Decomposing Saccade-related potentials using Independent Component Analysis (ICA)

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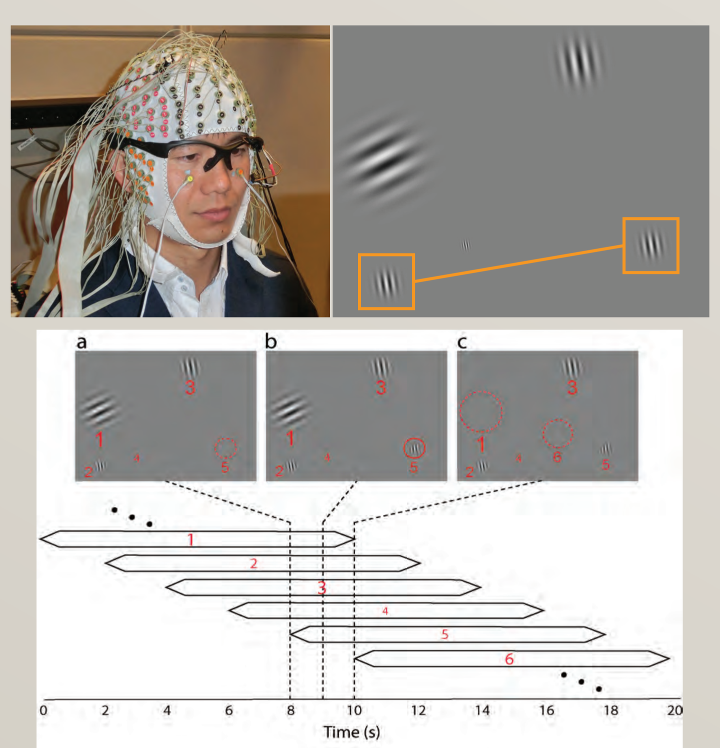
PURPOSE

We developed an active visual search task in which participants saccade freely across an evolving display of Gabor patches. Here we report the results from the EEG analyses of saccade-related brain/muscle potentials using independent component analysis (ICA) and independent component (IC) clustering.

METHOD

Participants were 20 healthy young adults (10 female, mean 20.9 yrs, SD 3.0, range 18-26). Five Gabor patches were always present on a gray background (20-inch LCD monitor at 60 cm). A sequence of 1200 patches were pseudo-randomly selected from four patch sizes and five orientations (SOA 2 sec, duration 5 sec). The task was to detect infrequent (15%) instances in which the size and orientation of the newest patch matched those of another patch that was still visible, prompting a button press. Eye-tracking data were obtained from the left eye while 205-channel, 512-Hz scalp EEG data were recorded. We studied event-related potentials (ERPs) timelocked to saccade events for the time courses of 650 localizable ICs assigned to 16 clusters.



