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What is a burst? Transient beta band phenomena in single-trial frontal oscillatory dynamics have different properties depending on the burst detection method used

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► **To cite this version:**

Zachary D Langford, Emmanuel Procyk, Charles R E Wilson. What is a burst? Transient beta band phenomena in single-trial frontal oscillatory dynamics have different properties depending on the burst detection method used. NeuroFrance 2023, May 2023, Lyon, France. <hal-04969297>

HAL Id: hal-04969297

<https://hal.science/hal-04969297v1>

Submitted on 27 Feb 2025

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Overview

- Motor and cognitive processes are reliably accompanied by trial-averaged differences in the beta band (12-35 Hz) localized to sensorimotor and frontal areas.
- Beta oscillations may have a pivotal role in coordinating cognitive control in frontal cortex (e.g. Buschman & Miller 2007).
- Whilst these oscillations appear to occur in temporally elongated bands, this is frequently an effect of trial averaging.
- Cortical oscillations are much better characterized as circumscribed bursts, when studied at the level of the single site and single trial (cf Feingold et al 2015, PNAS; Lundqvist et al 2016, Neuron).
- Studying the properties of these bursts is critical to revealing the role of oscillatory phenomena within frontal cortex.

- Across the field the methods used to detect and identify bursts varies between different studies
- Because of these differences, it seems that the definition of what constitutes a burst varies as well.

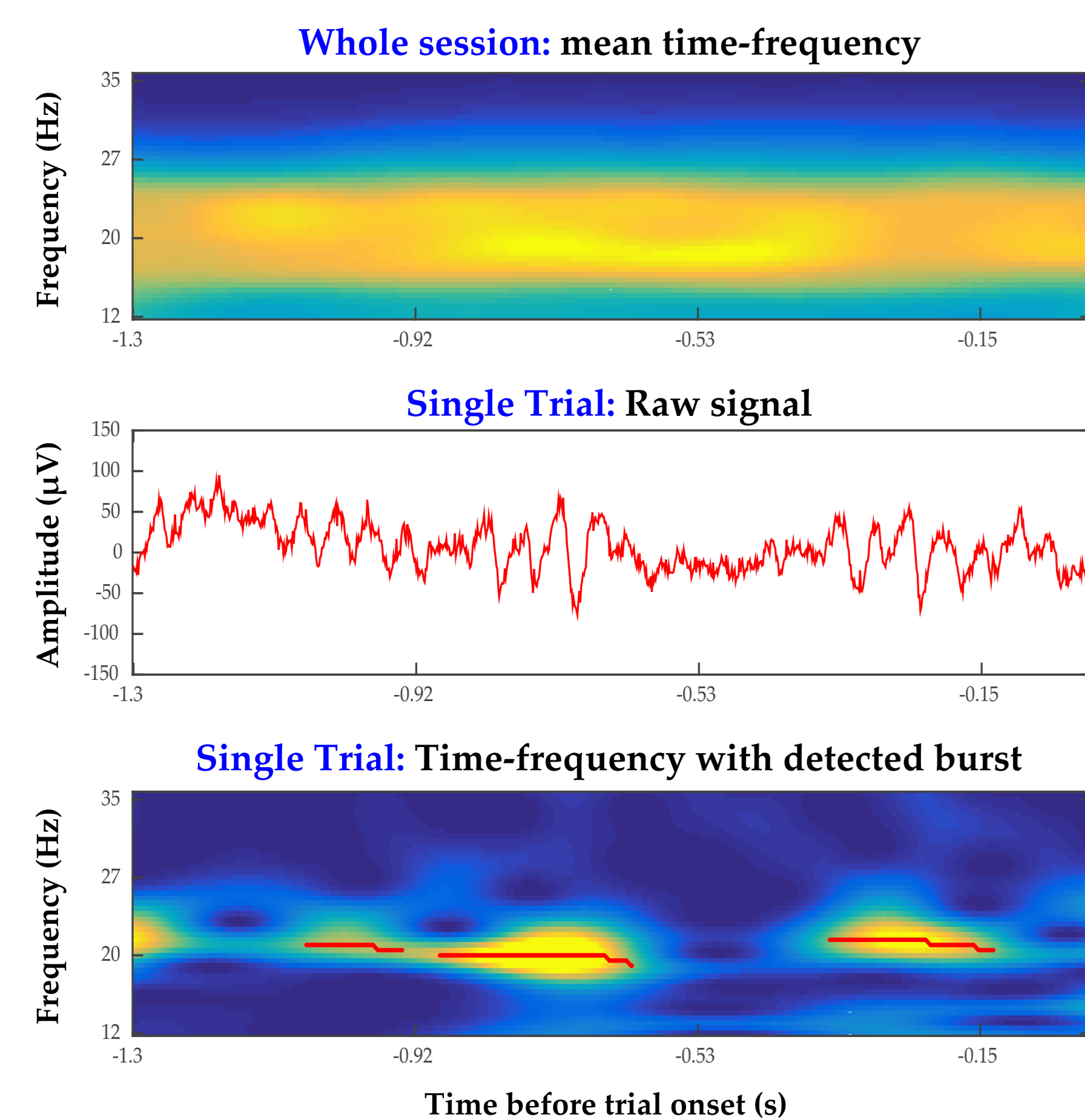
- Here we systematically compare published burst detection methods - power threshold and cycle-by-cycle approaches - on simulated and real neural data.

