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Modulation of ventral and dorsal attention networks during target detection: an EEG/fMRI study

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Abstract. Functional neuro-imaging and electrophysiological studies have documented a dynamic baseline of intrinsic brain activity during resting state, organized in discrete cerebral networks. To investigate their modulation during a target detection task, we proposed a completely data-driven approach combining information from simultaneous electroencephalography (EEG) and functional magnetic resonance imaging (fMRI). We observed five widely distributed large-scale networks. The P300-related activity measured from EEG data was used to identify the ventral and dorsal networks as linked to target detection, each showing a specific time-pattern.

Keywords: EEG, fMRI, multimodal imaging, P300, target detection.

1. Introduction

Previous functional neuroimaging studies have shown the presence of a dynamic baseline of brain activity that can be modulated by cognitive tasks. However, the cerebral mechanisms accounting for the observed trial-to-trial response variability have not been completely clarified. In order to investigate the modulation induced in brain functional connectivity by a target detection task, we used a completely data-driven approach, combining information from simultaneous EEG and fMRI.

2. Material and Methods

We studied 13 subjects during a visual oddball task. The EEG signals were recorded with a 32-channel MR-compatible system inside a MRI scanner operating at 1.5 T, used to simultaneously acquire the functional images. An ICA-based analysis of fMRI BOLD data allowed to characterize neuro-anatomically defined patterns, each of them with a definite spatial map and a specific time-course of activation. In addition, we reconstructed the temporal evolution of the P300 amplitude, which was then convolved with a canonical HRF. The correlation of this P300 time-course with the fMRI pattern time-courses allowed the identification of the cerebral networks linked to target detection. Time-domain analysis of the network responses to rare events allowed a finer characterization of their fluctuations.

3. Results

We investigated the single-trial P300 amplitude variations, after the reconstruction of the EEG data with negligible contamination of the disturbances induced by simultaneous fMRI scanning. With regard to fMRI analysis, five widely distributed networks were robustly and consistently identified by means of ICA: ventral and dorsal attention, visual, working-memory and somatomotor (see Fig. 1). The first two brain systems were found to be significantly associated with the P300 reference time-course. In order to get temporal information on the two cerebral networks of interest, we analyzed the time-courses of the single ICs that were associated with them. Although the activity of the two networks correlated with the modulation of the P300 response, only the ventral attention network consistently responded to the rare stimuli, whereas the averaging procedure seemed to attenuate the signals of the dorsal attention network (see Fig. 2).

