Saccadic Spike Potentials in Gamma-Band EEG and MEG: Characterization, Detection and Suppression

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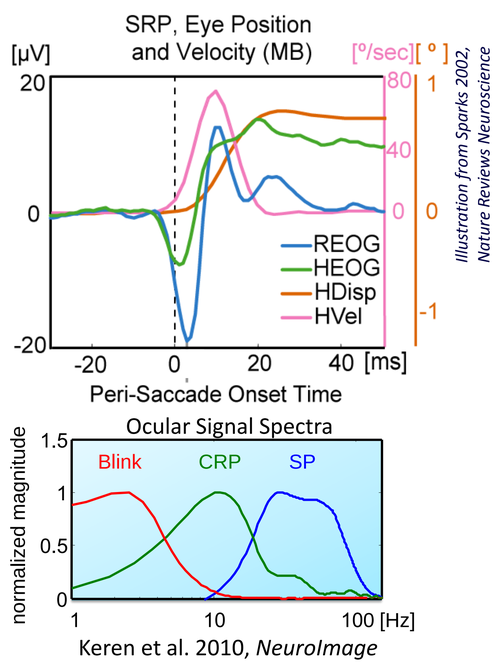
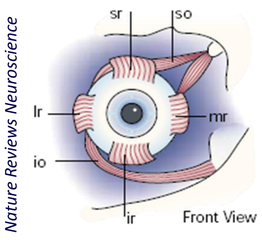
Saccadic Spike Potentials (SP) in EEG

Non-invasive recording of high frequency (gamma) neural activity in EEG and MEG is gaining increasing importance – it may have a major role in neural integration, attention and consciousness. However, we have recently shown that a **saccade-related Spike Potential (SP)** resulting from extraocular muscle contractions during microsaccades, seriously confounds the analysis of induced Gamma-Band Responses (iGBR) in EEG (Yuval-Greenberg et al., Neuron 2008). **The goal of this study is to characterize the SP and find ways to separate it from cerebral sources.**

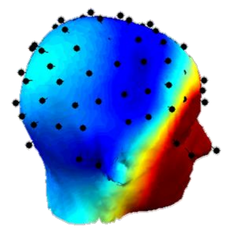
Characteristics of the SP:

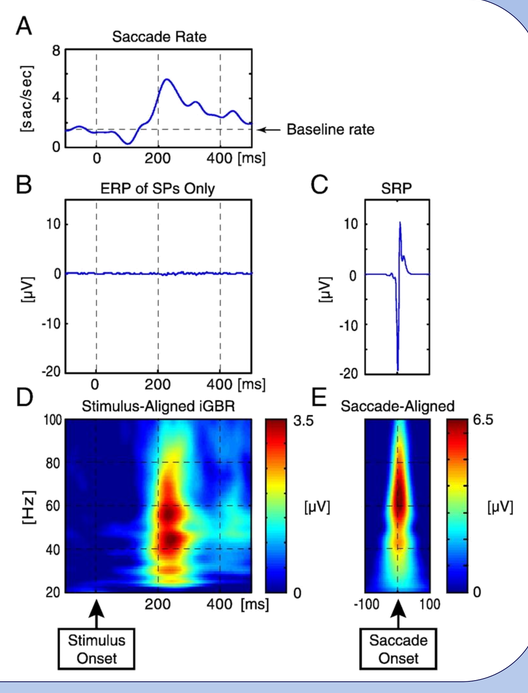
Time course: 22 ms biphasic deflection starting at the saccade onset.
Spectrum: 20-90 Hz
Amplitude: ~25 µV ptp for saccades of 0.5°, and grows with saccade size
Topography: anterior-posterior with steepest gradients around the eyes.
Directional tuning: steeper gradients ipsilateral to the saccade target.





RMS amplitude with average-reference[2]

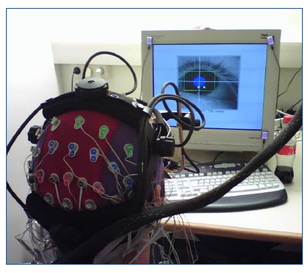




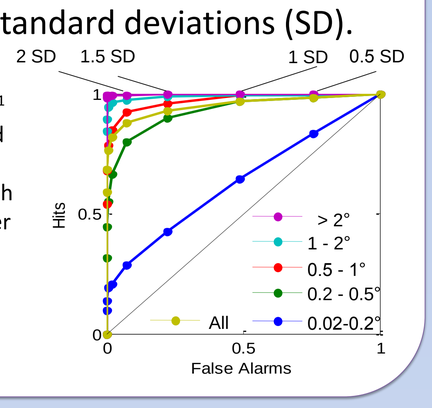
Saccade Detection in the EOG

When a video-based eye-tracker is not available, saccades can be detected in the EOG, as follows:

- Creating a "radial EOG" channel (average of the EOG channels with posterior reference)
- Band-pass filtering it to 30 – 100 Hz
- Setting a threshold of several standard deviations (SD).



