Measuring the Task Induced Oscillatory Brain Activity Using Tensor Decomposition

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ABSTRACT

The characterization of dynamic electrophysiological brain activity, which form and dissolve in order to support ongoing cognitive function, is one of the most important goals in neuroscience. Here, we introduce a method with tensor decomposition for measuring the task-induced oscillations in the human brain using electroencephalography (EEG). We validate this method using both simulation EEG data and real EEG data recorded during a task of irony comprehension. The results demonstrated that proposed method can track dynamics of the temporal-spectral modes of the rhythm in the brain on a timescale commensurate to the task they are undertaking.

BACKGROUND

The EEG consists of the activity of an ensemble of generators producing rhythmic activity in several frequency ranges. By application of sensory stimulation these generators are coupled and act together in a coherent way. This synchronization and enhancement of EEG activity gives rise to 'evoked' or 'induced' oscillations. The analysis for multi-way data (channel × time × frequency) of the evoked oscillation based on tensor decomposition has been studied [1]. In contrast, the data of induced oscillation can be generated by transforming the single trial EEG to time-frequency domain, which resulted in another data formation with channel × time*trial × frequency. In addition, to examine functional brain structure, source reconstruction techniques are applied to sensor-level EEG data, which can somehow overcome the limited spatial resolution of the EEG. Thus, a new data representation can be generated with source × time*trial × frequency.

MATERIALS AND METHODS

Simulated data

Three oscillating current dipoles perpendicular to the cortical surface were placed pre-selected brain regions (Fig.1). The duration of each trail of the simulated measurement was 1400 ms from -200 to 1200 ms.

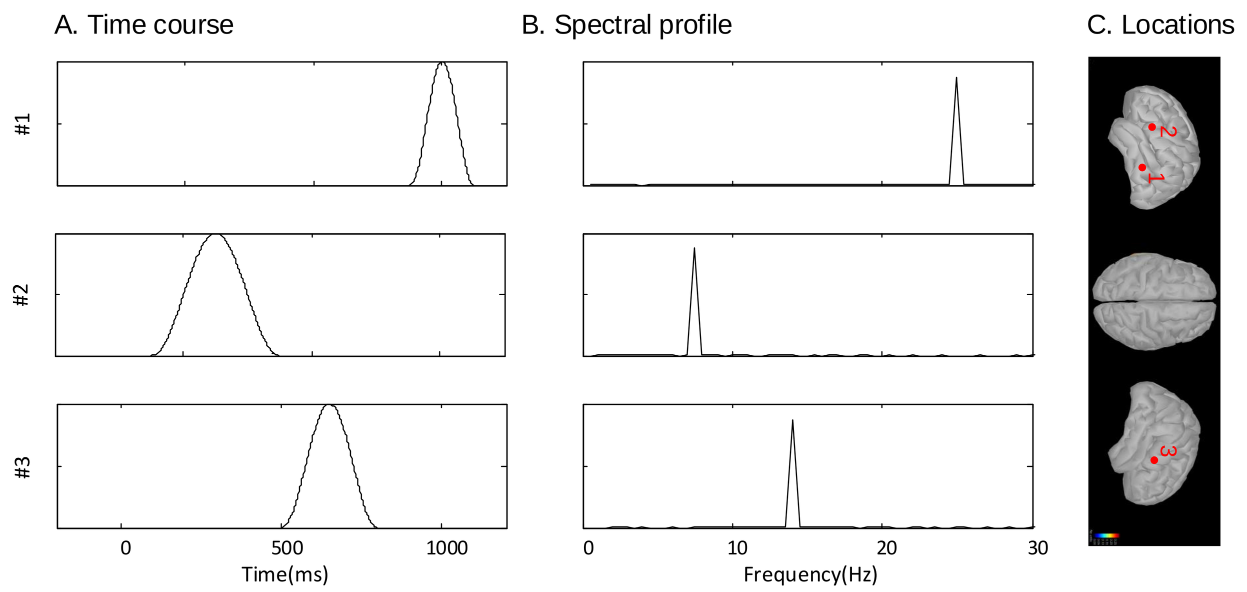

Fig. 1. Locations (C) of the simulated oscillatory current sources on an inflated and flattened brain surface and the time courses (A) and spectrum (B) of the three sources.

