Temporal and spectral electrooculographic features in an aiming task

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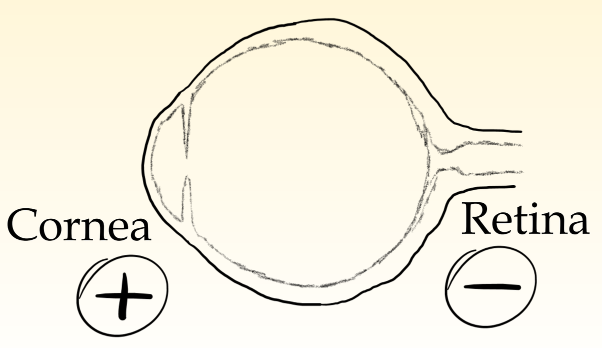
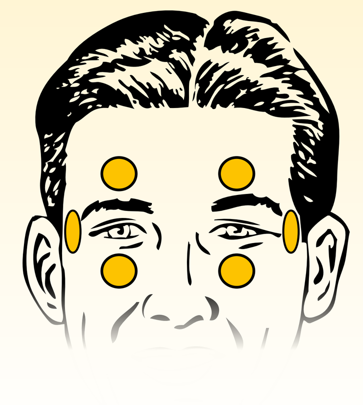
BACKGROUND





Growing interest in using **electrooculography (EOG)** to study eye movements in target sports

- temporal features (e.g., Quiet Eye durations) → **validity?**
- temporal & spectral features (time-frequency power) → **utility?**

which processing settings?

METHOD

Participants (n = 16) novices to experts

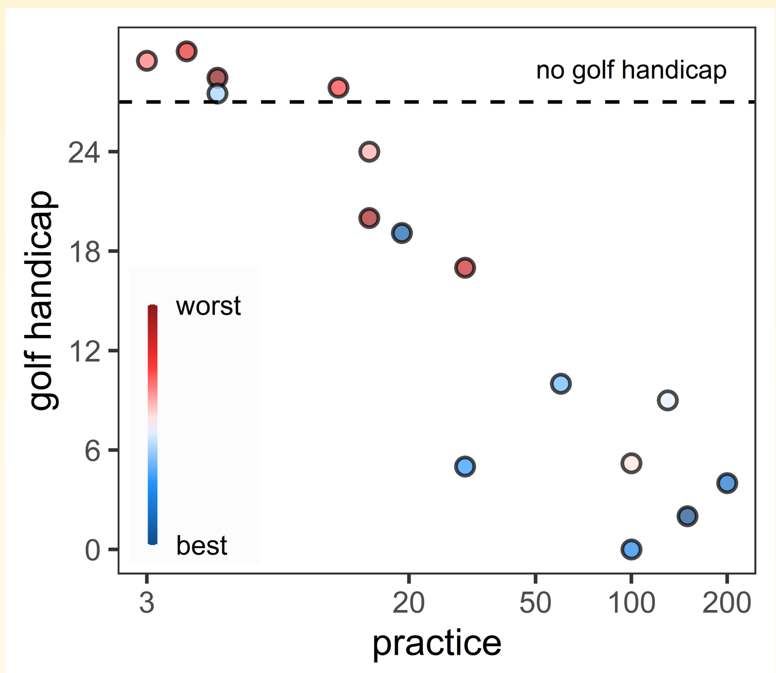


Figure 1. Participants' expertise in terms of recent practice and golf handicap. The color indicates individual performance accuracy in this study.

