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Removal of artifacts contaminated records from MEG records using a mixture of factor analyzers

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1 Introduction

Contamination of magnetoencephalogram (MEG) records by various artifacts seriously influences the estimation accuracy of magnetic sources. Although some methods have been proposed to reject contaminated records [1][2], most of them are ineffective when artifacts models are not available. In this study, we proposed to classify MEG records into contaminated records and others by mixture of factor analyzers (MFA). MFA provides a classification method which groups records into classes which are described by the model of factor analysis[3]. It is known that MFA is superior to conventional methods in its discrimination ability in a noisy environment [4]. It should be ideal in the classification of evoked responses on which large spontaneous waves are superimposed.We applied the proposed method to visual evoked fields (VEF) records.

2 Classification method

MFA provides a classification method which groups records into classes which are described by the model of factor analysis [3]. The data generation model of factor analysis is written:

$$\boldsymbol{x} = \boldsymbol{\Lambda z} + \boldsymbol{u} \tag{1}$$

$\boldsymbol{x}$ is Dx1 observed data, $\boldsymbol{\Lambda}$ is a DxK factor loading matrix, $\boldsymbol{u}$ is Gaussian noise according to $N(0, \boldsymbol{\Psi})$ which is called the unique factor, where $\boldsymbol{\Psi}$ is a diagonal matrix. $\boldsymbol{z}$ is a Kx1 matrix, called the common factor. It is assumed to be $N(0, \boldsymbol{I})$. We can write the data generation model of mixture of factor analyzers as follows:

$$\begin{aligned} f(\boldsymbol{x}) &= \sum_{j=1}^{M} \left\{ \mathrm{P}(w_j) \int f(\boldsymbol{x} \mid \boldsymbol{z}, w_j) f(\boldsymbol{z} \mid w_j) d\boldsymbol{z} \right\} \\ f(\boldsymbol{x} \mid \boldsymbol{z}, w_j) &= N(\boldsymbol{\mu}_j + \boldsymbol{\Lambda}_j \boldsymbol{z}, \boldsymbol{\Psi}) \\ \pi_i &= \mathrm{P}(w_j) \end{aligned} \tag{2}$$

where $\boldsymbol{\mu}_j$ is the average value of $\boldsymbol{x}$ for sub-model j. w_j is an event where data is generated by sub-model j. The learning algorithm of mixture of factor analyzers, which yields iteratively maximum likelihood estimators of $\boldsymbol{\pi}, \boldsymbol{\mu}, \boldsymbol{\Lambda}$ and $\boldsymbol{\Psi}$, is derived by using an EM algorithm as well as that of a Gaussian mixture model.

3 Classification of visual evoked fields

3.1 Measurements of visual evoked responses

We measured VEF elicited by luminance onset stimuli (120 trials) using a 64 channel MEG system (CTF, Inc.). Each signal channel was filtered with a low-pass filter (40 Hz). Initial noise reduction was performed using software provided by CTF. The simple average of VEF had the first remarkable peak at a latency of 75 [ms]. Figure 1 shows its topography ($\boldsymbol{\mu}_a$). Magnetic sources were estimated in the bilateral occipital lobe. The estimation error was 27 %. This component was presumed to be evoked by visual stimuli. However the large error suggested some records were contaminated. In fact, we confirmed that some records were contaminated by extraneous eye movement artifacts.

3.2 Classification of MEG records

We classified the VEF records at latency of 75 and 78 [ms] into four classes using MFA with K=3 and M=4. We repeated the analysis ten times using different initial values. After MFA, we estimated the magnetic sources for a gravity center of each class using the equicurrent dipole method for evaluating the analysis results. In many cases, the class with the smallest estimation error among classes of each analysis, whose magnetic sources were located in the bilateral occipital lobe, was presumed to model visual evoked responses. Figure 2 shows the estimation error of the simple average and that of the class with the smallest estimation error among classes of MFA for the five best results. The MFA are clearly superior to the simple average in the estimation error.

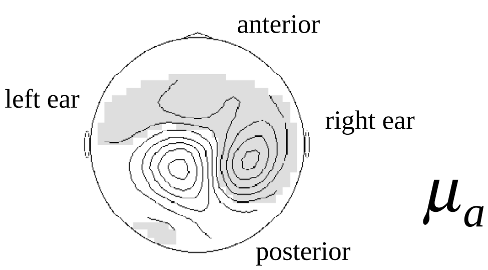

Figure 1: The isocontour map of the averaged data. White areas indicate a source of magnetic flux. Gray areas indicate a sink of magnetic flux. One contour line equals 10 fT.

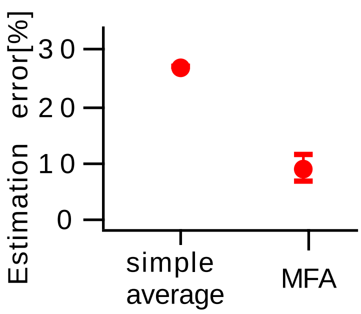

Figure 2: The estimation errors of magnetic sources. Horizontal bars indicate maximum and minimum values.