Experimental data

The data was collected at the University of Jyvaskyla, Finland. Thirty-eight participants were included in the final sample, in which there were 17 dysphoric participants and 21 control participants. The study was approved by the Ethics Committee of the University of Jyvaskyla. Stimuli with one-sentence spoken lines and colored pictures were applied.

Method

The analysis pipeline is illustrated in Fig. 2.

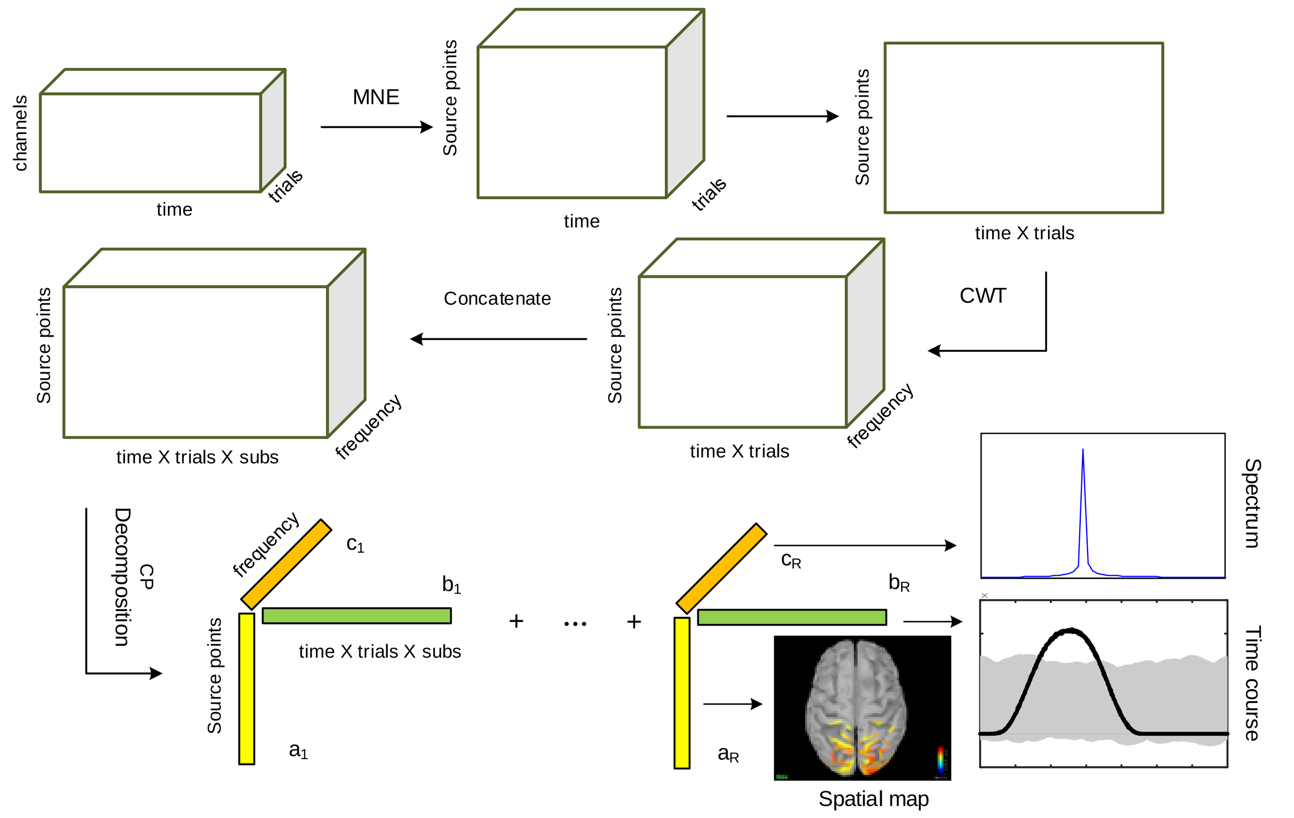

Fig. 2.Analysis pipeline of the CP decomposition applied to source-level third-order EEG data.

RESULTS

Results from Simulation

Fig. 3 shows the envelope time courses and the power spectra for all three correctly reconstructed brain networks and one noise artifact.. As can be seen that the location, spectra and the averaged time courses of the pre-set brain sources were reconstructed successfully.

