Isolating Single Cycles of Neural Oscillations in Spiking Activity

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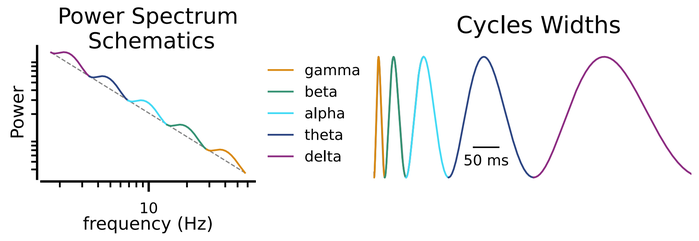
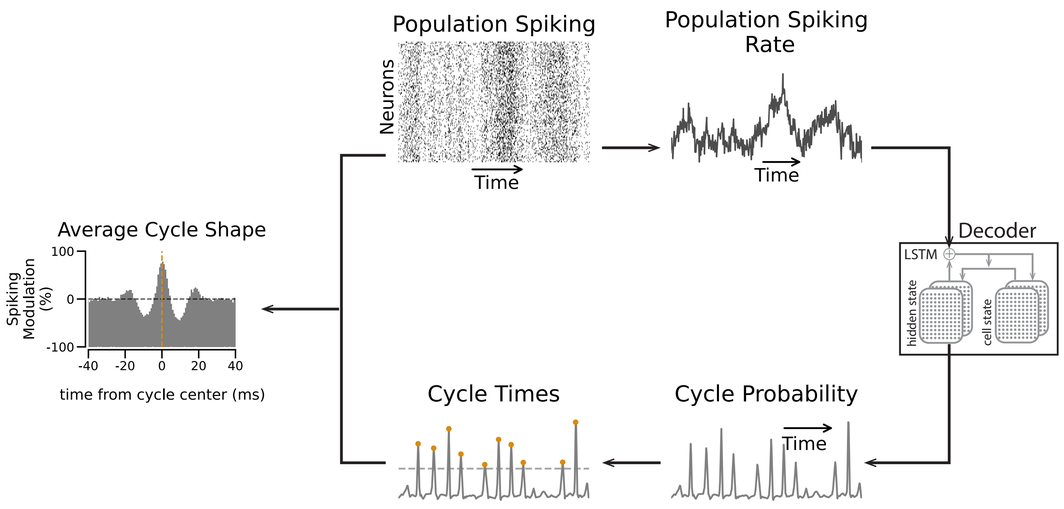
Abstract

Although the identification of neural oscillations has primarily relied on EEG and LFP, the intrinsic relation between neural oscillations and neuronal ***spiking*** is noteworthy. We investigate the potential to detect individual cycles of neural rhythms solely through the spiking activity of neurons, using recent advancements in densely recording large populations of neurons within a local network. Numerous spikes from neurons within a local network estimate the network's activity over time, enabling us to identify cyclic patterns. Here, we employ recurrent neural networks (RNNs) to effectively isolate individual cycles of neural oscillations from the spiking of a densely recorded population of neurons. This isolation occurs in the temporal domain, where cycles from different time scales may combine in various ways to shape the network's spiking probability.

