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MULTIPLE DIPOLE SOURCE MODELS FOR SCALP-RECORDED EVENT-RELATED POTENTIALS: EXAMPLE FROM COMPLEX VISUAL PROCESSING IN THE HUMAN BRAIN

Ina M. Tarkka

Electrical activity of the human brain can be recorded on the scalp. One of the advantages of the electrical recordings is the high temporal resolution by which e.g. cognitive processes can be followed from millisecond to millisecond. It is not uncommon to record simultaneously 128 electrode sites with high sampling rate and thus advanced mathematical and statistical methods are needed to sufficiently process the obtained data. Here an example of the analysis of the data recorded during a complex visual processing task is presented. Using advanced methods large amounts of data can be reduced and new information of the function of the human brain can be investigated.

1. Introduction

Multiple dipole source modeling is a non-invasive approach in the analysis of brain electrical recordings. Electrical recordings are made during different types of sensory stimulations or cognitive task performances on the human scalp using electro-encephalograhic technology. The more recording electrodes there are the more spatially detailed data is available for analysis. Here an example of a complex visual task and the source modeling of event-related potentials it elicits is presented. The task of comparing mismatching picture pairs elicits electrical

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brain responses different from those obtained for matching pairs. The phenomena of priming were first described in verbal tasks [1], and later were found also for non-linguistic stimuli [2, 3]. There is no agreement on the anatomical substrates for these processes. There is also evidence for multiple electrical components at the picture and face recognition latencies: N300 and N400 for pictures [3, 4], and N350 and N380 for faces [2]. Apparently, the priming processes may be influenced by the type of visual object. Cerebral responses, elicited by faces, differ from those elicited by other kinds of visual objects [5, 6]. The purpose was to find cerebral sources, which could explain the evoked electrical activity during the recognition and comparison of pairs of familiar faces and abstract patterns.

2. Methods

A total of 18 healthy volunteers participated in the experiment. Each trial began with one of the two cues (S1) followed by consecutive pictures (S2 and S3). Each picture was a photograph of a familiar face on which an abstract dot pattern was superimposed. One cue directed attention to compare faces (Face Task) and another to compare patterns (Pattern Task). EEG was recorded using a 128-channel net (Electrical Geodesics, Inc.). Before source modeling, averaged ERPs were filtered in 0.3-15Hz range. Spatiotemporal multiple dipole source models were created in BESA2000 (Megis Software GmbH), version 4.2, for the window of 80-600 ms from S3 onset. In the spatio-temporal model, the dipole source has a stationary location and orientation, and changes the moment (i.e. its strength) with time. The source waveform (SWF), or source potential, describes the temporal changes of the dipole moment. The residual variance (RV) describes the proportion of the recorded data that is not explained by the model. An ellipsoidal head model with four shells was used. The dipole model was developed first for the grand averaged ERPs, using an 88 mm head radius (mean value of our 18 participants). To determine the number and the starting locations of dipoles, we performed PCA, generated current source density maps, and considered the physiological feasibility of sources. Several models were developed using different strategies; they all converged to the same pattern of source locations, with slight variations. The model with lowest RV and best temporal separation of components in the SWFs was chosen as a base model for further analysis. We started by analyzing the DF data, after that the locations and orientations from DF model were applied to SF, DP, and SP grand average data and to individual data. The SWFs of the individual data were analyzed for every dipole. Grand averages for SWFs of each dipole were generated. The DF-SF and DP-SP conditions were compared using the non-parametric Wilcoxon matched pairs test. Each test procedure used 18 pairs of individual amplitudes (1 pair = 1 participant) at the synchronous time points of source waveforms for the same dipole. The two-tailed 95% probability was used as the significance threshold.

3. Results

The comparison of different faces elicited larger components at 400 ms than did the comparison of matching pairs of faces. The source models were first developed for the Face Task and then applied to Pattern Task data. Dipolar sources were located in the visual cortex, bilaterally in medial temporal and inferotemporal regions, and in the frontal area. The models differed in the temporal dynamics of dipolar strengths, i.e. source waveform configurations. The differences between the SWFs of the Face and Pattern tasks were tested and figure 1. details the differences between the source models explaining the tasks. For both tasks, the residual variances of the source models were about 3% for grand average data and around 10-13% for individual ERPs.

