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BRIEF REPORT

Synchronized network activity as the origin of a P300 component in a facial attractiveness judgment task

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Abstract

Many studies have used the P300 as an index for cognitive processing and neurological/psychiatric disorders. Here, we combined the source separation and source localization methods to investigate the cortical origins of the P300 elicited in a facial attractiveness judgment task. For each participant, we applied second-order blind identification (SOBI) to continuous EEG data to decompose the mixture of brain signals and noise. We then used the equivalent current dipole (ECD) models to estimate the centrality of the SOBI-recovered P300. We found that the ECD models, consisting of dipoles in the frontal and posterior association cortices, account for 96.5 ± 0.5% of variance in the scalp projection of the component. Given that the recovered dipole activities in different brain regions share the same time course with different weights, we conclude that the P300 originates from synchronized activity between anterior and posterior parts of the brain.

Descriptors: ERP, P300, SOBI, Facial attractiveness, Localization

The classical P300 is a positive-going event-related potential (ERP) component, which reaches its maximum at 300 ms (or more) after the presentation of a stimulus. It was first reported in a cue-target task in which participants were uncertain about the modality of the upcoming target (Sutton, Braren, Zubin, & John, 1965). The P300 component is observable in many tasks, such as target detection (Polich, 2007), outcome evaluation (Leng & Zhou, 2010; Wu & Zhou, 2009), and assessment of facial attractiveness (Schacht, Werheid, & Sommer, 2008; Werheid, Schacht, & Sommer, 2007). The P300 component is considered to be a neural signature of cognitive processes, and its variations can be used as markers for neurological and psychiatric disorders (Polich, 2007).

In the electroencephalogram (EEG) literature, the cortical origins of P300 are mainly investigated in studies employing the oddball paradigm or variations thereof (Linden, 2005), leaving a gap in the literature regarding the P300's generation beyond the oddball paradigm. Here, we elicited P300 responses in a task in which participants were first required to judge the attractiveness of a blurred face and then received an unblurred face as feedback for their judgment (Zhang, Li, Qian, & Zhou, 2012). There were two experimental factors: the first factor was attractiveness (attractive vs. unattractive), which referred to the facial attractiveness of feedback faces; the second was consistency (consistent vs. inconsistent), which referred to the attractiveness of feedback faces and whether or not they were consistent with participants' initial judgments of the blurred faces. In the previous study (Zhang et al., 2012), ERPs locked to the feedback faces showed that the P300 was more positive for faces consistent with than for faces inconsistent with the initial judgment, and was more positive for attractive faces than for unattractive ones. There was no interaction between attractiveness and consistency. These results suggested that the P300 can simultaneously encode different attributes of feedback. In the current study, we further investigated the functional significance of the P300 based on both its spatial origins and how it is modulated by experimental factors. We first applied a source separation algorithm to isolate the P300 component; we then used its scalp projection as input for source localization. In particular, we applied the second-order blind identification (SOBI; Belouchrani, Abed-Meraim, Cardoso, & Moulines, 1997) procedure to the continuous EEG data to isolate functionally distinct P300 sources for further investigation of their neuronal generators.

SOBI is a blind source separation algorithm that can be used to decompose scalp EEG signals into a set of putative recovered neuronal sources (i.e., SOBI-recovered components). Recent work has shown that SOBI is effective and robust in separating EEG data into physiologically interpretable components (Lio & Boulinguez,

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2013; Tang, 2010; Tang, Sutherland, & McKinney, 2005). Instead of simply minimizing the instantaneous correlation between recovered sources, SOBI quantifies their relatedness by simultaneously minimizing cross-correlations between all pairs of recovered sources and across all temporal delays (excluding autocorrelations; for details, see Belouchrani et al., 1997; Cardoso & Souloumiac, 1996). In this way, SOBI supports the use of temporal information contained in the EEG time series for source separation. Therefore, SOBI is capable of separating correlated neuronal sources, and a single SOBI component can be recovered when multiple brain regions share very similar time courses of activation through synchronization (Tang, 2010; Tang et al., 2005).

