Investigating Synchronization During Crossmodal Integration Using Electroencephalography

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Binding by Neural Synchronization

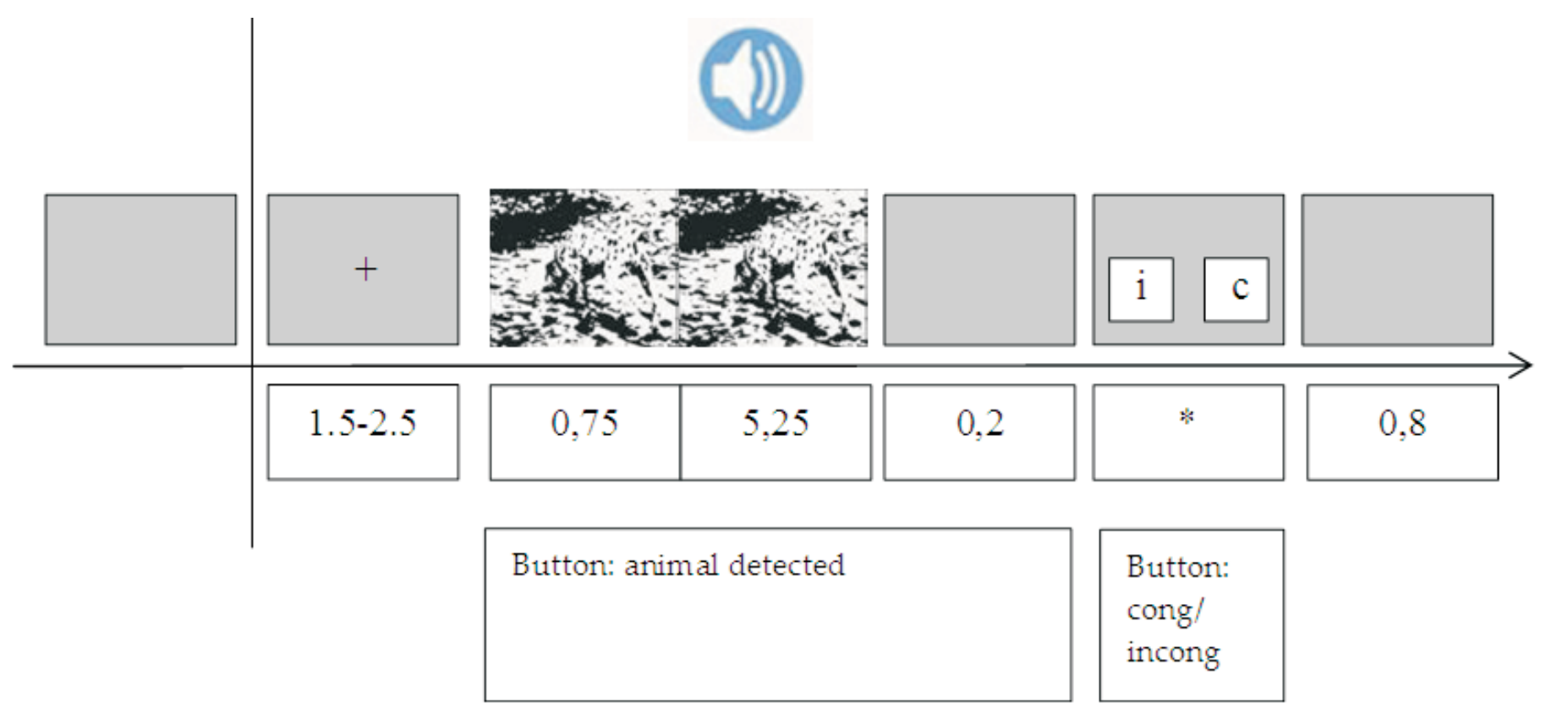
The synchronization of neural signals has been proposed as a mechanism for binding (Singer, 1999). The brain could use this mechanism to integrate information within single senses and between different modalities. Several studies have shown increased synchronization of brain signals during a variety of tasks that are associated with binding processes (König et al., 1995; Tallon-Baudry et al,. 1999; Rodriguez et al., 1999).

