Validation of SOBI-DANS method for automatic identification of horizontal and vertical eye movement components from EEG

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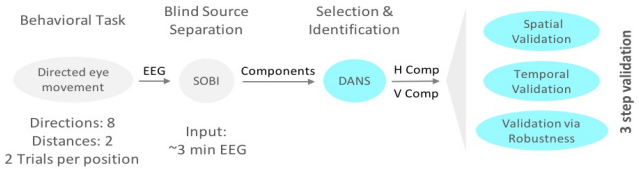
INTRODUCTION

Human perception, action, and cognition takes place in the context of natural eye movement. Yet, neurophysiological investigation of these neural processes are hindered by the presence of large amplitude artifacts associated with eye movement. One of the most popular methods for addressing this issue has been the use of blind source separation (BSS) including independent component analysis (ICA), to separate and enable the removal of ocular artifact from EEG.

Here we introduce a Discriminant ANd Similarity (DANS) algorithm to automatically identify two ocular artifact components from second-order blind identification (SOBI), a BSS algorithm previously used for artifact removal (Joyce et al., 2004) and for extracting neuronal sources during free eye movement (Tang et al., 2006). We demonstrate improved success rates over best work in the literature that does not use a co-registered eye tracker (95% matching human experts in Mognon et al., 2011) and provide the previously missing quantitative validation (Mannon et al., 2018 review) for the ocular origin of the identified SOBI components that code separately for horizontal and vertical eye movement.

METHODS

Study Flow Chart

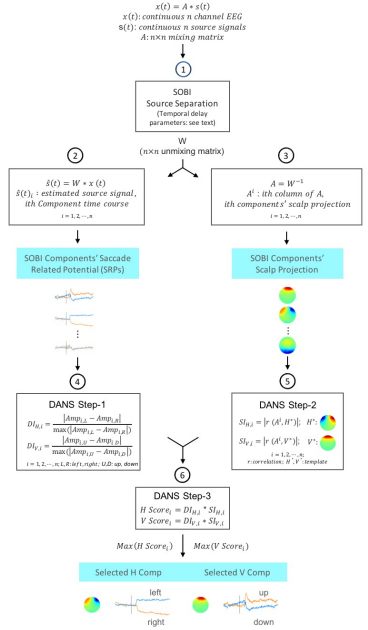


Data Acquisition and Processing

- 64-channel ANT EEGOTMMylab system (500Hz sampling rate, 50 Hz notch filtered)
- SOBI applied to continuous un-epoched data
- Saccade related potentials (SRPs) triggered on target onset were computed
- Scalp projection of each SOBI component generated and modeled by ECDs

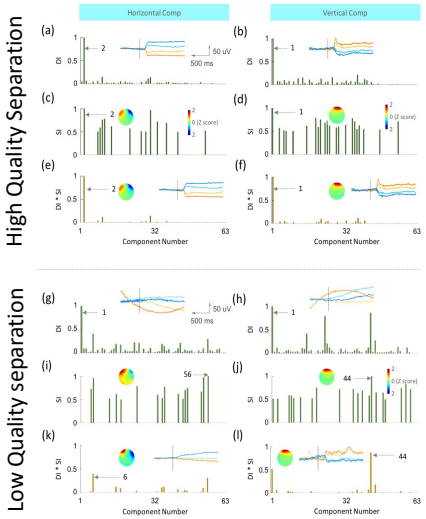
Automatic selection by DANS

- Temporal discriminability of the saccade-related potential (SRP), quantified by a **discriminant index (DI,** DANS step 1). Spatial similarity of a component's scalp projection to that of an ocular artifact component, quantified by a **similarity index (SI,** DANS step 2). Maximum of DI*SI gives the selected horizontal (H) or vertical (V) Comps (DANS step 3).
- Performance on identification of SOBI components coding for horizontal and vertical eye movement was measured by % of participants in which H and V Comps were found and the % of agreement with 4 human experts' selections.



RESULTS

DANS Identification of H and V Comps



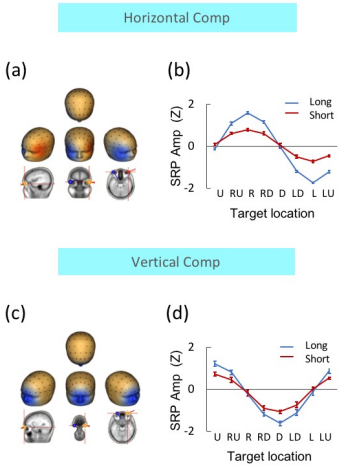
Left (a-f): participant with high quality separation; g-l: participant with low quality separation. Both DI and SI are needed to correctly identify the H and V Comps in case of low quality separation (k & l).

SOBI-DANS extracted and identified an H and V Comp in 100% of participants. Selections were in 100% agreement with two human experts.

Right Spatial validation (a & c): (1) goodness of fit values > 96%; (2) highly reliable identification across individuals (data not shown).

Temporal validation (b & d): (1) SRP amplitude significantly modulated by direction and distance; (2) significant interaction effect at the level of individual participants (data not shown).

Spatial and Temporal Validation



U-up, R-right,, D-down, L-left

DISCUSSION

The combination of SOBI blind source separation and DANS automatic selection achieved identification of components coding for horizontal and vertical saccadic eye movement in 100% of participants. Furthermore, the identified H and V Comps are in 100% agreement with those selected after visual inspection by four trained human experts.

Individual level *spatial validation* of the H and V Comps by the goodness of fit of ECD modeling sets the upper limit (H Comp: 96% ± 0.6%; V Comp: 98% ± 0.6%) for neural signals that may remain unmixed, offering a quantitative evaluation of the ocular origin of the H and V Comps. Individual level *temporal validation* of the H and V Comps by the ANOVA interaction effects (DIR by DIS) shows large effect sizes (η_p^2 for H Comp: 0.94 ± 0.02; V Comp: 0.84 ± 0.02), suggesting clear tuning of the SRP amplitude by saccade direction and distance.

These findings indicate that the ocular artifacts extracted by SOBI-DANS actually contain rather precise information about saccadic eye movement and the generators of these components' activity are mostly (> 96%) ocular in origin. This study offers a starting point for constructing an EEG-based virtual eye tracker and investigating, in an unitary process, neural mechanisms underlying human cognitive functions in the natural context of free eye movement.

We thank G.F Wong, PKY. Chan, SW. Yan, L. Pei, A.J. PrivItera, and Dr. JY. Liu for their assistance.