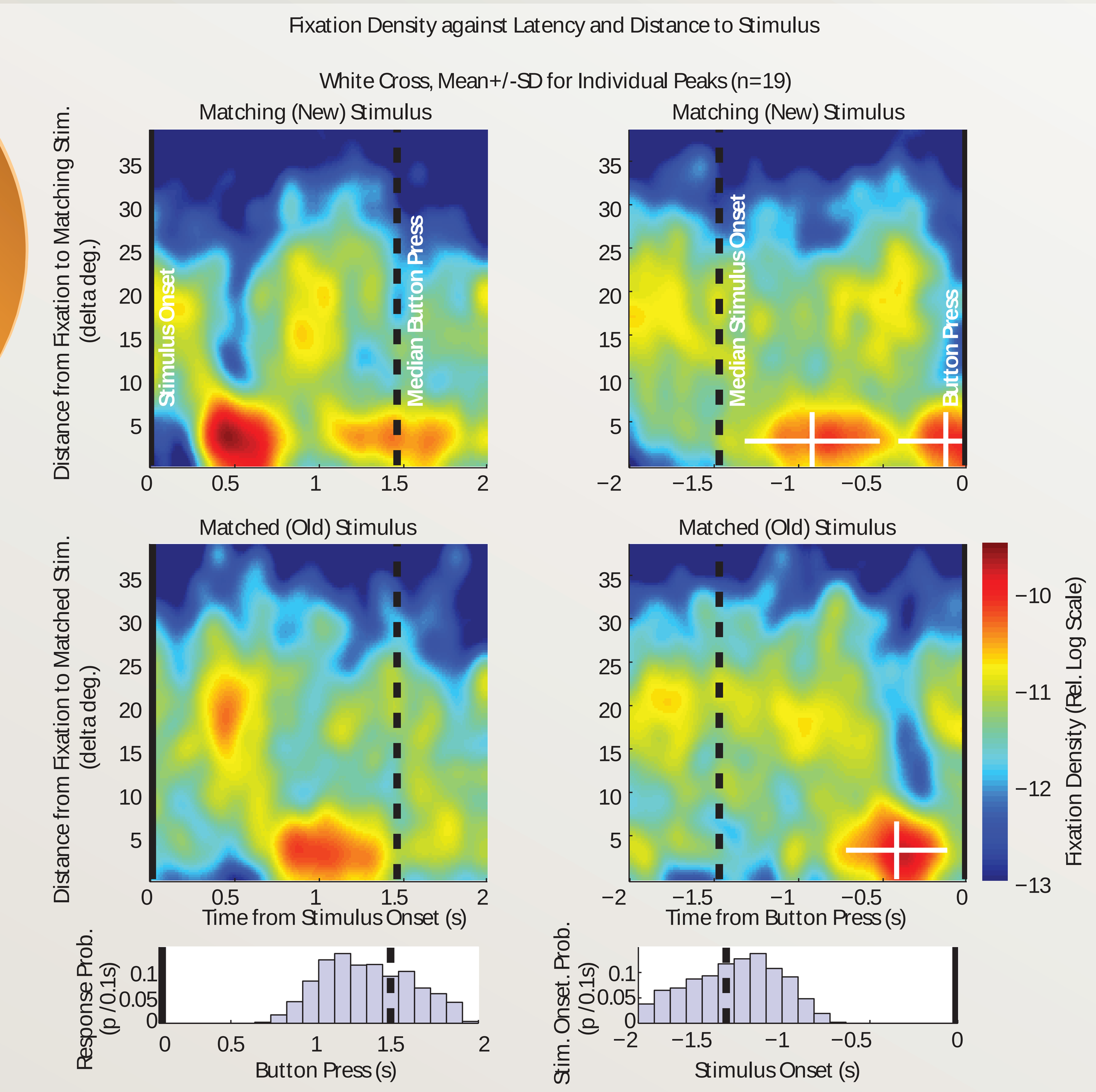
Top left, Experimental setup. 205ch EEG cap and in-house developed wearable eye-tracker (30 Hz sampling rate) were applied to the subjects.. During the recording, a chin rest was used. There are five Gabor patches on the random position on the screen. Every two seconds, the oldest one disappeared and and a new one came in. Subject's task was to press a button as soon as they detect a matched pair in both size and angle.

Flow of the Process

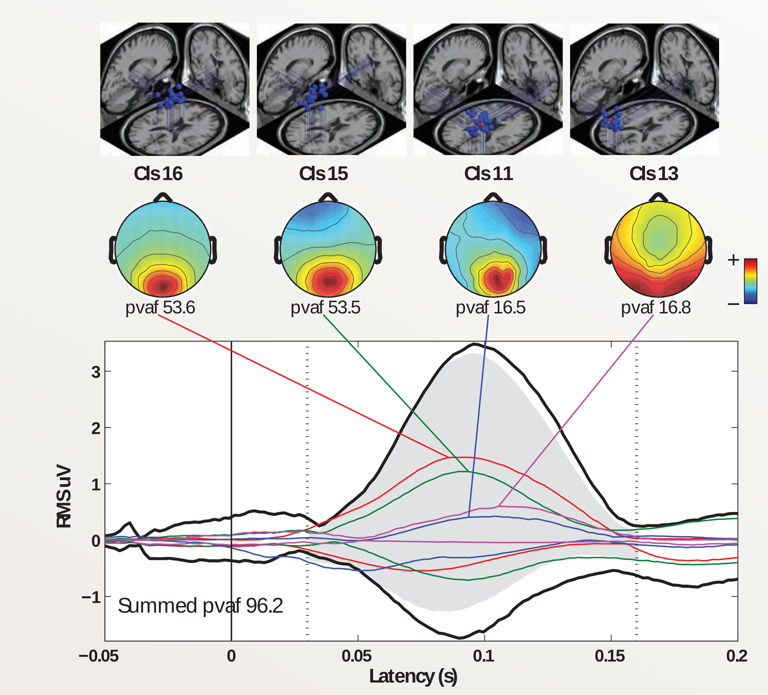
1. Estimate saccade onset and offset latency using eyetracker data (30Hz sampled).
2. Identify presaccadic spikes in ICA-decomposed EOG activities (512Hz sampled) using the results from 1. Additionally, ICA on spike only (-15 to 15 ms, reduced to 48 ch) was performed.
3. Refine saccade onset and offset latency based on the results from 2.
4. Analyze event-related brain potentials using event markers for presaccadic spikes and fixation onsets.