Performance[1] of EOG-based saccade detection with an eye-tracker as a gold standard (ROC curve):



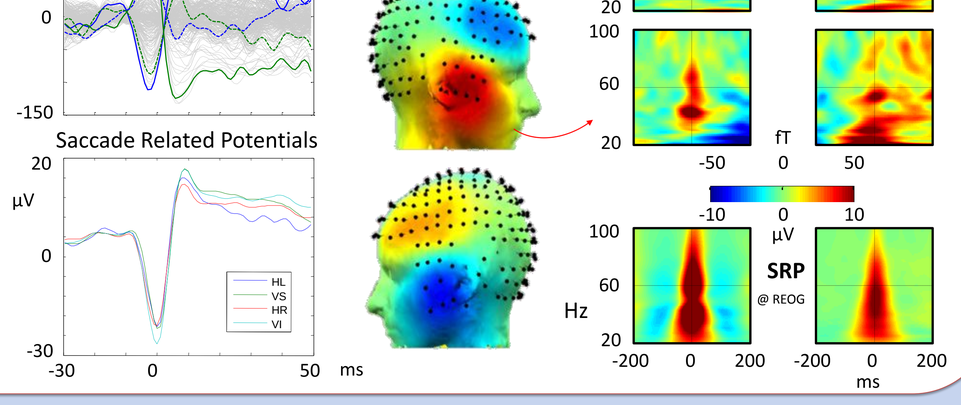
SP Effect in MEG

The average magnetic fields time locked to saccade onsets (as detected in the EOG) show a "spike field" (SF) with comparable characteristics to the SP in the EEG.

Induced SFs can be seen in in several peri-orbital channels.

Induced SFs do not stand out against the background activity as much as their electric counterparts.

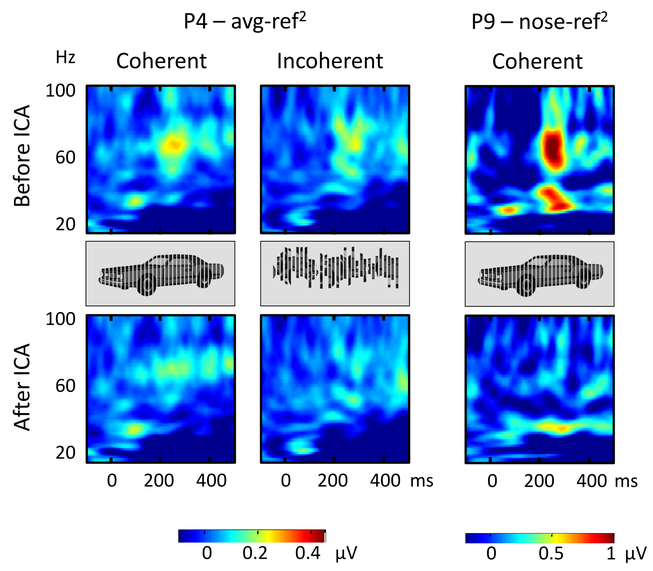
It is unclear whether SFs can be seen at all in stimulus-induced fields.