Task: 60 4-m golf putts

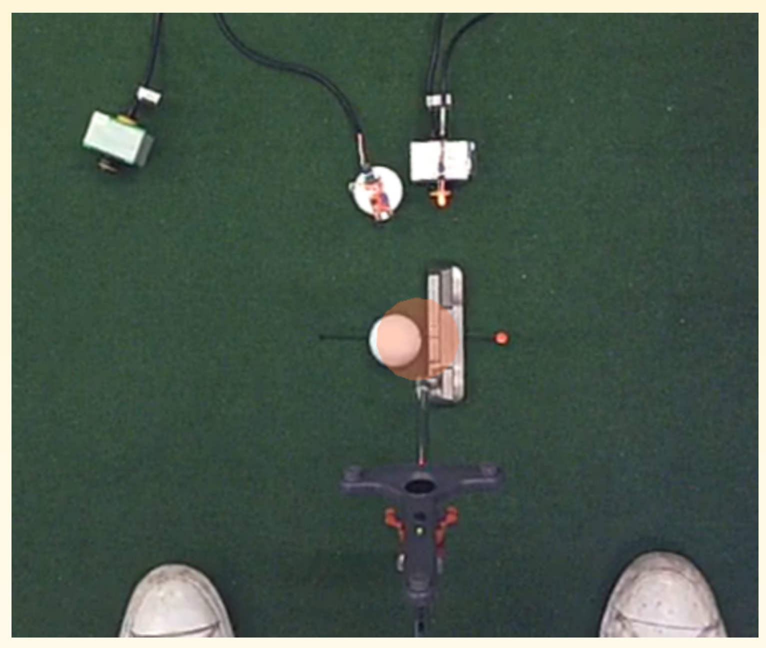


Figure 2. Eye tracker view showing the putting setup. The shaded orange circle represents the gaze location within a 3° diameter.

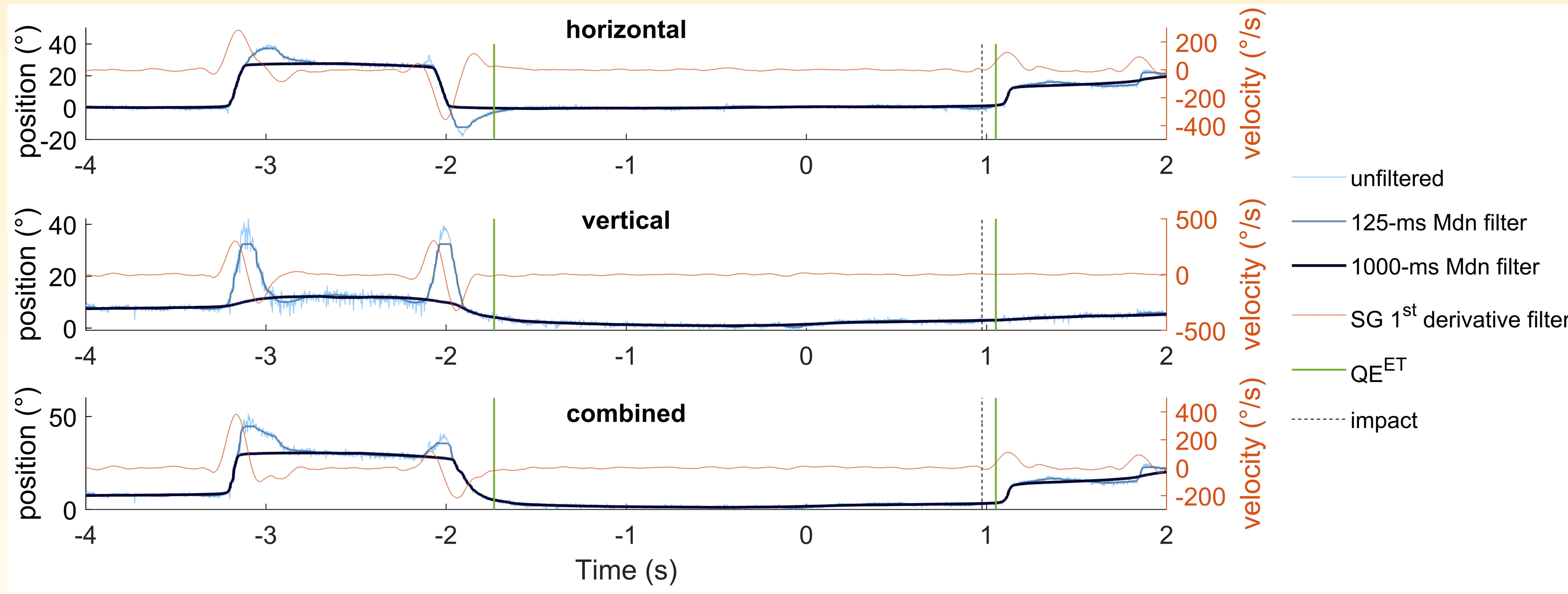
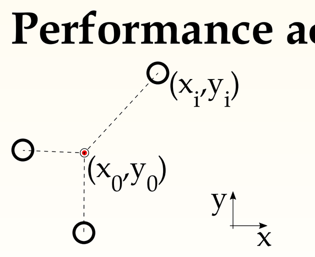