Code

Code and detailed explanation of the analyses available through the QR code or find "langfordzd" on Github



1. Beta oscillations occur as bursts



Macaque frontal cortex ECoG: Wilson et al 2016 PLoS Biology

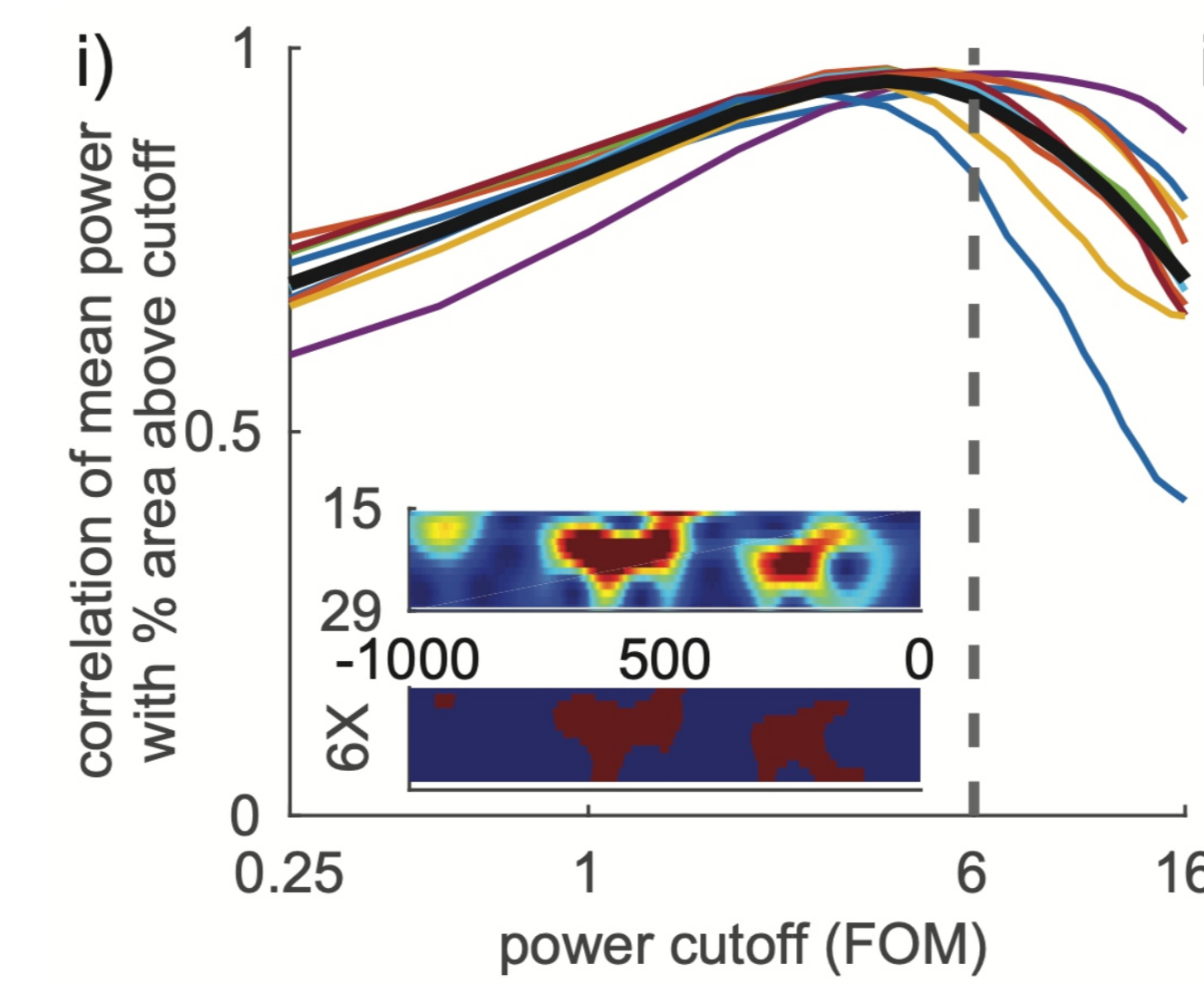
Oscillations are dynamic within single trials.