Top, the fow of the integrative processes on signals from the eyetracker and EEG. EEGLAB [1] and MoBILAB [2] were used for the analysis in additioni to custom Matlab code.

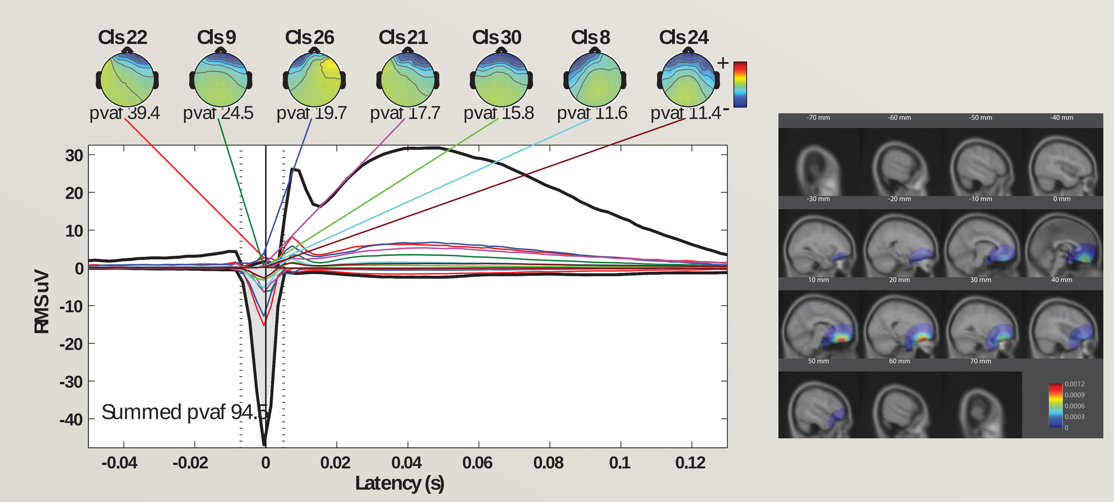
RESULTS



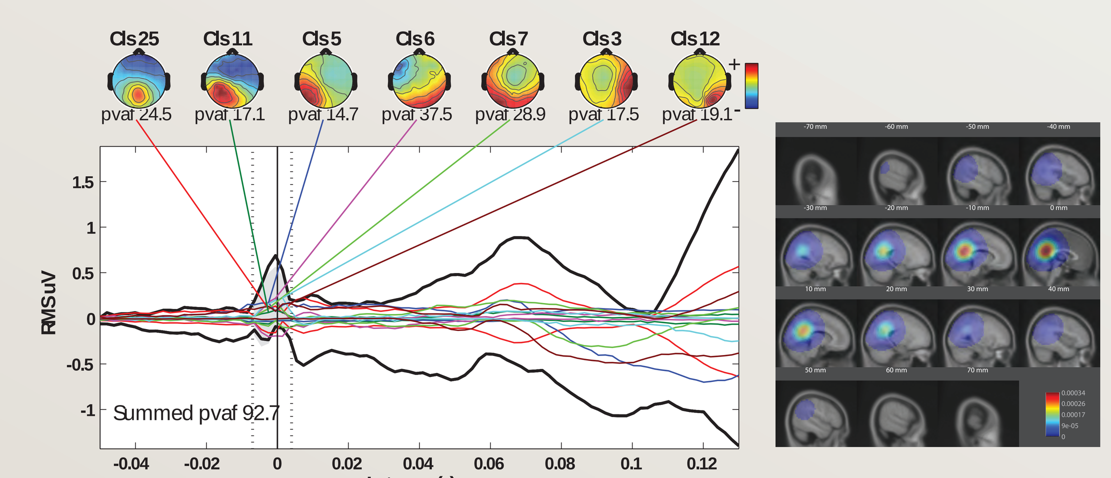
Top, fixation densitygram as a function of time to stimulus/button onset and distance from the center of the targets. The overall hit rate was high (89%). In the figure, the top row shows 'Matching (New) Stimulus' which refers to one of the paired taret stimulus that appeared later, and the bottom row shows 'Matched (Old) Stimulus' which refers to the one that appered first. The left column shows the data sorted to the onset of Stimuls, and the right column shows the same data but sorted to Button Press. Larger delta degree means fixation point being far from the stimulus. In the right column, the white cross indicates mean +/-SD for individual subject peaks (n=19).