Method

The dataset used here was collected in our previous study (see Zhang et al., 2012, for more details). EEGs from 64 channels were recorded from 16 undergraduate students (eight female) during a facial attractiveness judgment task. EEG data were sampled at d

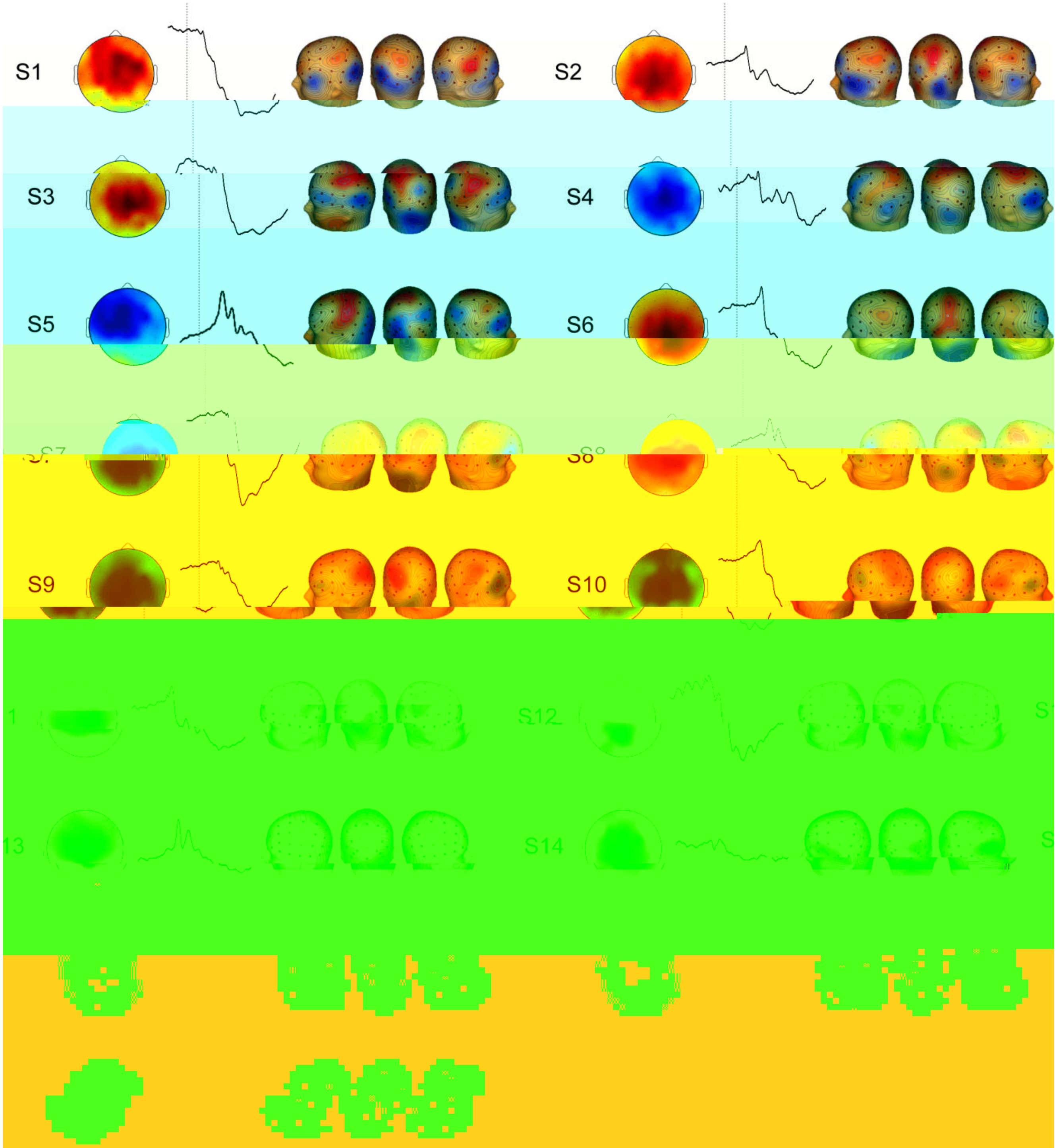

Figure 1. Scalp projection, ERP waveforms, and current source density (CSD) maps of the SOBI-recovered visual P300 component in each of the 16 participants (calbar: 5 μV, 200 ms). Scalp projections and ERP waveforms were the basis of identification for P300 candidates, whereas CSD maps were used in the estimation of dipole pair frequency and their locations. Vertical line indicates the onset of the unblurred face. Gavg = group average across all participants.

components displayed characteristic P300 responses, reflecting a positive-going waveform, which reached its maximum 14.4 ± 1.6 μv at 528 ± 31 ms postonset over participants. Spatially, the scalp projections were consistent with typical distributions of the P300 component, showing frontocentral ($n = 3$), central ($n = 8$), and centroparietal ($n = 5$) distributions.

The ECD models accounted for $96.5 \pm 0.5\%$ ($n = 16$) of the variance in the scalp projections of the SOBI-recovered P300 (Table 1), consisting of dipoles in the frontal (inferior frontal gyrus, $n = 12$; middle frontal gyrus, $n = 5$; superior frontal gyrus, $n = 1$) and posterior association cortices (angular gyrus, $n = 11$; precuneus, $n = 2$, supramarginal gyrus, $n = 1$; inferior temporal gyrus, $n = 1$; superior temporal gyrus, $n = 2$; occipital gyrus, $n = 12$; lingual gyrus, $n = 3$). For each individual, the recovered P300 dipole activities in the frontal and posterior regions shared the same time course with different weights, indicating that these brain regions cooperated via synchronization. In addition, we performed source localization using standardized shrinking LORETA-FOCUSS (SSLOFO), which is representative of the distributed source models. Localization results are similar to those based on ECD models.

Repeated measures ANOVANOVANOVANOVANOVANOVANOV different brain regions shared the same time course of activation, suggesting that these brain regions cooperated via synchronization.