A multiple trial average does not account for this dynamism. Burst properties contain potentially important information

2. Bursts can be detected by setting a power threshold or by determining cycle-by-cycle consistency thresholds

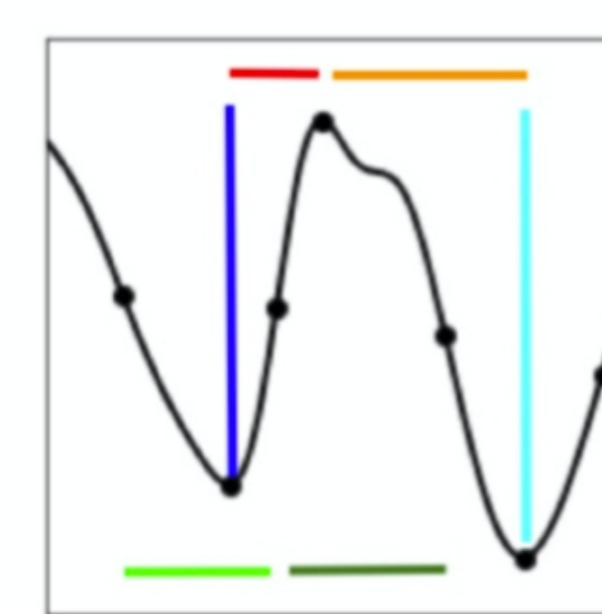
Power Threshold

The Power Threshold (PT) approach extracts activity as being part of a burst when instantaneous power passes a 6 median threshold. This threshold represents roughly the peak of a correlation between mean power and % of spectrogram above the cutoff. Approach validated in Shin et al 2017, eLife, similar to Lundqvist et al 2016, Neuron.



