SOBI WITH ROBUST ORTHOGONALIZATION TO REMOVE THE ARTEFACT STIMULUS IN EVOKED POTENTIAL
5Hz Current Sinusoidal Stimulus

Eduardo de Queiroz Braga, Carlos Julio Tierra-Criollo
Department of Electrical Engineering, UFMG,Av. Presidente Antônio Carlos 6627,Belo Horizonte,Brasil

Gilberto Mastrocola Manzano
Clinical Neurophysiology Laboratory , UNIFESP, São Paulo, Brasil

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Abstract: The psychophysical evaluation of the sensibility of the thin and thick fibers with sinusoidal current stimulation was proposed in the 80s. After that, researches observed that 5 Hz stimulus would be related to the thin unmyelinated fiber. This work aims a quantitative analysis of the cerebral cortex response to 5 Hz stimulus, through the identification of the latency components of the evoked potential (EP) that were estimated by the coherent mean after remove the stimulus artefact by using the Independent Component Analysis. Electroencephalography (EEG) signals were collected at Cz electrode (10-20 International Standard System) of 5 volunteers. The EP estimated with 5 Hz stimulus using the Second Order Blind Identification associated with Robust Orthogonalization (SOBI-RO) associated with the coherent mean presented the following components: $N_1 = 104$ ms (one volunteer), $P_1 = 179$ ms (four volunteers) and $N_2 = 234$ ms (three volunteers), $P_2 = 280$ ms (three volunteers) and $N_3 = 493$ ms (all volunteers). The SOBI-RO techniques can be a very useful tool in artefacts and noise reduction on the EP estimation.

1 INTRODUCTION

Our knowledge about the world is built over different sensations. The perceptions begin at receptors cells and are transmitted to the central nervous system through primary afferents fibers .In the somatic system, these fibers have different diameters and transmit different sensations to the spinal cord: thin fibers transmit pain and temperature, and thick fibers transmit the sense of touch. An instrument of psychophysical sensibility evaluation, proposed in the 80's, is based on the principle that activation of different diameters fibers depends on frequency of sinusoidal currents: 5 Hz to non-myelinic fibers (Masson et al., 1989; Ro et al., 1989), 250 Hz to thin myelinic fibers and 2 kHz to thick myelinic fibers.

The evoked potential (EP) by electric stimulus can be obtained using the coherent mean (Misulis, 1994; Regan, 1989). When a sinusoidal current of 5 Hz is used to stimulate, a strong level of artefact in this frequency is collected in the EEG electrodes. The 5 Hz artefact damage the EP and the extraction of this artefact (synchronised to the stimulus) is very difficult because of is into EP frequencies. In this case, alternative tools can be used. In this context, the use of statistics tools can help us. The Second Order Blind Identification associated with Robust Orthogonalization -SOBI-RO (Belouchrani et al., 1997; Belouchrani and Cichocki, 2000) can be a useful technique where the stimulus artefact is presented in the same frequency band of the EP. It can be applied in EEG electrodes that are spatially located in the scalp where each electrode is considered like a linear mixture of blind brain sources.

In the present work, the SOBI-RO was used to detect and remove independent components associated with the artefact and rhythm that difficult the analysis on Cz channel. The reconstructed signals would present the epochs without the artefacts, and then, the ERP could be better identified using the coherent mean.

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2 MATERIALS AND METHODS

The EEG signals were collected in 5 normal volunteers with closed eyes, without neurological disease or medication. The experimental protocol was performed in the Clinical Neurophysiology laboratory on UNIFESP and was approved by the Local Ethic's Committee. The electrodes of stimulation (10mm diameter gold electrodes) were placed in the medial and lateral surfaces of the distal phalanx, of the second finger of the left hand with a thin amount of conductive gel. The 5 Hz sinusoidal current stimulus with twice the sensibility threshold was applied by the Neurometer Current Perception Threshold (CPT)-USA. The Electroencephalogram (EEG) signals were collected in the Cz channel and the reference was A1+A2 (connected ear). In addition, the stimulus signals were collected on left wristband (Pi). These signals were used for synchronization of the epochs. Six sessions with one hundred of epochs (20s each, followed by 10s without stimulation) were recorded with a sample rate of 500 Hz by the NeuroScan SymAmpsTM – USA. In each epoch were extracted two seconds before and six after the stimulus where it expects to find the EP. The 100 epochs of 8 seconds were applied in the SOBI-RO algorithm labelled *ICALAB* 2.5 for *MATLAB* (ICALAB 2004).