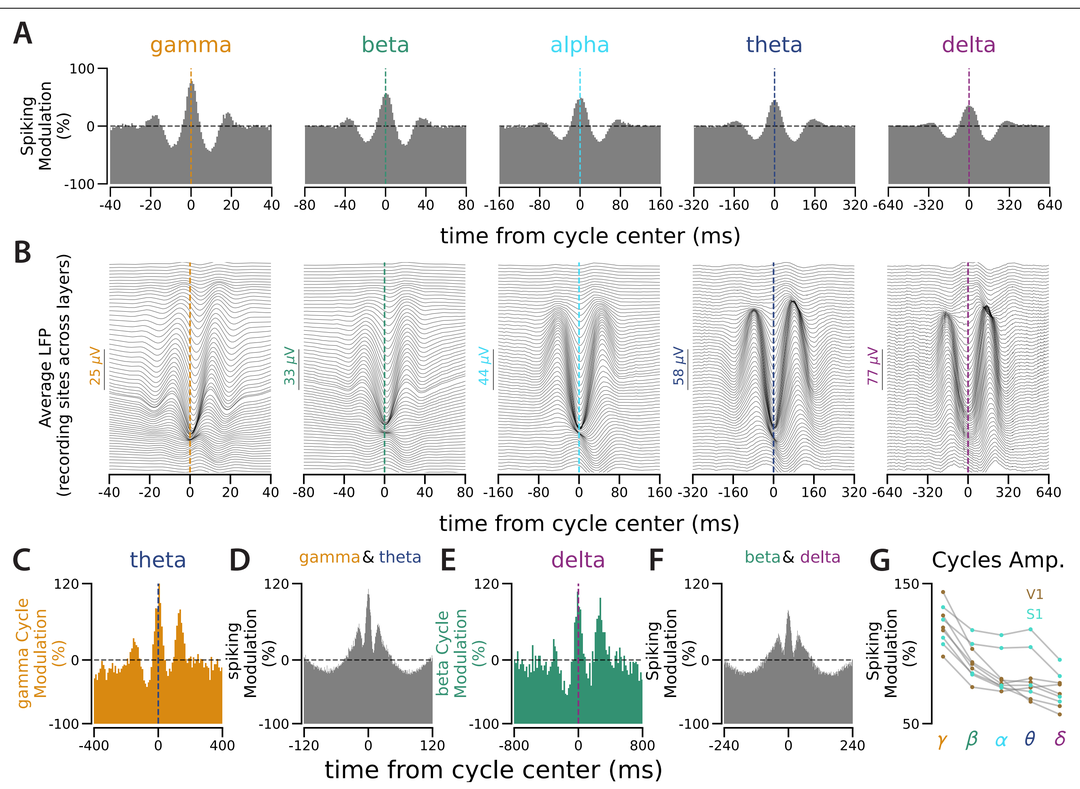
Introduction



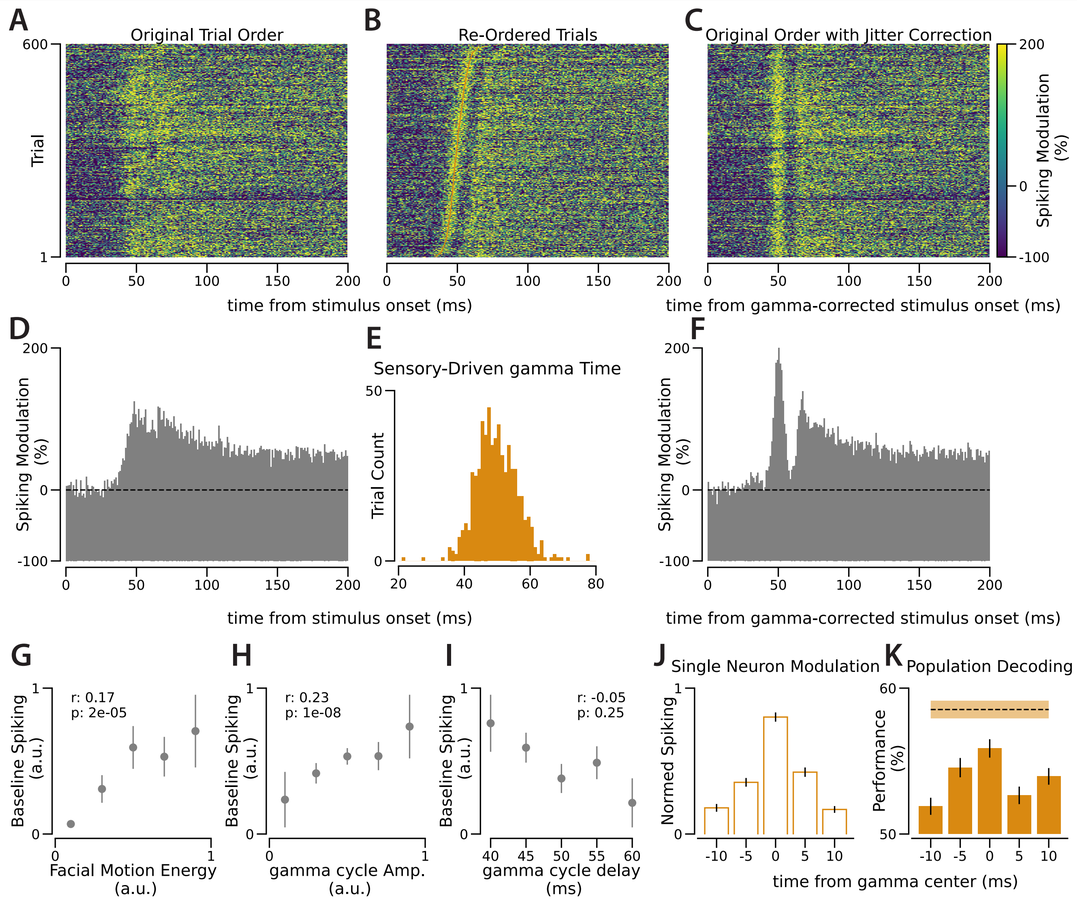
Cycle	Duration
gamma	20 ms
beta	40 ms
alpha	80 ms
theta	160 ms
delta	320 ms