Electroencephalography as a Method to Detect Binding

Using EEG we investigated correlates of temporal binding in different crossmodal tasks. We focused on induced gamma (>24 Hz) energy and phase locking of signals. Regarding the specific role of temporal dynamics, it is reasonable to benefit from the method of EEG. If one aims to study the functional relationship between cortical areas, the temporal co-activation of areas needs to be inspected in the most precise way possible. Temporal dynamics of the neural networks involved happen in the millisecond range - this can be best detected by EEG.

A Crossmodal Detection Task

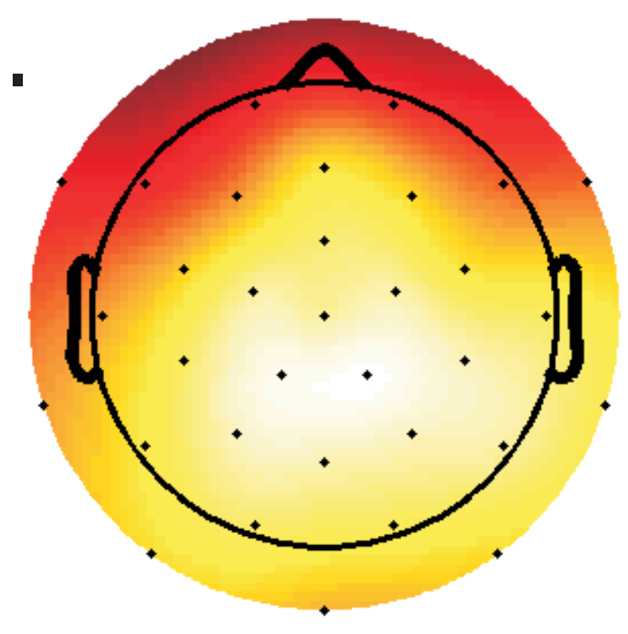
17 subjects watched 150 camouflage pictures of natural scenes with animals or without animals while listening to a matching or non-matching auditory cue indicating the type of the animal. They had to detect and identify the animal.