3.3 Meaning of MFA parameters

In this section, we examined the MFA parameters and checked validity of the classification results. Figure 3 shows an example of acquired MFA parameters. The average of class 1 ($\boldsymbol{\mu}_1$) had similar topography to the simple average ($\boldsymbol{\mu}_a$). Its magnetic sources were located in the bilateral occipital lobe. The estimation error was only 11%, which was much less than that of the simple average. The average of class 2 and 3 ($\boldsymbol{\mu}_2$ and $\boldsymbol{\mu}_3$), showed different topography from the simple average. These waves presumably reflect spontaneous waves, because their topography is similar to that seen in a single trial record for this subject, without regard to latency. The average of class 4($\boldsymbol{\mu}_4$), showed large activity in the anterior area, which seems to be caused by eye movements. These results suggested MFA classified VEF records into artifacts contaminated records, records which contained mainly spontaneous waves, and records which contained mainly evoked responses.

Other MFA model parameters also supported that MFA worked effectively. The variance of the common factor had a peak value in the anterior area. This seemed to reflect artifacts such as eye movements. Factor loading was only shown for the fourth class. Here we denote the factor loading of class 4 as $\boldsymbol{\Lambda}_4 = \{\boldsymbol{\Lambda}_{41} \quad \boldsymbol{\Lambda}_{42} \quad \boldsymbol{\Lambda}_{43}\}$. $\boldsymbol{\Lambda}_{41}$ and $\boldsymbol{\Lambda}_{42}$ have symmetrical topography. This is very plausible because many brain activities and eye movement artifacts have symmetrical structure. $\boldsymbol{\Lambda}_{43}$ was supposed to reflect spontaneous waves as well as $\boldsymbol{\mu}_2$ and $\boldsymbol{\mu}_3$.

4 Conclusion

The estimation error of class 4 ($\boldsymbol{\mu}_4$) was much less than that of the simple average. This suggested MFA grouped VEF records into artifacts contaminated records, records which contained mainly spontaneous waves, and records which contained mainly evoked responses. The proposed method could be useful in analyses of various evoked responses and event related activities.

References

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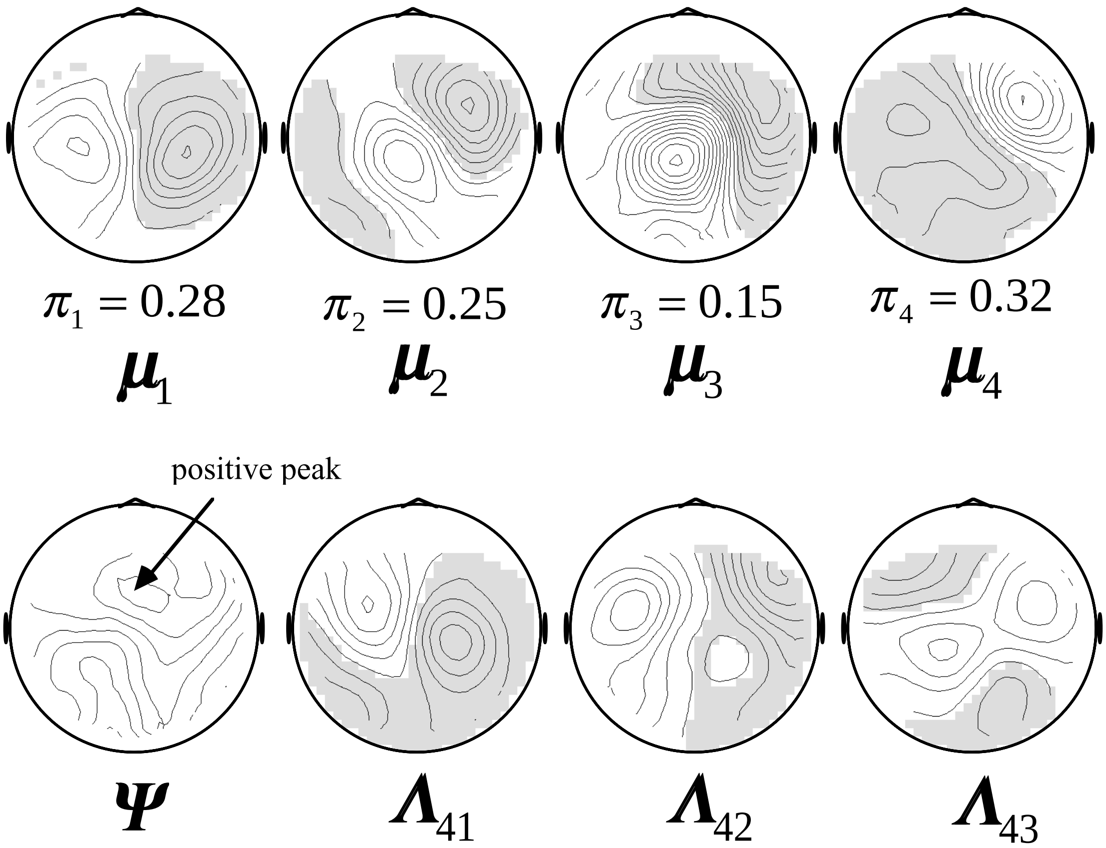

Figure 3: The isocontour map of the averaged data. White areas indicate a source of magnetic flux. Gray areas indicate a sink of magnetic flux. One contour line equals 20 fT.