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Predicting V1 spike dynamics using scalp EEG in macaques

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Introduction: Despite decades of electroencephalography (EEG) research, the relationship between EEG and underlying spiking dynamics remains unclear. This gap in knowledge limits our ability to infer intracranial signals from EEG, a critical step to bridge electrophysiological findings across species and to develop non-invasive brain-computer interfaces (BCIs).

Methods and Results: We recorded both spiking activity from a 32-channel floating microarray permanently implanted in parafoveal V1 and scalp-EEG in a male macaque monkey. While the animal fixated, the screen flickered at different temporal frequencies (0, 5, 10, 20, and 40 Hz) to induce steady-state visual evoked potentials (SSVEP). We analyzed the relationship between the V1 multi-unit spiking activity envelope (MUAe) and EEG frequency bands to predict MUAe at each time point from EEG. We found that the phase and amplitude of EEG frequency bands are differentially related to V1 MUAe, and this relationship is further dependent on stimulus frequencies. Additionally, phase-amplitude coupling exists between EEG bands. Using multivariate linear regression to predict MUAe from EEG frequency bands, we found that flickering SSVEP stimuli help predict MUAe from EEG better than non-flickering stimuli at both the trial-averaged and single-trial levels. Subsequent analyses revealed that the amplitude, phase, and coupling of EEG bands each contribute to model predictions, with MUAe signals in shallow cortical layers predicted better than deep layer MUAe. Interestingly, the phase of stimulus frequency also improved EEG-to-MUAe prediction.

Conclusion: Our study shows that non-invasive EEG can predict V1 spiking activity under SSVEP stimulus conditions by utilizing the phase and amplitude of EEG frequency bands. By bridging the gap between invasive cortical signals and non-invasive EEG signals, these results help identify candidate scalp EEG signals that could benefit brain-computer interfaces.

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