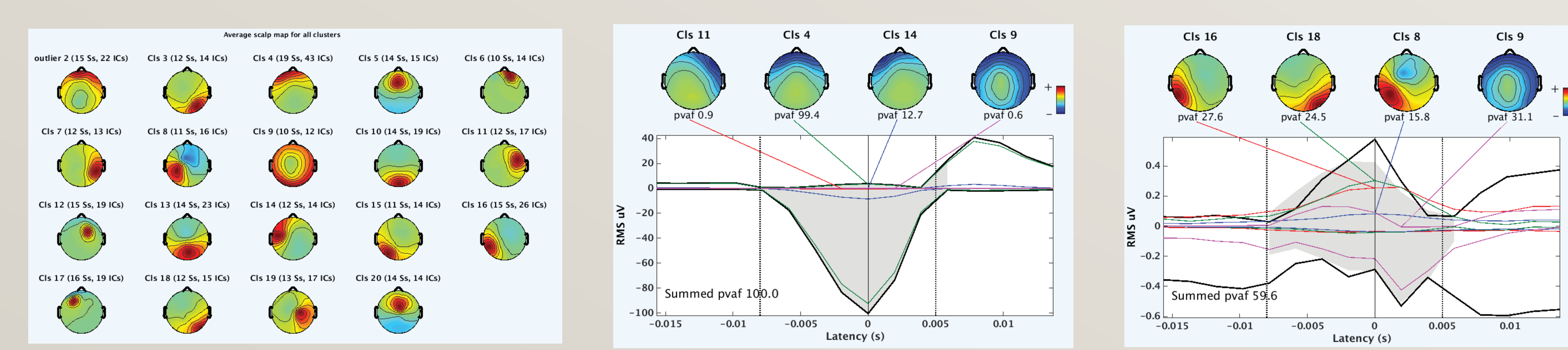
Top, EEGLAB std_envtopo() results plot. Around 350/4000 independent components of EEG were grouped into 19 clusters with the criterion of the locations of equivalent current dipoles estimated to each independent components. Total of 80 ICs included in the 4 clusters account 96.2 % of variance in the lambda response observed in the scalp channel measurement. These lambda contributors are located near or in the occipito-



Top left, evntopo plot of the presaccadic spike. 850/4000 independent compoennts were grouped into 30 clusters. The envtopo analysis on the presaccadic spike revealed frontal sources. Top right, dipole density plot of the identified clusters.



Top left, occipito-parietal sources of the presaccadic spike. Removing frontal clsuters revealed a smaller spike (note the difference in scales) at the latency of the presaccadic spike. The envtopo analysis identified occipito-parietal sources. Top right, dipole density plot of the identified clusters.



Top left, ICA was performed on precassadic spikelatency only (-15 to 15 ms, n=20, mean 5787 spikes, SD 773, range 4287-6874; the number of channels was subsampled to 48.) It replicated the results that presaccadic spike is also contributed by occipito-temporal sources. Top middle, the four largest clusters out of 18 clusters. These clusters are all associated with frontal sources. Top right, the next four largest clusters after removing the four frontal clsuters show in the Top middle plot. The envtopo analysis confirmed the contribution by the occipitotemporal clsuters. Note the scale difference between Top middle (from -100 to 40 RMS microVolt) vs. Top right (from -0.6 to 0.4 RMS microVolt)

CONCLUSION

ICA clustering analysis revealed multiple sources of the lambda response and pre-saccadic spikes. Posterior cortical contributions to the pre-saccadic spike might index corollary discharge to suppress activity of the visual cortex during saccades.

REFERENCES:
[1] Delorme A, Makeig S. 2004. EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis. J Neurosci Methods 134:9-21.
[2] Ojeda A, Bigdely-Shamlo N, Makeig S. 2014. MoBILAB: an open source toolbox for analysis and visualization of mobile brain/body imaging data. Front Hum Neurosci 8.

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