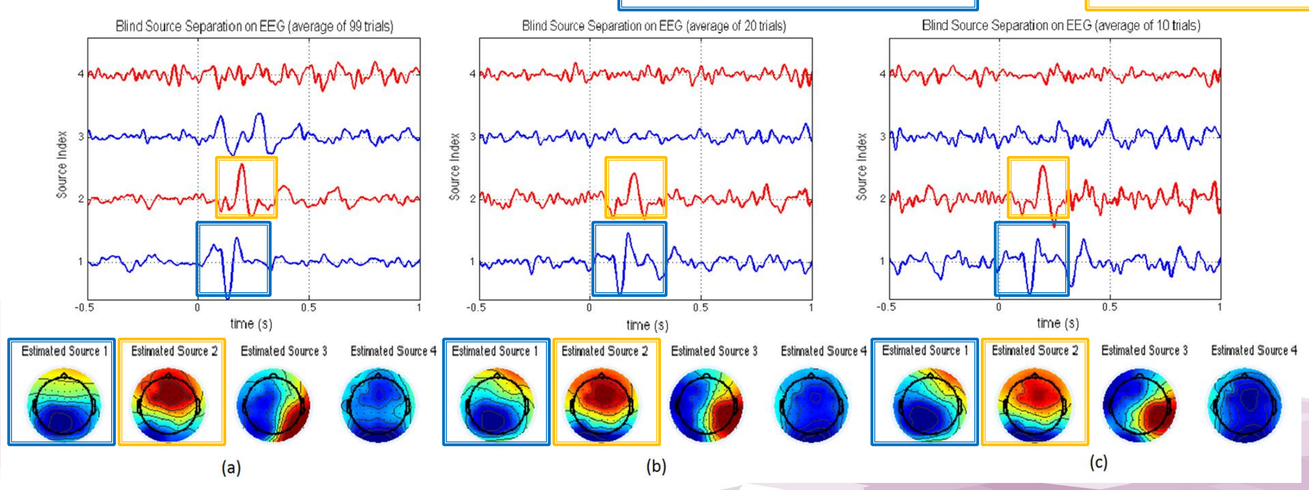
Black line: ERP from one electrode (an average of 99 trials); Blue line: Each single trial EEG signal of the 99 trials. (a) From electrode Fz. (b) From electrode Oz.



ERP from Fz and Oz, with average time as 99, 20 and 10 trials separately. As the average times decrease, the SNR of the ERP curves drops and ERPs become harder to observe.

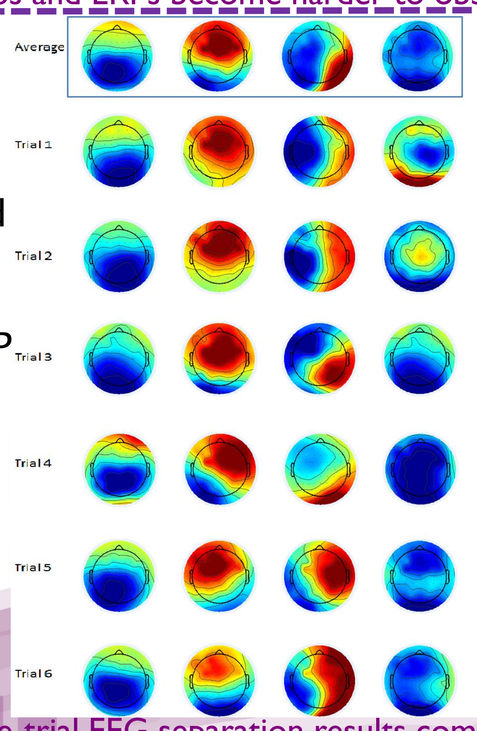
Blind Source Separation based on WEP to extract the ERPs

- Performance of BSS on EEG to extract the ERPs under different average times.
- Isolate two main ERP components: an exogenous process and a cognitive process.



BSS based on WEP to extract the ERPs, with average time as 99, 20 and 10 trials separately. As the average times decrease, the main separated sources remain stable.

- **Single-trial ERP** separation results have demonstrated the consistency of these two main ERP components.



Single-trial EEG separation results compared with the average of 99-trials separation results.