Figure 3. Effects of filters (median, Savitzky-Golay differentiation) applied to the EOG signals. Units were converted to degrees of visual angle (°) through gaze calibration. Time 0 s corresponds to movement initiation. The black dotted line indicates putter-ball impact. The green vertical lines indicate QE onset and offset as scored from Eye Tracking data.

Performance accuracy



Radial Error

$$\mathrm{Mdn}\left(\sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}\right)_{trials}$$

Oculomotor techniques

- **QE^{ET}** Quiet Eye duration from Eye Tracking
- **QE$^{EOG\text{-}dispersion}$** Quiet Eye duration from EOG positional data
- **QE$^{EOG\text{-}velocity}$** Quiet Eye duration from EOG velocity data
- **AP^{EOG}** time-frequency EOG power with no baseline
- **RP^{EOG}** time-frequency EOG power relative to a baseline

FINDINGS

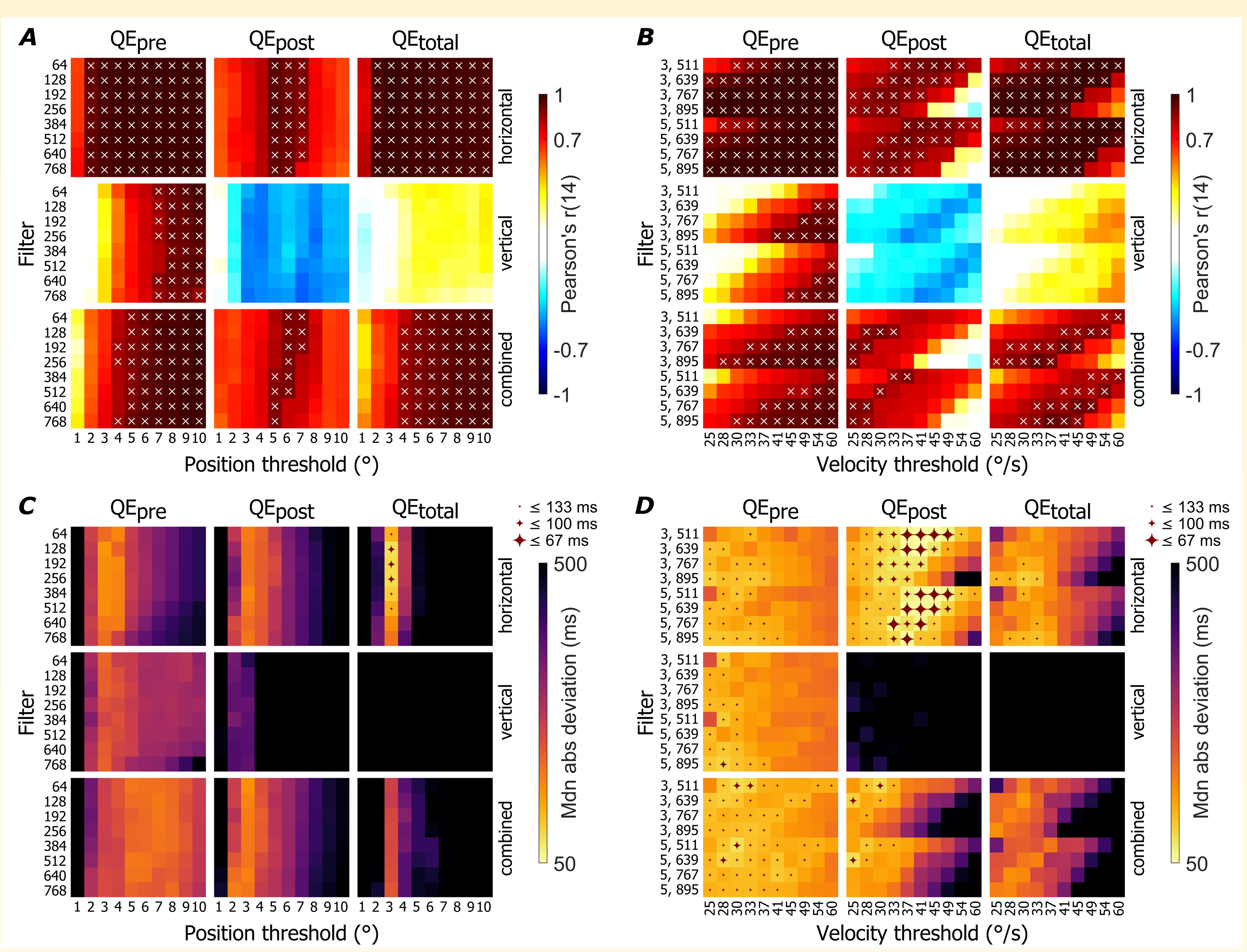


Figure 4. Concurrent validity of QE^{EOG} against QE^{ET} through Pearson's correlations as a function of processing settings (*panel A*: dispersion ; *panel B*: velocity). The ✕ symbol highlights statistically significant results (p < .05) obtained through permutation testing with the extreme-value correction. Temporal discrepancy as Median absolute deviation from the values obtained from Eye Tracking (*panel C*: dispersion ; *panel D*: velocity).

QE^{EOG} validity

- Threshold algorithms can yield valid and accurate measurements
- best settings