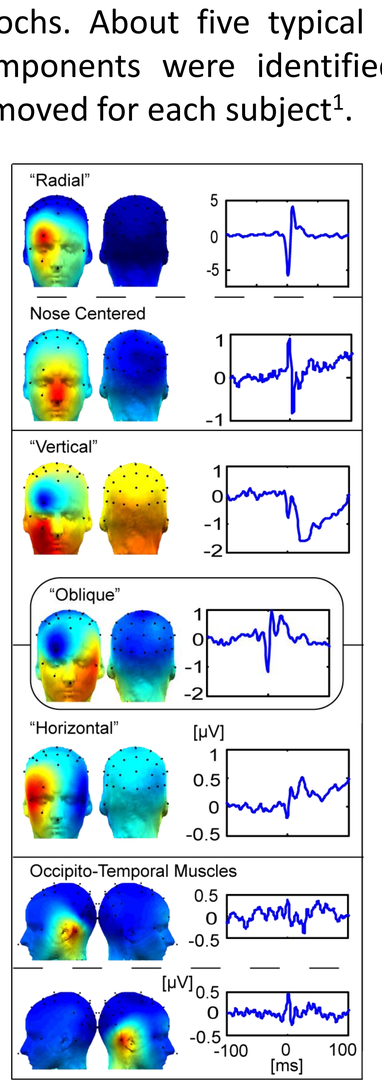


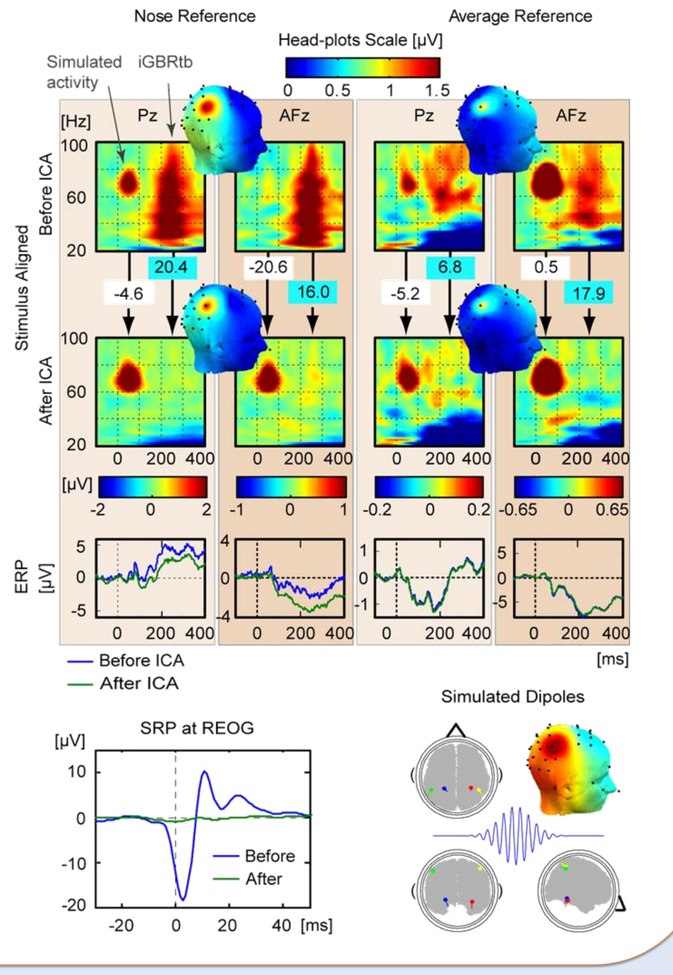
Suppression by ICA

Dedicated application of ICA can significantly reduce the SP effect in the EEG, and reveal potentially 'true' cerebral gamma activity.

Below, ICA was trained on a concatenation of all 800 ms mean-centered peri-stimulus epochs and all 80 ms mean-centered peri-saccade (using an Eye-Tracker) epochs. About five typical ocular components were identified and removed for each subject[1].

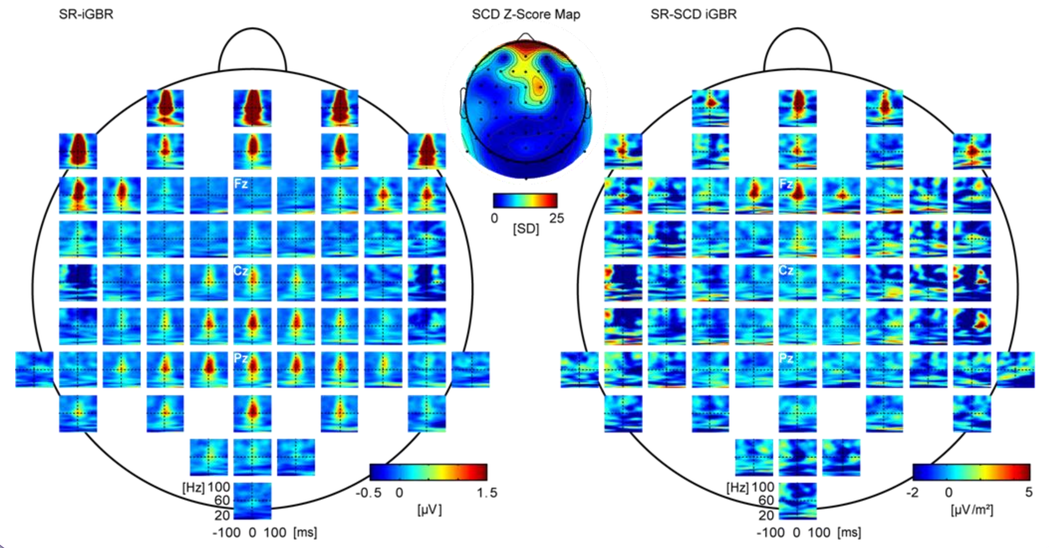






Suppression by SCD

Using Scalp Current Density (Laplacian) the SP effect is largely attenuated in posterior channels, but less in anterior channels[2]:



Conclusion

- Recording gamma-band activity on the scalp requires specialized methods to reduce contamination by micro-saccadic extra-ocular muscle activity locked to the experimental paradigm timings.
- MEG also reflects this extra-ocular myoelctric signal, but to a lesser extent.

Methods

1. 42 ch. EEG (Biosemi, 1024 Hz) were recorded simultaneously with binocular eye tracking (Eyelink II, 500 Hz), while subjects viewed color drawings of objects and novel shapes.
2. Subjects viewed drawings of objects cut to stripes that either maintained position or were shuffled and rotated, to impair recognition. 71 EEG channels were recorded.
3. MEG (4D Neuroimaging; Magnes WH-3600, 248 magnetometers, 1017Hz) and 4 EOG channels referenced to the average of the mastoid channels were recorded; subjects performed a self-paced visual search within complex colored images.
4. MEG and EOG as in (3); subjects viewed faces and watches in either normal configuration or with scrambled components, either with or without face contour.