From Shin et al 2017, eLife

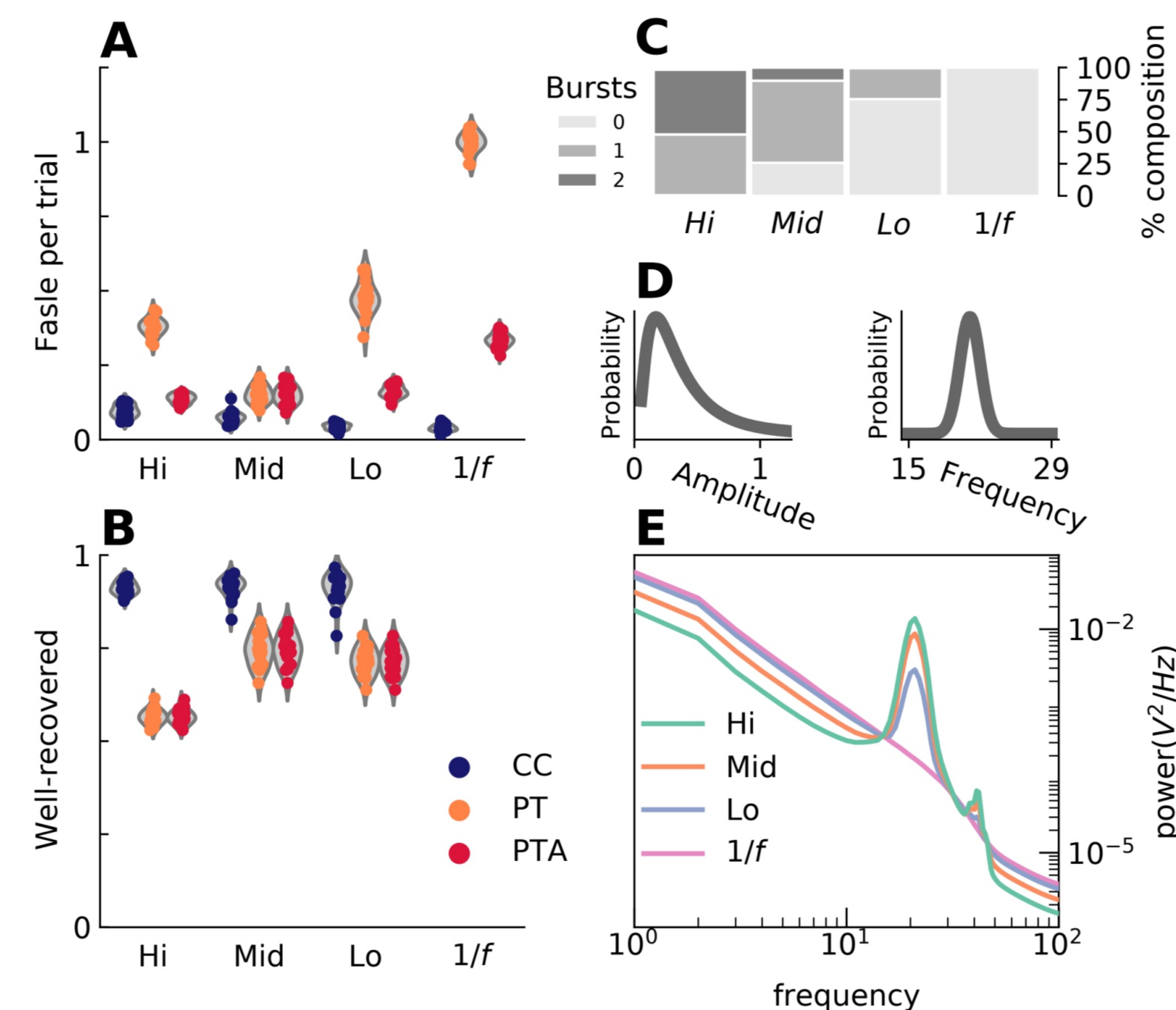
Cycle-by-Cycle



The Cycle-by-cycle (CC) approach extracts individual cycle properties from raw signal (without Fourier transform). Sections of activity must reach criteria of amplitude consistency, period consistency, and monotonicity to be considered oscillatory. Parameters were chosen to (1) not detect bursts in 1/f noise, and (2) maximize correlation between instantaneous amplitude and reconstructed signal. Approach from Cole & Voytek 2019: <https://bycycle-tools.github.io/>

