Journal of Neuroscience Methods 266 (2016) 137–140

Contents lists available at ScienceDirect

Journal of Neuroscience Methods

journal homepage: www.elsevier.com/locate/jneumeth

Short communication

The face-responsive M170 is modulated by sensor selection: An example of circularity in the analysis of MEG-data

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HIGHLIGHTS

- We studied biased strategies for the identification of face-responsive MEG-sensors.
- M170 amplitudes elicited by either faces of 2 friends or a loved one were analyzed.
- Sensor-selection was based on all (unbiased) or one (biased) of 3 face-categories.
- M170s obtained from the biased selection were increased upon the respective faces.
- Unbiased selection including all face-categories equally revealed no true effect.

ARTICLE INFO

Article history:
Received 26 November 2015
Received in revised form 5 March 2016
Accepted 31 March 2016
Available online 1 April 2016

Keywords:
Circular analysis
Circularity
Selection bias
Face recognition
Magnetoencephalography
M170

ABSTRACT

Background: Magnetoencephalography (MEG) experiments create large data sets obtained from many sensors at different locations. Therefore, a process of sensor-selection prior to hypothesis-driven data analysis is common, e.g., when studying the face-selective M170 component occurring at temporal sites around 170 ms post-stimulus. However, the strategies to identify sensors of interest vary across investigations, and frequently the contrast used for sensor-selection is not independent from the contrast between experimental conditions.
New method: We re-analyzed data from a previously published MEG-experiment where participants viewed faces of either a loved person or two friends. We included different strategies for identifying face-responsive sensors based on all or each one of the face-categories before comparing M170 amplitudes across conditions.
Results: When sensor-selection was based on signal strength elicited by one experimental condition alone, a comparison across face-categories revealed significantly increased M170 amplitudes for the respective face category. Conducting the same analysis following sensor-selection based on averaged activity across all face-categories did not yield different M170 amplitudes.
Comparison with existing method: Whereas this pitfall of selective analysis has been studied and discussed in detail for fMRI methods there is no comparable re-analysis of real EEG/MEG-data.
Conclusions: Our results demonstrate that selection-bias is as relevant for EEG/MEG analysis as for fMRI methods. Sensor-selection must be independent from the contrast analyzed with statistical comparisons, because otherwise a distorted or 'circular' analysis might result.

1. Introduction

Given the large quantity of multivariate data provided by methods such as functional magnetic resonance imaging (fMRI), multi-array electroencephalography (EEG) or magnetoencephalography (MEG), selective data analysis is often necessary to study signals of interest. For instance, in MEG studies on face processing the analysis of event-related fields (ERFs) within sensor-space such as the face-selective M170 is typically restricted to regionally

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http://dx.doi.org/10.1016/j.jneumeth.2016.03.022
0165-0270/

arranged clusters of sensors. These sensors of interest can be identified making use of previous research using different methodologies suggesting a consistent topography and chronology of activations by face stimuli occurring between 140–200 ms in posterior and lateral sensors over occipital and temporal areas (for review see Eimer, 2011). However, if sensor-selection is not only based on physiological or anatomical assumptions a phenomenon termed 'circular analysis' (Kriegeskorte et al., 2009) might lead to distorted and eventually flawed results. This problem would for example arise when the comparison of M170 amplitudes elicited by different types of faces were based on the averaged signal strength for only one of the face-categories. This can be verified by comparing the contrasts used for selection and analysis as vectors, which should be orthogonal to each other (i.e., their inner product is zero) to yield an independent analysis (given that presentation times, experimental design, etc. are matched between conditions). An example of this can be found in the article by Kriegeskorte et al. (2009, p. 536; see also the supplementary discussion in the online version of the article): the responses to two stimulus-categories are equally used for sensor-selection (contrast $A+B$) before statistical comparison between both stimuli (contrast $A-B$); $\boldsymbol{c}_{\text{selection}}$ $[1\,1]^T \times \boldsymbol{c}_{\text{test}}$ $[1\,-1]^T = 0$.

Although the issue of circularity is not confined to a particular methodology such as fMRI but is instead relevant whenever data analysis is selective (Vul and Pashler, 2012), most of the articles on this topic concentrate almost exclusively on neuroimaging techniques (e.g., Kriegeskorte et al., 2010; Vul et al., 2009). Specifically, the extent of distortions caused by a non-independent analysis of fMRI data has been demonstrated by means of comparing artificial and realistic data as well as conducting parallel or repeated analyses (Baker et al., 2007; Kriegeskorte et al., 2009; Poldrack and Mumford, 2009; Vul et al., 2009). On the contrary, only one article concerned with the topic of selection bias in EEG and MEG data analysis has demonstrated that selection based on signal strength massively increased the type-1 error in artificial, pure noise data (Kilner, 2013). Whereas there is no doubt about the relevance of the topic for electrophysiological methods, there is an apparent lack of concrete examples and, possibly awareness of the problem. Therefore, we conducted a simplified re-analysis of MEG-data from a previously published experiment on processing of personally familiar and loved faces (Tiedt et al., 2014, 2013), adopting two different (independent compared to circular) sensor-selection strategies. Aim of the current analysis was to illustrate how sensor selection 'favoring' each one of three face categories for the analysis of the M170 component might not only distort the results but lead to statistically significant results.