  - **QE$^{EOG\text{-}dispersion}$** horizontal channel, 3° threshold, 256-point median filter
  - **QE$^{EOG\text{-}velocity}$** horizontal channel, 33°/s threshold, 5th-degree, 767-point SG diff. filter

RP^{EOG} utility

- Combined temporal and spectral features are more reliably associated with performance than temporal features alone
- best settings
  - time-frequency power expressed as decibel change from a standing baseline
  - high-frequency horizontal power during movement

Table 1. Results of the nested cross-validated Theil-Sen regression predicting performance (i.e., radial error) using each of the five oculomotor techniques. Median squared logarithmic error on the test set (MdnSLE$_{test}$) is reported as measure of generalization error (i.e., expected error on unseen data), along with interquartile range of the logarithmic errors on the test test (IQRLE$_{test}$) and their ranges (RangeLE$_{test}$). The technique with the smallest MdnSLE$_{test}$ value is the best at predicting performance when applied to unseen data. The technique with the smallest IQRLE$_{test}$ value is the most consistent across different test sets.

Technique	MdnSLE$_{test}$·10^4	IQRLE$_{test}$·10^2	RangeLE$_{test}$·10^2
QE$^{EOG\text{-}dispersion}$	124.02	22.74	[-15.36, 27.88]
QE^{ET}	68.58	16.37	[-14.88, 20.22]
QE$^{EOG\text{-}velocity}$	54.96	15.36	[-32.66, 26.27]
AP^{EOG}	22.11	11.61	[-8.48, 25.57]
RP^{EOG}	4.96	5.49	[-7.68, 31.16]