From Cole & Voytek 2019, J Neurophysiol

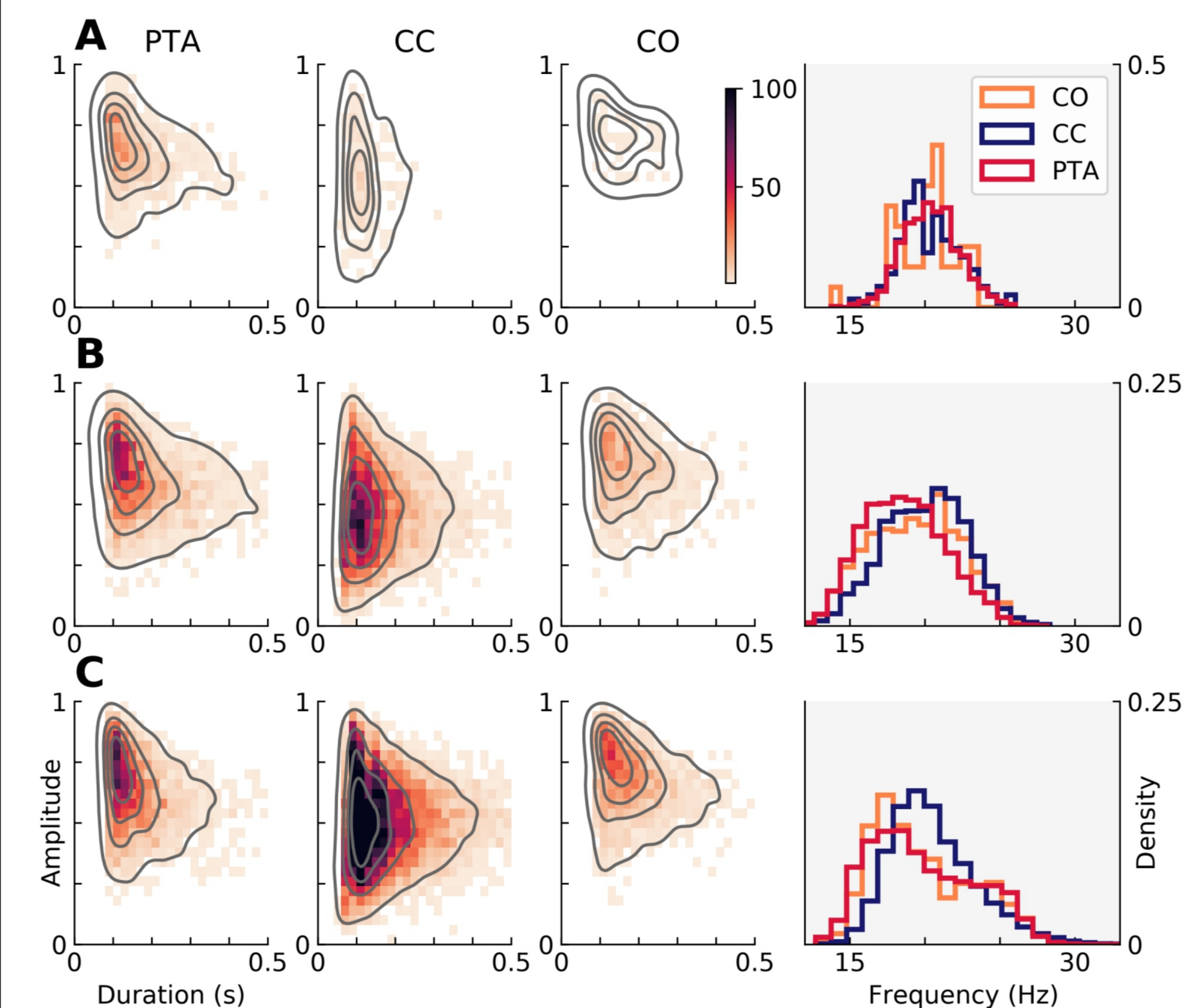
3. Cycle-by-cycle approach better recovers simulated bursts, and detects fewer false bursts in noise