2.1 The SOBI-RO

The SOBI-RO (*Second Order Blind Identification with Robust Orthogonalization*) is a statistic tool of ICA (*Independent Component Analysis*). This tool considers the measured signals like a linear combination of unknown sources (Hyvrinen et al, 2001). In this context, the epochs **x** can be expressed like:

$$\begin{aligned} x_1(t) &= a_{11}s_1(t) + \ldots + a_{1n}s_n(t) \\ x_2(t) &= a_{21}s_1(t) + \ldots + a_{2n}s_n(t) \\ &\vdots \\ x_m(t) &= a_{m1}s_1(t) + \ldots + a_{mn}s_n(t) \end{aligned} \quad (1)$$

Or can be represented as:

$$\mathbf{x} = \mathbf{A.s} \quad (2)$$

Where **X** is the epochs collected in Cz channel and synchronized whit the stimulus. **A** is an unknown mixing matrix that make the data **x** a linear combination of the unknown sources **s.**

A pre step in the ICA is the *Whitening*. It is used to represent the data in a new space, where the signals are decorrelated with exhaustion. Belorachrin and Cichocki (2000) presented a robust technique applied in the whitening process called Robust Orthogonalization that can give us a better estimation of the coefficients of the whitening matrix **W**.

In the Robust Whitening, a set of covariance matrices of **x** at different lags is used to estimate the *whitening* matrix:

$$\mathbf{R}_x(\tau) = \mathrm{E}[\mathrm{x(t).x}^*(\mathrm{t} - \tau)] = \mathbf{A}\mathbf{R}_S(\tau)\mathbf{A}^H \quad (3)$$

Where $\tau = 1,\ldots,K$

The method uses an optimization algorithm that estimate a linear combination of evaluated covariance's matrices R_X:

$$\mathbf{C} = \sum_{\tau=1}^{K} \alpha_\tau \hat{\mathbf{R}}_X(\tau) \quad (4)$$

The eigen value decomposition (EVD) of C is performed:

$$\mathbf{C} = \mathbf{U}_C\, diag[\lambda_1^2,\ldots,\lambda_n^2]\mathbf{U}_C^T \quad (5)$$

And the whitening matrix is:

$$\mathbf{Z} = diag[\lambda_1,\ldots,\lambda_n]^{-1}\mathbf{U}_C^T \quad (6)$$

The whitened data **z** is expressed like:

$$\mathbf{Z} = \mathbf{W}.\mathbf{x} = \mathbf{W}.\mathbf{A}.\mathbf{x} \quad (7)$$

W.A is a unitary matrix **U**. In this context, the objective of SOBI is to discover this matrix **U**. For this, a cost function called *join diagonalyzer* -JD (Belouchrani et al., 1997) is used. For that, a set of covariance matrices of the data **z** is taken at different lags:

$$\hat{\mathbf{R}}_\mathbf{Z}(\tau) = \hat{\mathbf{W}}\hat{\mathbf{R}}_\mathbf{X}(\tau)\hat{\mathbf{W}}^T \quad (8)$$

Using second order information for theses matrices it is possible to find the matrix **U** by an optimization method of search.

Then, the mixing matrix A and the sources can be estimated by:

$$\hat{\mathbf{A}} = \hat{\mathbf{W}}^\#\hat{\mathbf{U}} \quad (9)$$

$$\hat{\mathbf{s}}(t) = \hat{\mathbf{U}}^H\hat{\mathbf{W}}\mathbf{x}(t) \quad (10)$$

where # is a pseudo-inverse matrix and H is a Hermitian matrix.

2.2 Application of SOBI-RO

After the SOBI-RO detection, the independent components passed by a visual inspection, and the components related with the 5Hz stimulus were deselected. The new epochs were reconstructed and the coherent mean applied. But in this average, the alpha rhythm was strongly present. Thus, in a second approach, the SOBI-RO was applied to remove frequency components of 8-10Hz that can be associated with spontaneous EEG.

3 RESULTS

The EP for volunteer #1, obtained with the original EEG signal at Cz channel (Figure 1a), presents high level of the 5 Hz artefact that difficult the analysis. After removing this 5 Hz artefact with SOBI-RO, the EP can be seen most clearly in the Figure 1b. The power spectral density (PSD) shows the attenuation of the 5 Hz frequency and odd harmonics of 5 Hz (Figure 2).