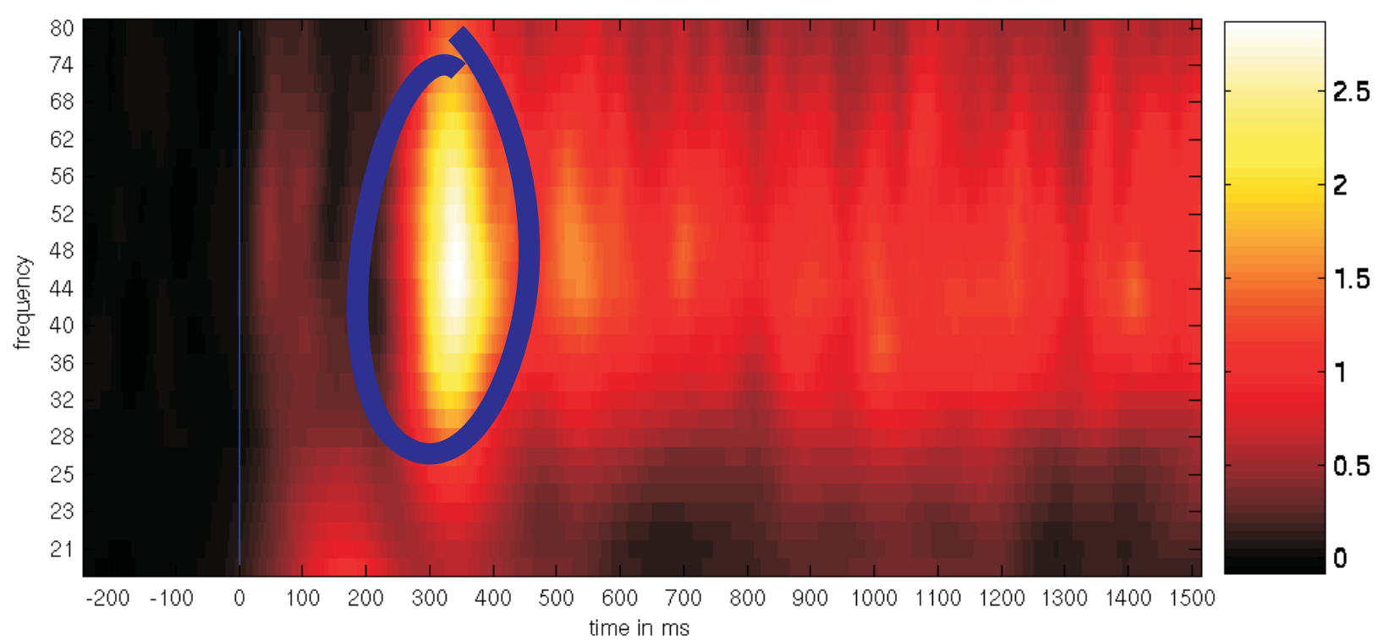


Multimodal stimuli are suitable to study interaction of spatially distinct neuronal assemblies. Moreover, if the synchronization of activity reflects a binding mechanism, this synchronization should be enhanced when a coherent percept is created as reaction to a stimulus presented. Degraded pictures are hard to recognize, motivating participants to attend to the auditory cue. The use of both, visual and auditory, information should enhance the binding of the stimuli.