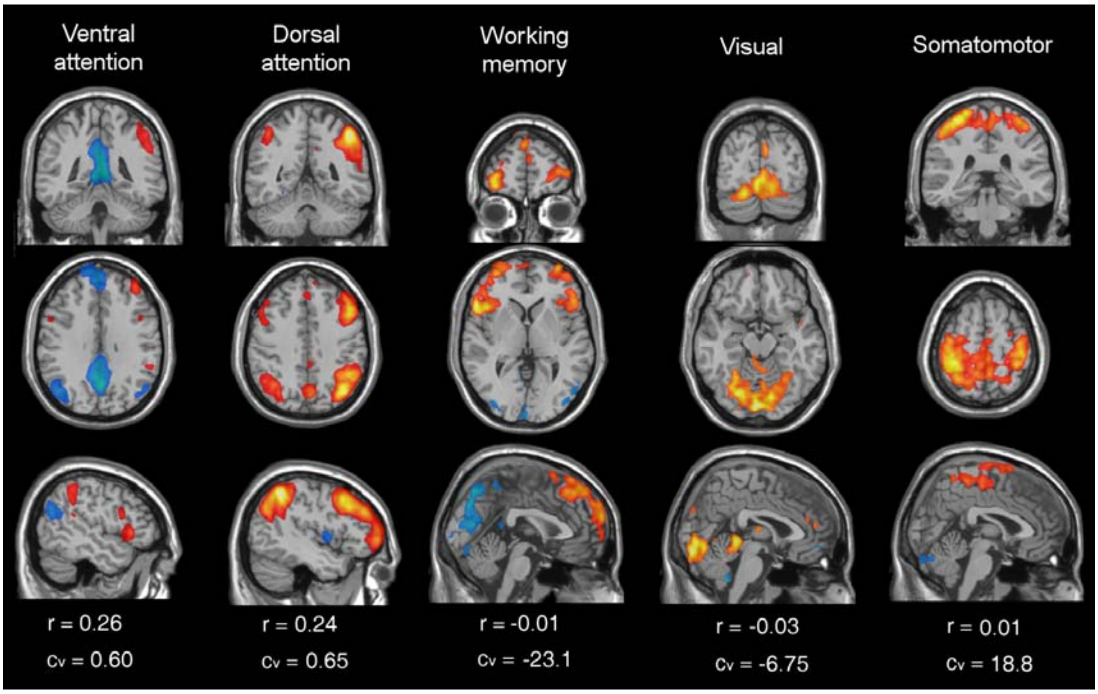

Figure 1. *Five networks separated from the fMRI datasets, and that are consistently found across subjects. The average value and the coefficient of variation of the correlations with the P300 reference time-course is provided for each network.*

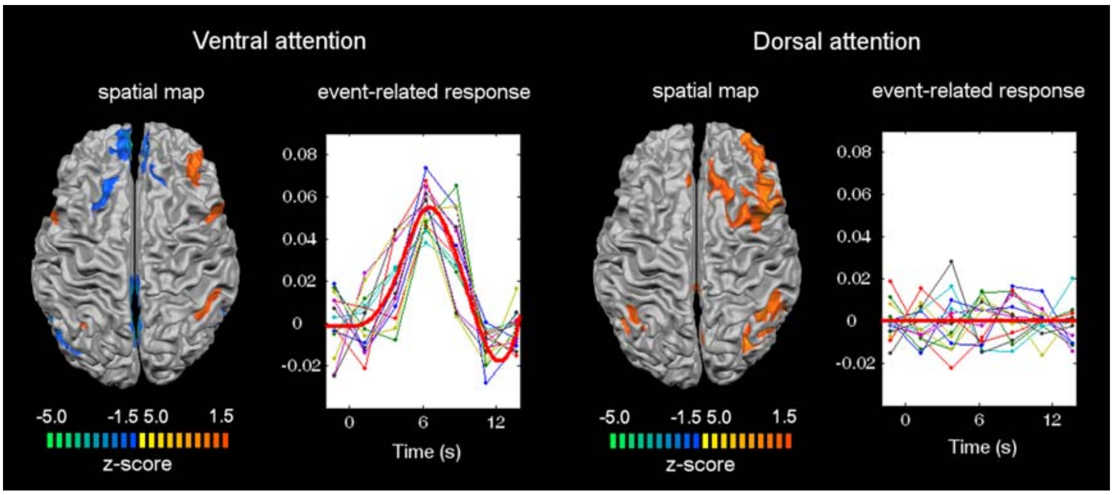

Figure 2. *Spatio-temporal analysis of the ventral and the dorsal attention networks. Their cortical representations (a,c) are shown, along with their time-courses in response to rare events (b,d). The maps contain regions with positive (yellow-orange) or negative (azure-blue) z-scores.*

4. Discussion

It has recently been observed that the neuronal activity either recorded with intracranial derivations or with electrodes placed over the scalp, correlates with the BOLD signal. Accordingly, a non-invasive method for multimodal integration might be achieved by investigating correlations between EEG responses and BOLD. Using information from concurrent EEG and fMRI, we have linked the cerebral dynamics observed through electrophysiological and hemodynamic measures for the investigation of the target detection. This coupling has been used for understanding the different contribution of distinct cortical networks to target detection.

Previous neuroimaging and electrophysiological studies showed a large number of P300 generators, specifically supplementary motor areas, anterior cingulate, middle and superior frontal cortex, insula, posterior parietal cortex, and temporo-parietal junction, which were suggested to belong to different functional systems. From this standpoint, our analysis allowed separating two independent spatio-temporal patterns of brain activity associated with target detection. The first pattern is composed of brain areas that are activated by the presentation of the rare stimuli (ventral attention network), and other areas that are concurrently deactivated (default-mode network). In turn, the dorsal attention system is usually engaged during voluntary orienting and is thought to mediate goal-directed stimulus-response selection. Interestingly, our analysis revealed that the time-course of this network reflects a modulation of cerebral activity, which is averaged out if time-locked to the presentation of targets, and is whatever associated with the P300 amplitude fluctuation across trials.

In conclusion, we obtained a deeper insight into the potential generators of the P300 component, and into the cerebral processes related to the modulation of the ventral and dorsal attention systems during the oddball task.

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