ERP results revealed that it took longer for the P300 to reach its maximum for unattractive faces than for attractive faces and for the inconsistent condition than for the consistent condition. The P300 latency is believed to be a sensitive measure of the time needed to evaluate visual stimuli (Polich, 2007). Compared with unattractive faces, attractive faces may have higher motivational significance and thus may capture attention more easily (Johnston & Oliver-Rodríguez, 1997; Schupp et al., 2000), facilitating attractiveness evaluation in working memory. Moreover, compared with the consistent condition, faces in the inconsistent condition may take a longer time to be encoded in working memory due to the process of conflict resolution. Therefore, it is possible that the frontal-posterior network, which generates the P300 component, supports the working memory operation during the evaluation of facial attractiveness and consistency. This suggestion is in line with a previous study showing that synchronization between frontal and posterior association cortices plays an important role in working memory processing (Sarnthein, Petsche, Pappelsberger, Shaw, & Von Stein, 1998); in working memory processing, relevant information is held and continuously updated in frontal areas, while sensory information is stored in posterior association cortices.

The scalp projections of the P300 component varied across participants. Both individual differences in processing the feedback faces and the unsteadiness of the physical positions of EEG channels on the head could contribute to this variation (Tang, 2010). Importantly, however, there existed a relatively stable configuration of P300 generators across these participants.

In conclusion, the present study found that (a) there exists a functionally distinct visual P300 component in facial attractiveness judgment after source separation; and (b) this P300 originates from synchronized activity between the frontal and posterior association cortices, which may be associated with working memory processes involved in the task.

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