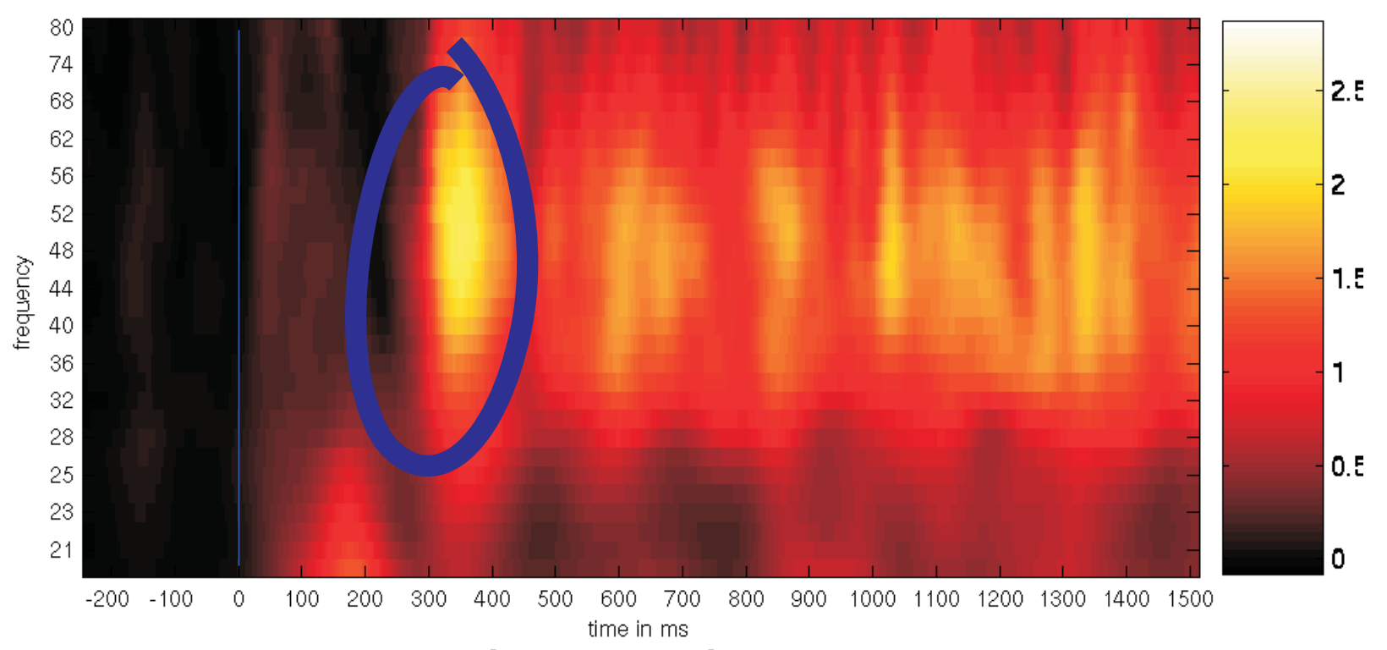
Increased Energy for Detected Targets

We found stronger induced gamma energy, time locked to stimulus onset, when an animal had been detected compared to animals not found. Similar patterns occurred for measures of global phase synchronization within the same time frame and frequency range. This supports the assumption that the measured oscillatory gamma energy is related to the binding of an object representation. While earlier studies showed increased energy for learned and recognized stimuli (cf. Tallon-Baudry et al., 1999), this study indicates that previous experience is not necessary to enhance the gamma response.