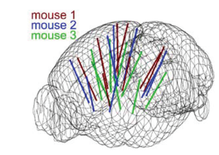
Cycle Detection in Population Spiking of Mouse Primary Sensory Cortex



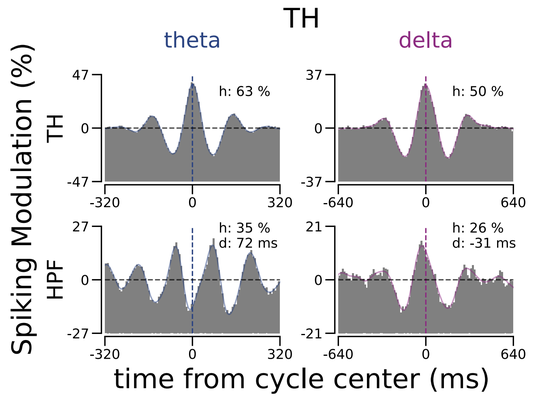
Sensory-Driven gamma Cycles Capture the Variation in Signal Transfer Time between Retina and V1 across Trials

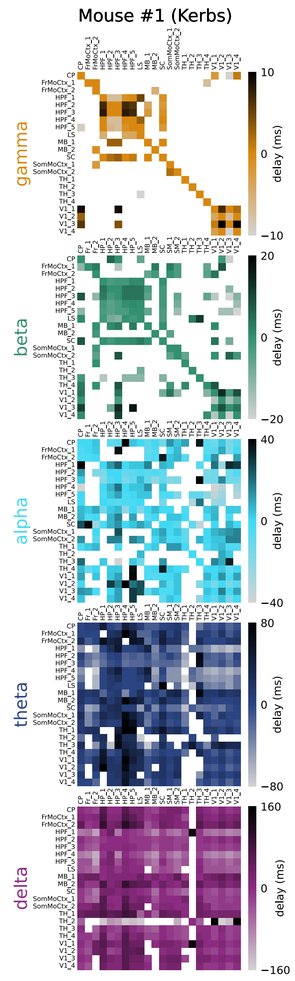


Correlated Activity across Brain Regions in Different Time Scales



Steinmetz, N., Pachitariu, M., Stringer, C., Carandini, M., and Harris, K. (2019). Eight-probe Neuropixels recordings during spontaneous behaviors.