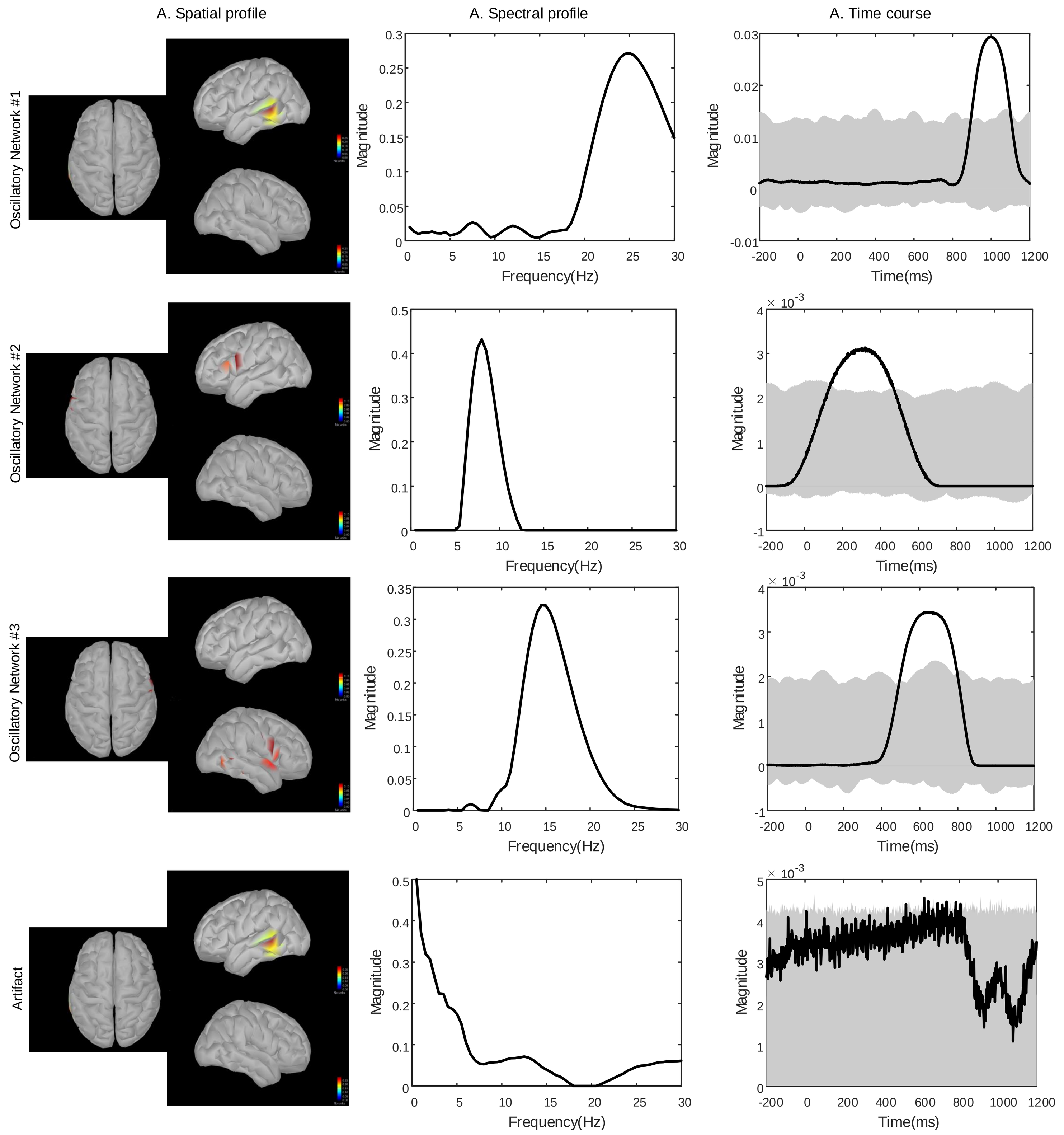

Fig. 3. Results of simulation. A: spatial maps of extracted components. B: Spectral factor of the components. C: Time courses of components, averaged across trials (black line). The grey shaded region represents the null distribution based on a hypothesis that the response is not time locked to the tasks. Significance (P<.05) is attributed if the black line appears outside the null distribution. Rows 1 to 3 show the three induced oscillatory sources. Row 4 demonstrates an artifact.

Results from Simulation

Fig. 4 shows the results of our method applied to the real EEG data.