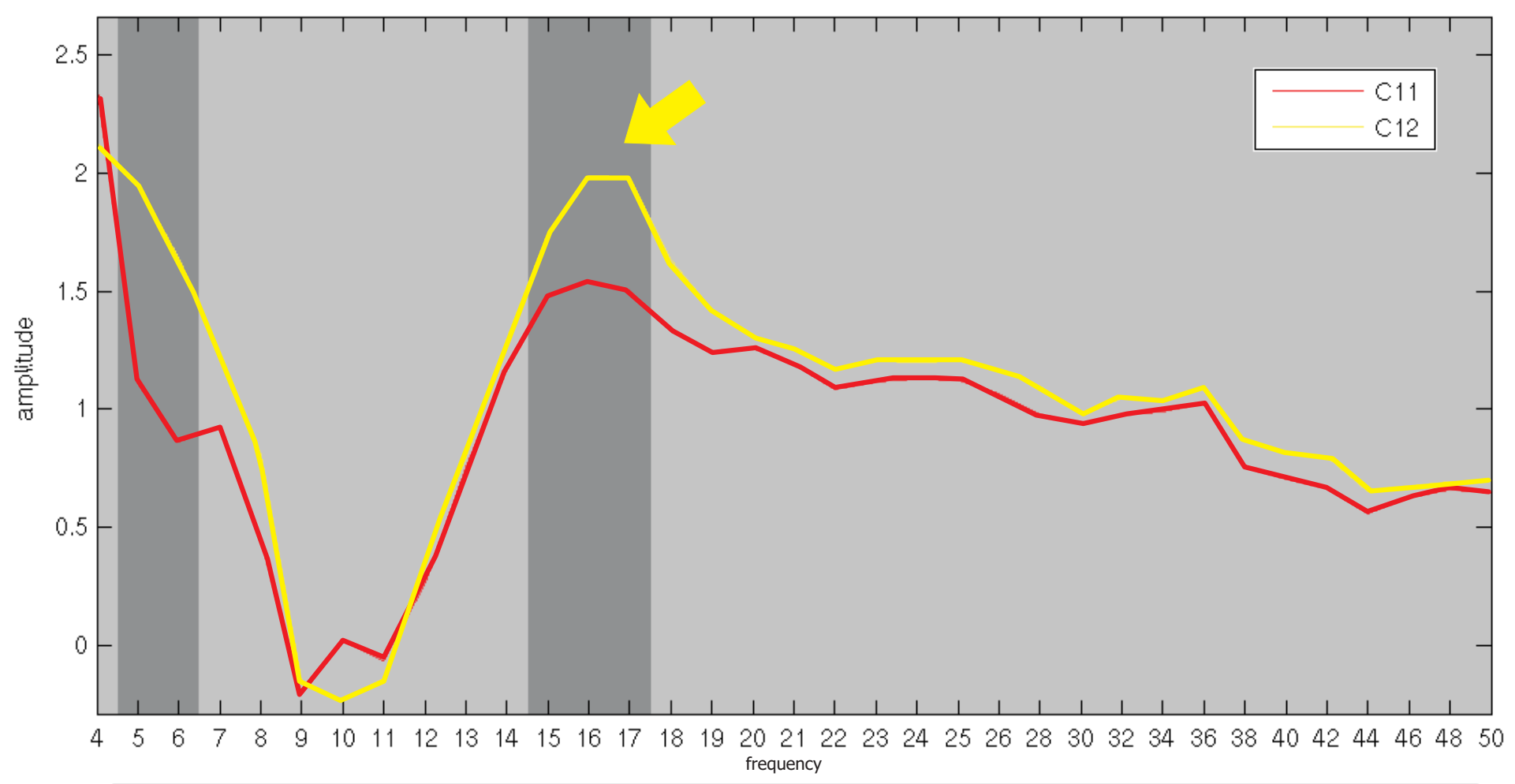




Detected Animals



Undetected Animals



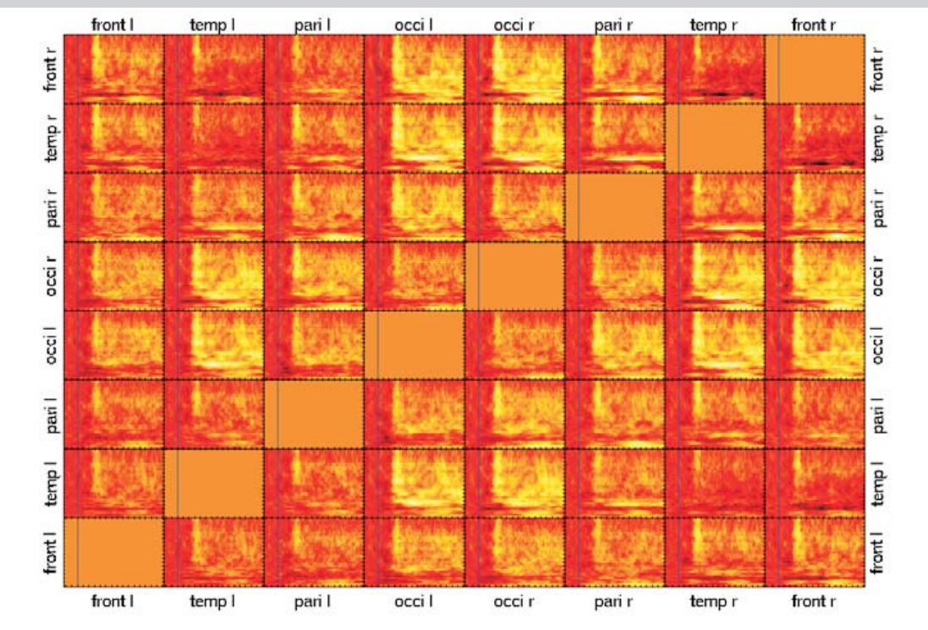
C11: Matching Stimuli; C12: Conflicting Stimuli