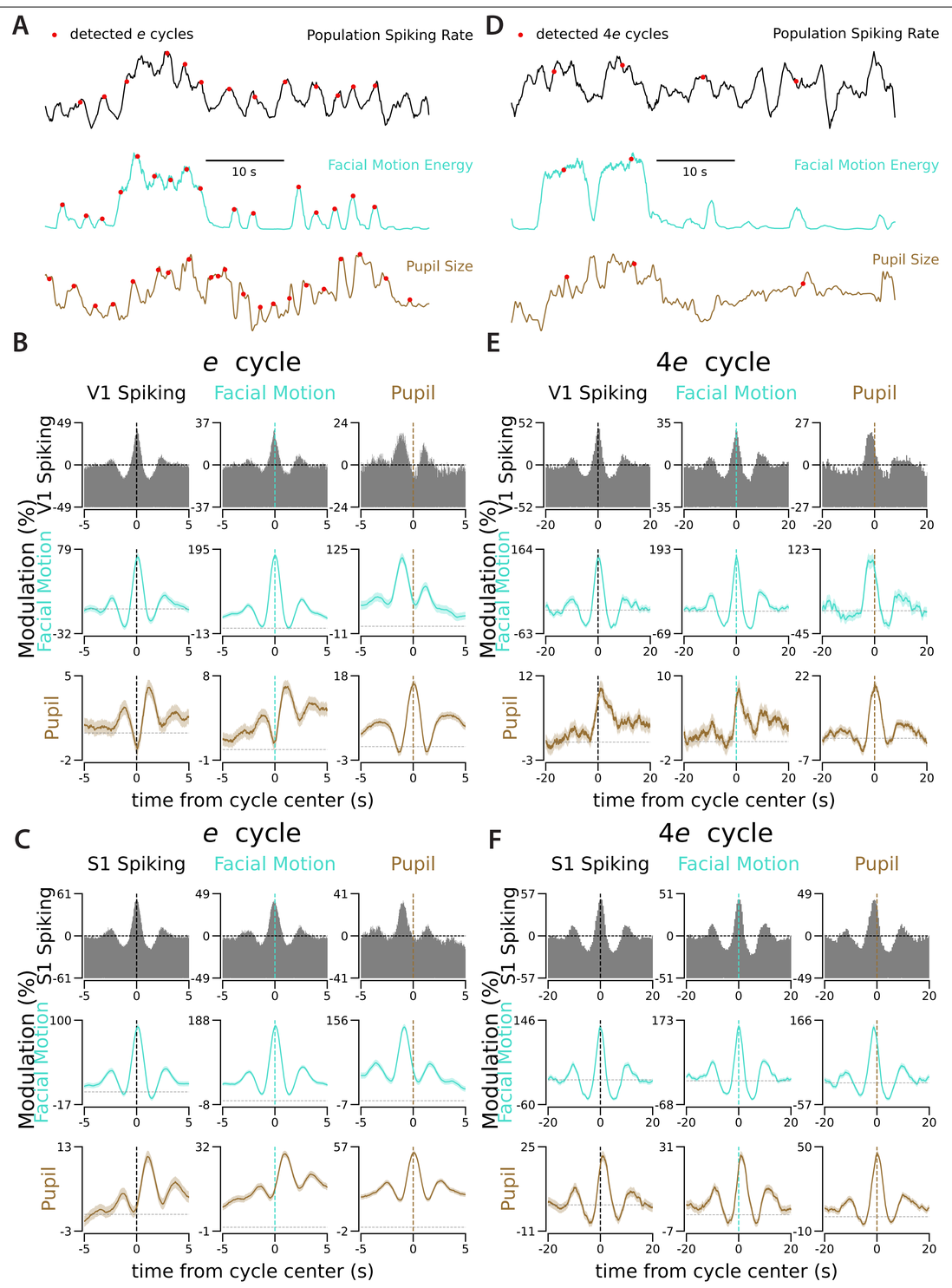




Ultra-Slow Cycles

Cycle Name	Duration
quarter e	640 ms
half e	1.25 s
e	2.5 s
2e	5 s
4e	10 s

Isolating Ultra Slow Cycles in Population Spiking, Pupil Size, and Facial Motion: Similar Basis Functions?



Summary

- Using an RNN in the time domain, we identified the timing of individual cycles of neural oscillations from densely recorded population spiking.
- The cycles captured in population spiking reflect the rhythmic patterns of LFP and their cross-frequency couplings.
- In visual stimulation experiments, isolated sensory-driven gamma cycles can compensate for variations in signal transfer time between the retina and V1.
- By isolating cycles of different neural oscillations across brain regions, we observed correlated dynamics that are time-scale dependent between these regions.
- Multi-second cycles, identifiable from population spiking, pupil size changes, and facial movements, revealed correlated dynamics between them.