Tracking horizontal eye movement via ocular components extracted from EEG by second-order blind identification (SOBI)

Rui Sun[1], Cynthia Chan[2], Janet Hsiao[2], Akaysha C. Tang[1,3**]

[1.] The Laboratory of Neuroscience for Education, Faculty of Education, the University of Hong Kong [2.] Department of Psychology, the University of Hong Kong [3.] The MIND Research Network, Albuquerque, NM, USA

INTRODUCTION

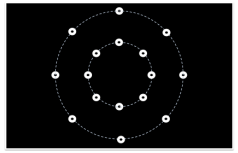
Ocular artifact in EEG has long been viewed as a problem for interpreting EEG data in basic and applied research (Mannan et al., *IEEE Access*, 2018). Blind source separation (BSS), particularly second-order blind identification (SOBI), has been used to extract ocular artifact components (Joyce et al., *Psychophysiology*, 2004). Attempts have been made to make use EEG data to track gaze position (Joyce et al., *Psychophysiology*, 2002)

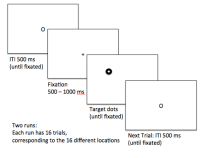
Companion poster (G182, Sun et al., CNS, 2020) showed that two components (Comps), recovered by SOBI, can code horizontal (H) and vertical (V) saccadic eye movements. Here we attempt to use these SOBI derived H and V Comps alone to construct a model to predict horizontal gaze positions in the context of a directed eye movement task. We aim to answer two questions: (1) how much data will be needed to calibrate the model to produce asymptotic performance in prediction? (2) What is the asymptotic level of performance of our virtual eye tracker?

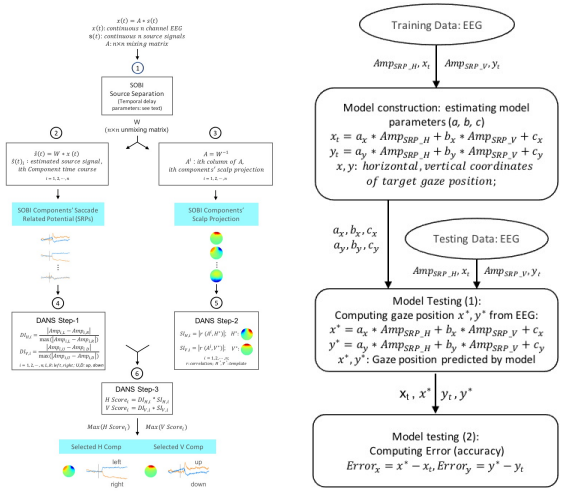
METHODS

Data Acquisition

- Single-subject performing directed eye movement to targets in 10 blocks of 16 trials
- Stimuli per block: dots on 17.5-inch monitor with a screen resolution of 1280x720 pixels in 8 directions and 2 distance of 12.2° and 6.1° of visual angle
- Eye tracking data by SMI REDn eye tracker (60Hz) co-registered with EEG.
- EEG data (64-chan ANT EEGOTMMylab system) collected at 500Hz







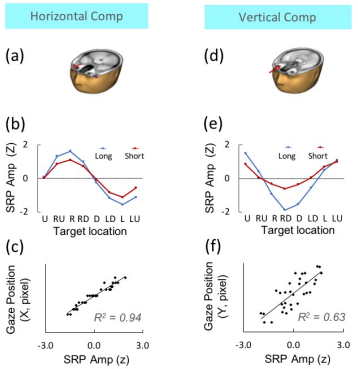
Data processing flowcharts

- Using SOBI blind source separation to derive unmixing matrix W from different amounts of continuous EEG data. W_i: W derived using data from $Block_1$ to $Block_i$ (i=1,2, 9)
- DANS to identify one pair of H and V Comps from each W_i
- Model Construction using training dataset: M_i—model constructed using training data from BK_1 to BK_i
- Fitting linear regression model of gaze position as a function of saccade related potential (SRP) response of H and V Comps in training data
- Using the model parameters obtained above to predict gaze positions using testing dataset: BK_{i+1} to BK_{10} (i=1,2, 9)
- Performance measured against target locations (x_t, y_t)

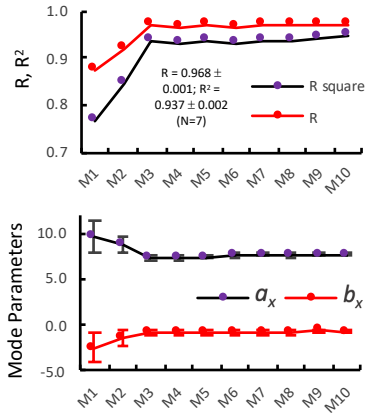
RESULTS

1. H & V Comps examples:

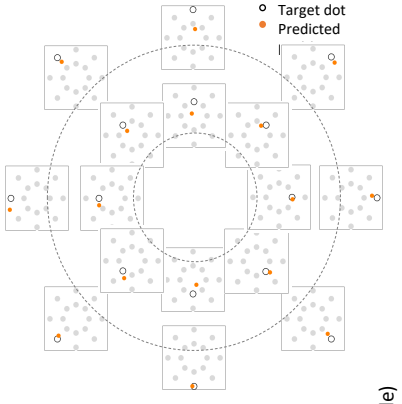
- Dipole locations are consistent with an ocular origin.
- SRP amplitude is tuned by direction and distance.
- SRP amplitude is highly correlated with gaze position.



2. Model performance on training data

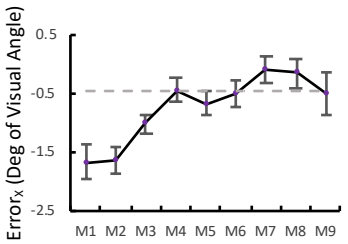


3. Model performance on testing data



- SOBI-DANS performance: an example
- Testing data from Block 6
- Predictions made by M4
- Errors in vertical dimension are bigger
- Only error in the horizontal dimension is further analyzed in this work

Asymptotic performance reached with a minimum of 4 blocks of data: accuracy 0.44 ± 0.10 degree of visual angle (*N*=318) corresponding to an accuracy of 3 mm at a 40 cm reading distance and 3 cm at a 4 meter recommended distance for watching a 32" TV.



Summary

We successfully constructed models from EEG data that predict gaze position in the horizontal dimension with a high level of accuracy.

Our preliminary results raise the possibility of transforming ocular artifacts into predictive signals for tracking eye movement.

The SOBI-DANS method may enable the investigation of neural mechanisms underlying natural reading, during which eye movement is an integral part of neural information processing.

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