Increased Synchronization for Crossmodal Conflict

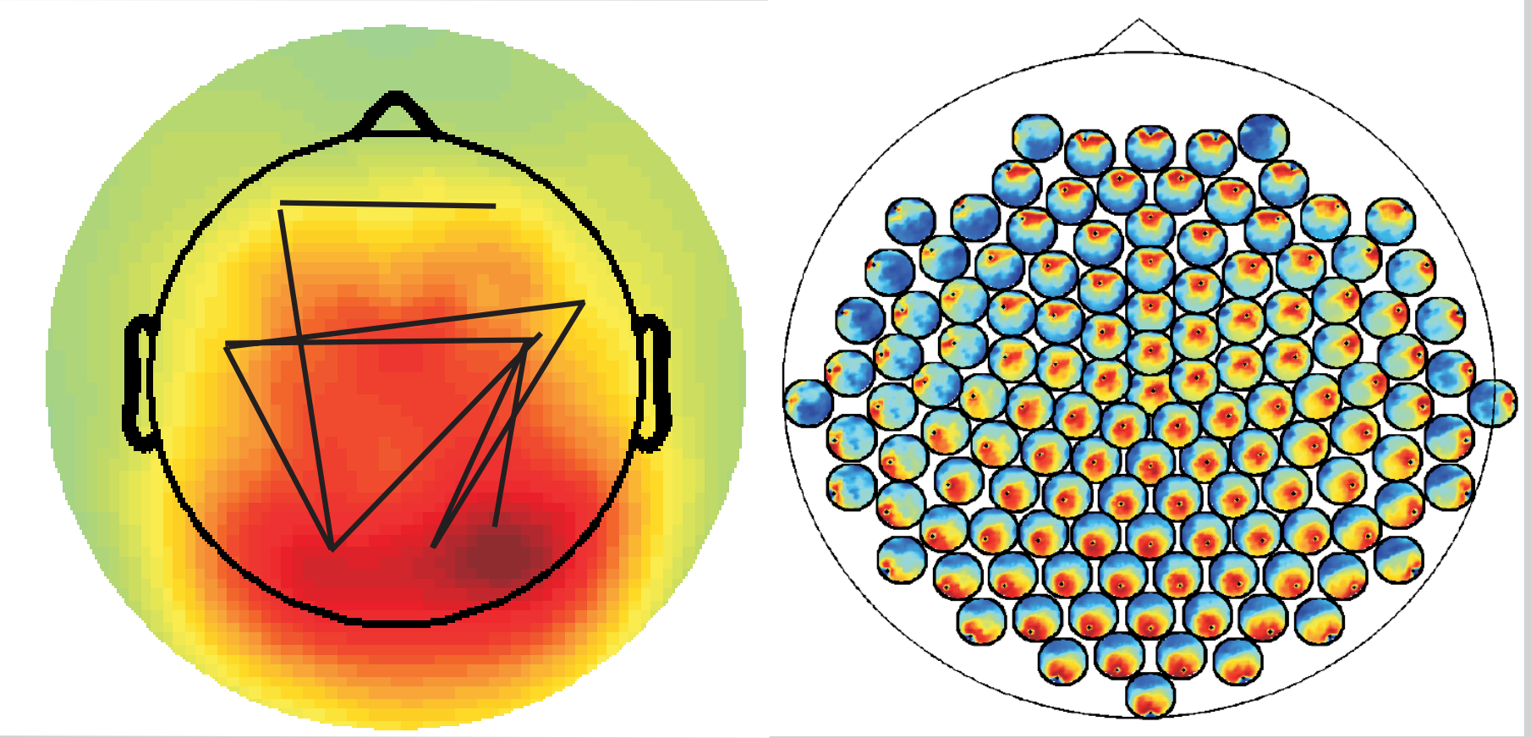
We have also found significant differences in synchronization within the beta frequency band (13-18 Hz) before the recognition button press, the effect being stronger for incongruent picture-sound combinations compared to congruent stimuli. The increase in synchrony found within the lower beta band is interpreted as a correlate of crossmodal integration (von Stein et al., 2000). As it was stronger for the incongruent sound condition, this enhanced beta band synchrony could be a correlate of the integration of conflicting information.