4. Discussion

The models proposed here for the recognition and comparison of visual targets explain about 97% of grand average ERP and about 90% of individual data and show clear temporal and spatial separation of active sources. In Face and Pattern tasks, the activity in the range between 300 and 600 ms was mainly explained by two dipolar sources in the anterior brain areas (anatomically close to anterior cingulum and nucleus caudatus). The match/mismatch differences were seen in the activation patterns of these sources (see figure 1, dipoles 1 and 2). Those differences were found to be task-specific in our experiment. The activity of dipolar sources 1 and 2 in the anterior brain areas showed both match/mismatch and task-specific differences in our experiments. Dipole 1 showed similar temporal behavior in both conditions of Face task; however, it was stronger for DF than for SF condition. Corresponding frontal finding was reported for completing familiar faces with congruous and incongruous parts [2]. In Pattern task, the activity of this dipole had a dynamics similar to that in Face task, but the amplitude was noticeably smaller. Obtained sources in our models estimate the activity which is common for all conditions, like the primary visual processing, and also differential activity seen in secondary processing of different types of objects such as faces or patterns.

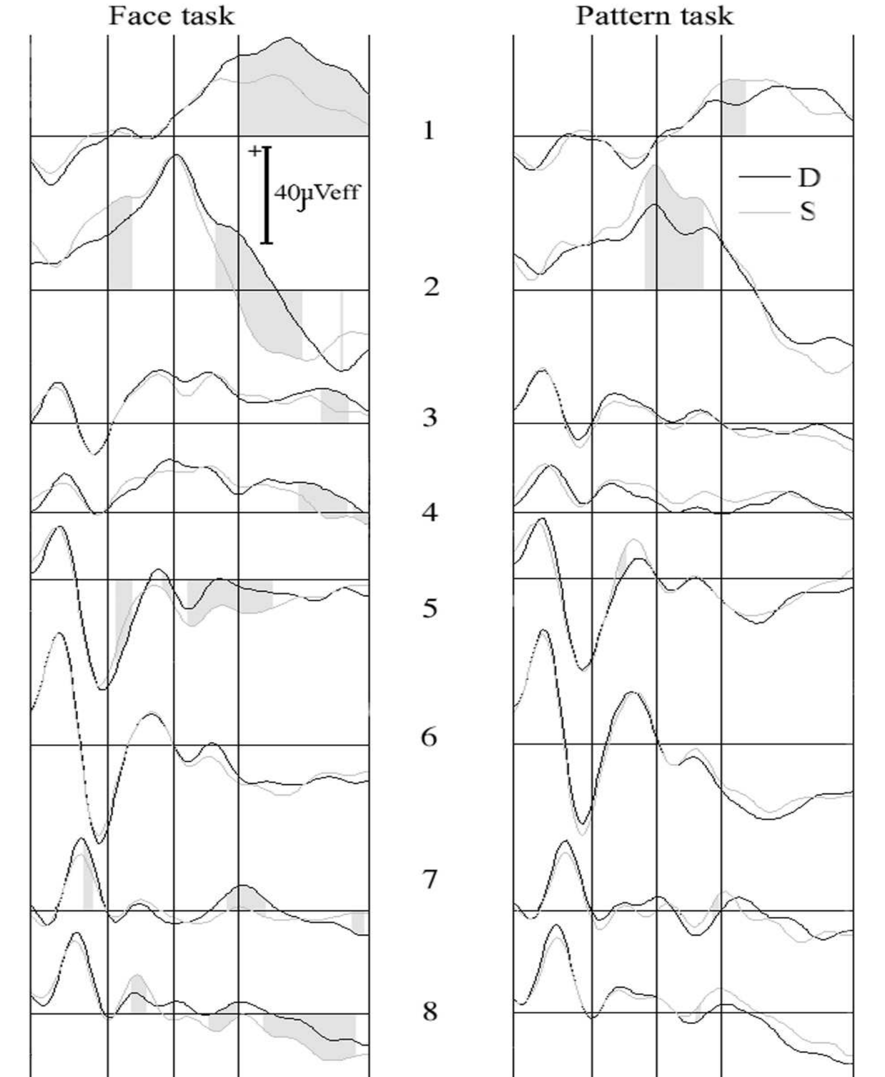

Figure 1: Grand average source waveforms for paired conditions. Numbers from 1 to 8 correspond to the numbers of dipoles, D = different face or pattern, S = same face or pattern. The statistically significant group differences are marked with gray color.

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