2. Materials and methods

2.1. Participants and experimental procedure

We analyzed data from 28 healthy subjects (mean age 25.5 years, range 20–35 years; 14 female, two were left-handed). All participants viewed photographs of three opposite-sex faces of their romantic partner as well as another two close friends for six seconds. Pictures (size 100 × 100 pixels; viewing angle 11.5°) were in color and showed only the faces of the depicted persons. Stimuli from each category were presented 30 times in randomized order with variable inter-stimulus intervals. Participants were instructed to recall a positive, non-erotic emotional memory of a situation with the depicted person during face presentation. MEG-recordings were conducted using a whole-head device with 93 channels (ET160; Eagle Technology Inc.) in an acoustically and magnetically shielded room; sensors were first-order axial gradiometers with a baseline of 5 cm. Further details about the experiment can be taken from Tiedt et al. (2013, 2014). The study was approved by the institutional ethics review committee and conducted in accordance with the Declaration of Helsinki; all participants provided their informed written consent.

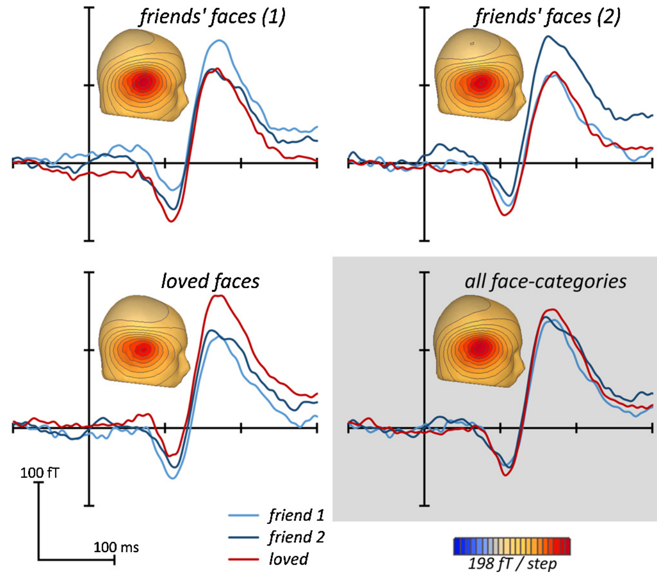

Fig. 1. Impact of sensor-selection on M170 amplitudes.
Grand-averaged ERFs across all participants ($n=28$) showing the M170 obtained from sensors (three per individual) selected by signal strength between 140–200 ms post-stimulus. In the non-circular condition (highlighted in grey), sensor-selection was based on the averaged signal across all face-presentations. In the circular conditions, this was based on activity in response upon each one of the three face-categories (as indicated). Topographic maps of activity 140–200 ms (grand-average) are shown as insets for the respective face-category or average across categories, respectively. The outward-going magnetic flux (positive polarity) is depicted in red with steps as indicated. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

2.2. Data analysis

MEG-data was analyzed using the software BESA® (*Brain Electrical Source Analysis*; BESA GmbH, Germany). Pre-processing steps included low and high cut-off filtering (0.1 Hz, 12 dB/oct; 20 Hz, 12 dB/oct; 50 Hz Notch) and artifact rejection including independent component analysis (ICA). The baseline included 300 ms preceding stimulus presentations, resulting in epochs of 6300 ms. Based on previous research as well as inspection of grand-averaged topographic maps in the respective time-window, we expected a positive polarity (indicating an outward-going magnetic flux) of the M170 over the right hemisphere. Out of all 93 channels, three regionally arranged sensors were selected per signal strength between 140–200 ms (M/N170 time-window) in each participant. We restricted the analysis to the right hemisphere by exclusively selecting positive values. In the 'non-circular' condition, selection was based on the averaged activity across all three face-categories, resulting in the contrast $\boldsymbol{c}_{\text{selection-1}}$ $[1\,1\,1]^T$. In the 'circular' condition, signal strength elicited by only one of the three face-categories (i.e., loved faces, two friends' faces) in this time-window was used for sensor-selection; accordingly these selection contrasts can be given as $\boldsymbol{c}_{\text{selection-2}}$ $[1\,0\,0]^T$, $\boldsymbol{c}_{\text{selection-3}}$ $[0\,1\,0]^T$, $\boldsymbol{c}_{\text{selection-4}}$ $[0\,0\,1]^T$. The peak-amplitudes of the M170 obtained from both the circular and non-circular conditions were then entered into repeated measures analyses of variance (ANOVA). If applicable, we used Greenhouse–Geisser corrected degrees of freedom (df) for violations of the sphericity assumption. Post-hoc comparisons between face-categories and analysis conditions were made by using paired-samples t-tests; significance criterion for all tests was $p<0.05$