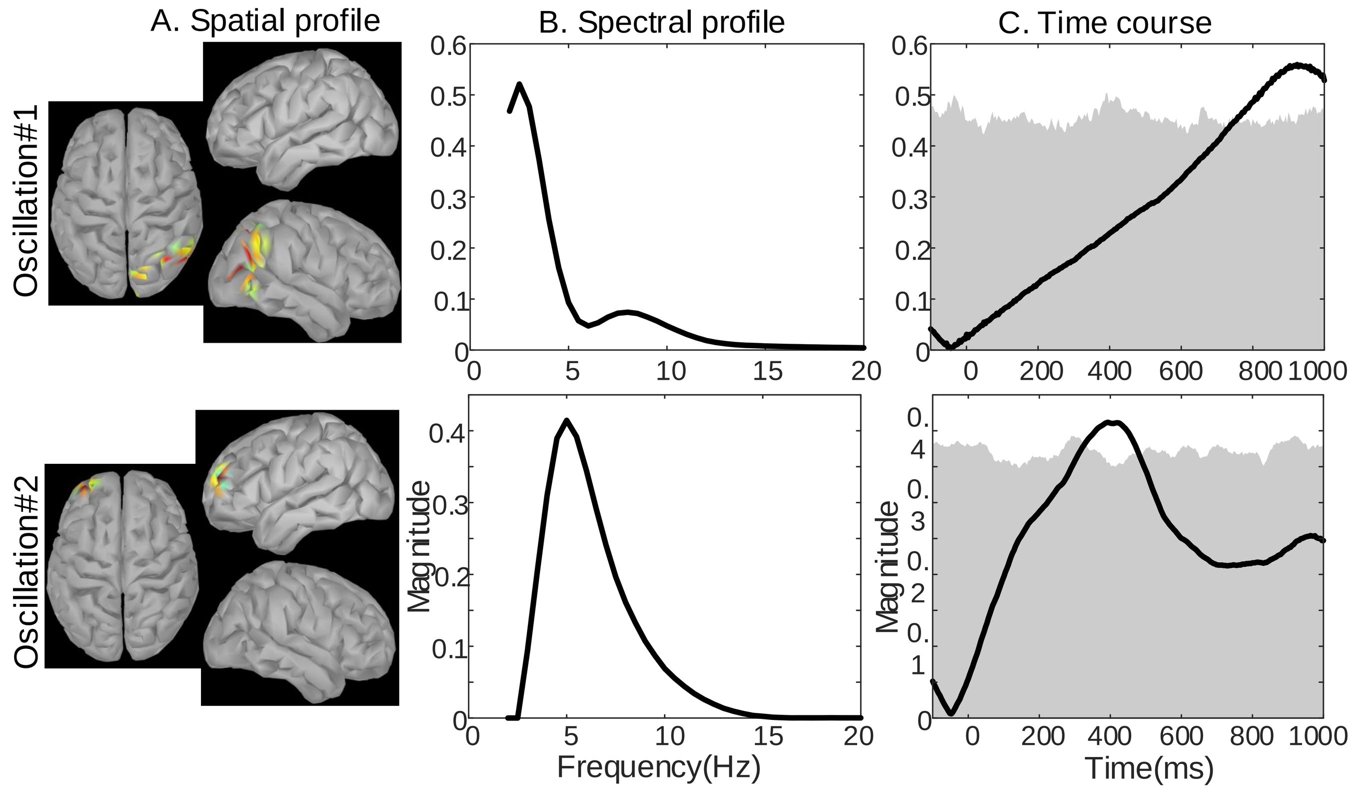

Fig. 4. Results of experiment data. Row 1 shows the Delta oscillation involved in comprehension of irony in right temporal-occipital junction after 800 ms of the stimulus onset. Row 2 demonstrates the Theta rhythm was elicited in Broca's area after 400 ms of the ironic stimulus onset.

CONCLUSION

The proposed method was validated by both simulated data and real EEG data. When application to real EEG data collected from task of irony comprehension, we found brain activity of interest, which was associated with irony comprehension. The results demonstrated that the Delta rhythm was elicited in Broca's area after 400ms of the ironic stimulus and the theta oscillation involved in comprehension of irony in right temporal-occipital junction after 800ms of the stimulus.

REFERENCE

[1] Cong, Fengyu, et al. "Tensor decomposition of EEG signals: a brief review." Journal of neuroscience methods 248 (2015): 59-69.

CONTACTS

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