A rhythm into 8-10Hz frequencies is also presented, but before and after stimulation (Figure 1.b). The new EP shows the attenuation of this band (Figure 2a and 2b). The components identified in this EP (Figure 3, Table 1) were: $P_1 = 188$ ms, N_1=234 ms, $P_2 = 268$ ms and $N_2 = 441$ ms. The grand-average of the five volunteers EP's presented components at $N_1 = 109$ ms, $P_1 = 200$ ms, $N_2 = 230$ ms, $P_2 = 279$ ms and $N_3 = 441$ ms (Table 1).

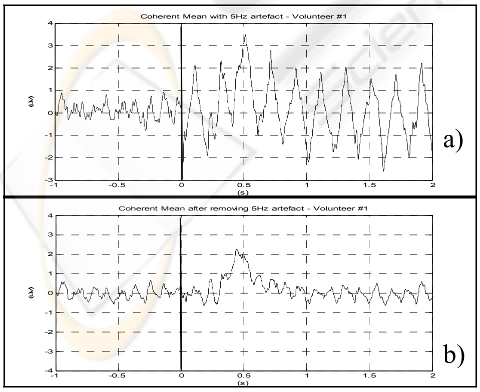
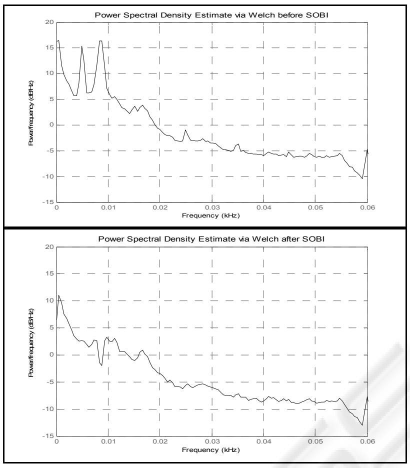


Figure 1: EP of Cz channel (volunteer #1), (a) before and (b) after SOBI-RO removing 5Hz component. Time 0 s represents the beginning of the stimulation.



a)

b)

Figure 2: PSD of EEG signals (volunteer #1) (a) before and (b) after SOBI-RO.

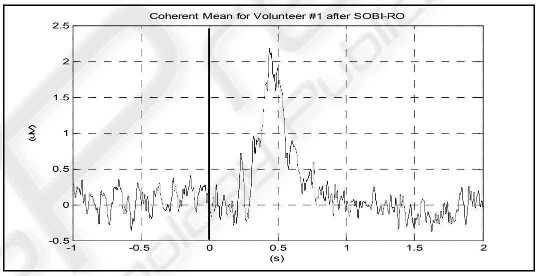


Figure 3: The EP after removing the artefact and 8-10Hz related IC's.

4 DISCUSSIONS

During the process to remove the 5Hz artifact with SOBI-RO, the IC that represents this frequency was clearly identified and removed. We can see in the PSD (Figure 2) that the 5Hz stimulus artifact and odd harmonics were completely removed. This shows that the SOBI-RO was efficient in this step. However, on the process for identifying of IC's related to the 8-10Hz band (possibly, associated with the spontaneous alpha rhythm during closed eyes) was more difficult. For each volunteer, ten or more IC's related with this band were founded. Some IC's showed a variation of the amplitude with the stimulus .This fact does doubtful their removals and suggests the necessity of a better method of detection based on the statistical information of the IC's. In this work, the procedure was repeated ten times (using 70 epochs randomly selected each time) for evaluating the experimenter bias (due the visual selection of the IC's). The results were similar in all cases.

The EP identification was only possible after SOBI-RO pre-processing. The N_1 component was only identified in the EP of volunteer #2. This component will be confirmed in future researches, with more experiments. In the other hand, the components P_1, N_2 and P_2 were present in a great number of volunteers. All volunteers presented the N_3 component (between 441ms and 604 ms). The grand average also shows the N_1, P_1, N_2, P_1 e N_3 components (Table 1).

Table 1: Components of the EP of five volunteers and Grand Average after applying SOBI-RO.

Volunteer	N_1 (ms)	P_1 (ms)	N_2 (ms)	P_2 (ms)	N_3 (ms)
#1	-	188	234	268	441
#2	104	206	-	-	424
#3	-	139	237	283	562
#4	-	181	230	290	434
#5	-	-	-	-	604
Mean	104	179	234	280	493
Standard deviation	-	28	4	11	84
Grand Average					
	109	200	230	279	441

5 CONCLUSIONS

This work presented a useful application of SOBI-RO with the objective of removing the 5 Hz sinusoidal current artefact and spontaneous activity in the 8-10 Hz band. The conventional filtering can not remove theses frequency bands without remove information of the EP.

Research with SOBI-RO can be very useful in signals where the artefact stimulus frequency is in the same band of the EP.

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