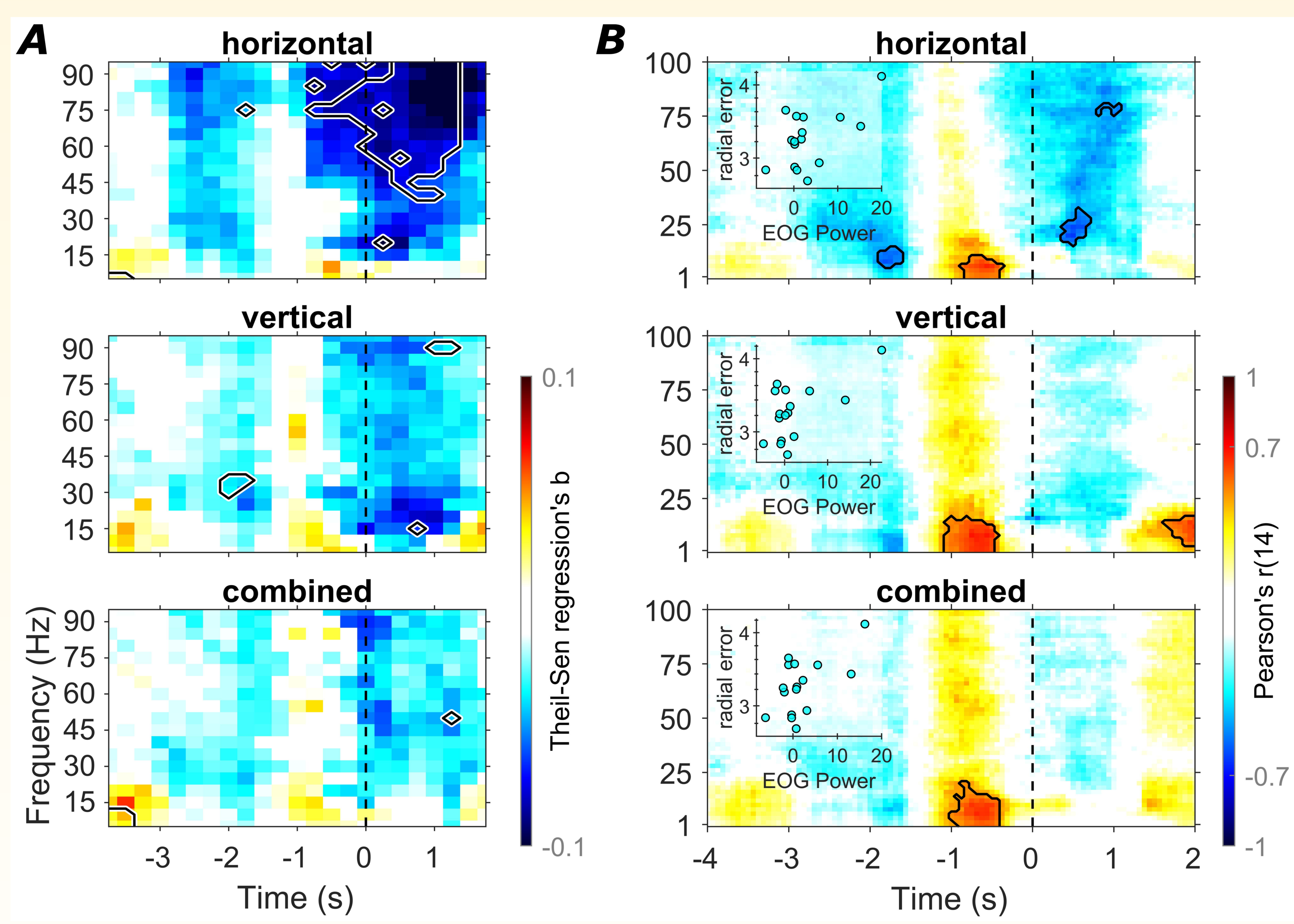


Figure 5. *Panel A*: Theil-Sen regression slopes describing RP^{EOG} hyperparameters as predictors of performance. The contour lines highlight the full dataset slopes corresponding to cross-validation errors below the 5th percentile. *Panel B*: Correlation coefficients between performance (radial error) and RP^{EOG}. The contour lines highlight statistically significant results (p < .05) obtained through permutation testing with cluster correction. Scatterplots describe the relation identified by the largest time-frequency clusters for each channel.