The Challenge of Visualizing Coherence

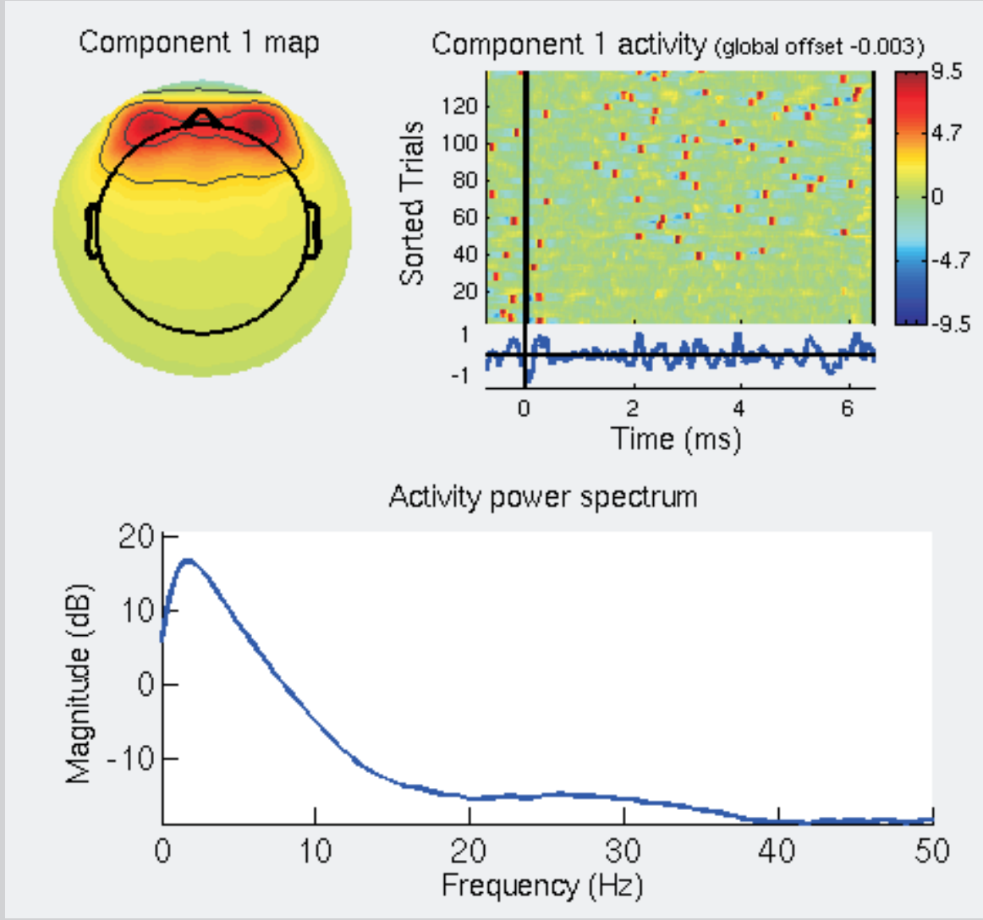
Useful visualizations of coherences are rare. The amount of information that is embedded in coherence data is overwhelming: 128 pairs of electrodes, at each point in time, for each frequency and each condition. The classical line plot is only usable for a small number of electrodes. The head-in-the-head plot (cf. Nolte et al. 2004) shows the coherence of each electrode with all other electrodes at one point in time and one frequency. The time-frequency matrix view shows the coherence of a selection of electrodes for all points in time and all frequencies.



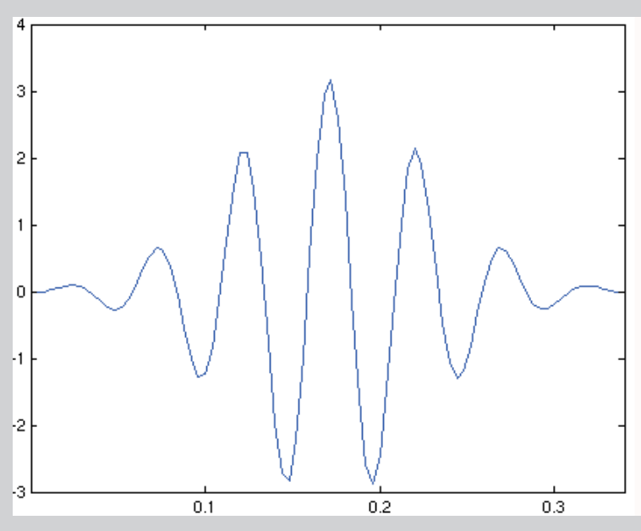
Dependent on the requirements one has to choose the right visualization.



Independent Component Analysis and Wavelet Transformation as Methods of Choice



To clear the data of artifacts, we use Independent Component Analysis (cf. Delorme et al., 2004). ICA extracts independent source signals from the recorded data. Thereby, it unmixes artifactual signals and brain signal. After deleting the artifactual signals (eye blinks, muscle artifacts,...), ICA transform the remaining data back to its orignal projection.



Wavelet Transformation offers a better time-frequency resolution than Fourier Transformation by using differently scaled wavelets for each frequency of interest. We use wavelets to extract the energy and the phase of the recorded signals (cf. Lachaux et al., 1999; Tallon-Baudry et al., 1999).

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