In simulated data we show the detection of false bursts (A) and the recovery of simulated bursts (B) across detection methods. *Cycle-by-cycle performance is superior in both cases.*

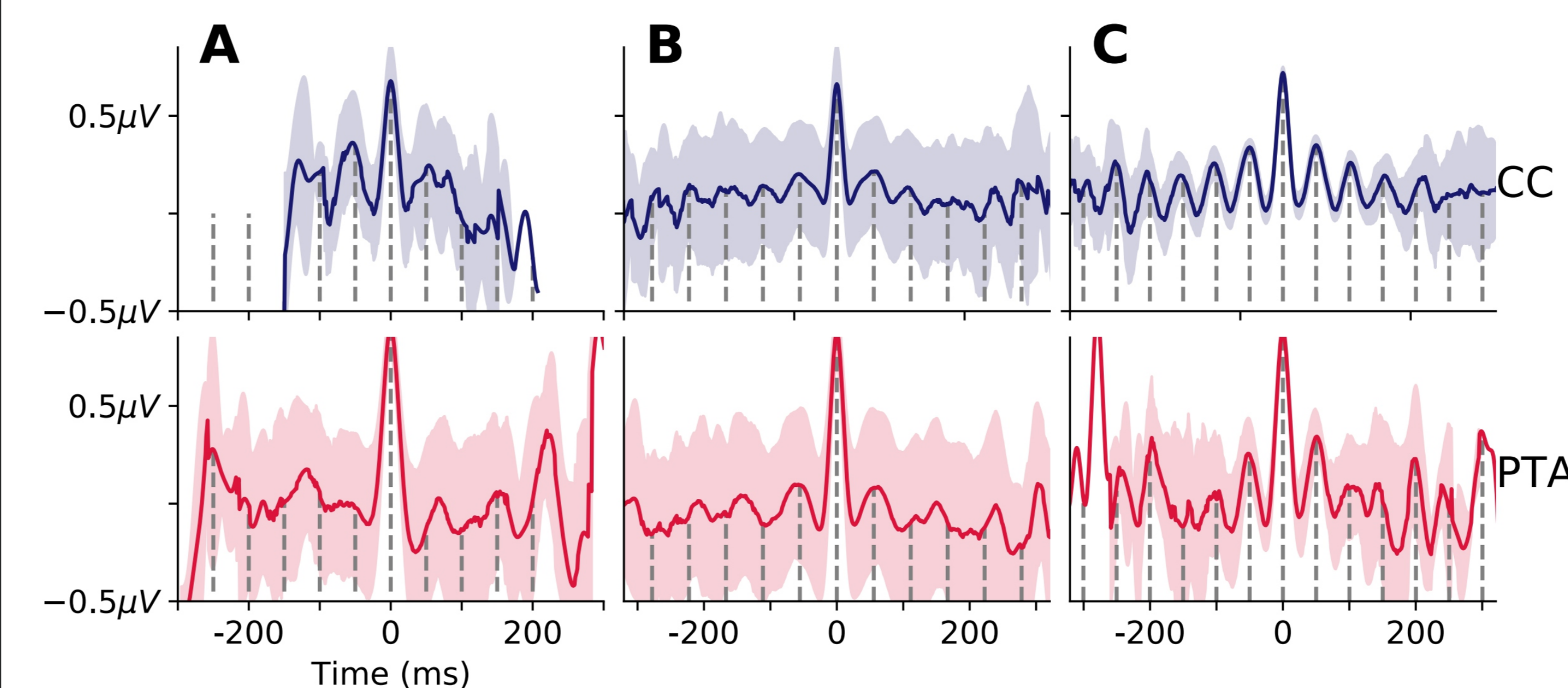
Parameters of the simulation on the right: Different burst probabilities across tested simulations (C), distribution of simulated burst amplitude and frequency (D), and averaged PSD for each set of burst probabilities (E).

4. The properties of the bursts recovered in neural data vary according to detection method



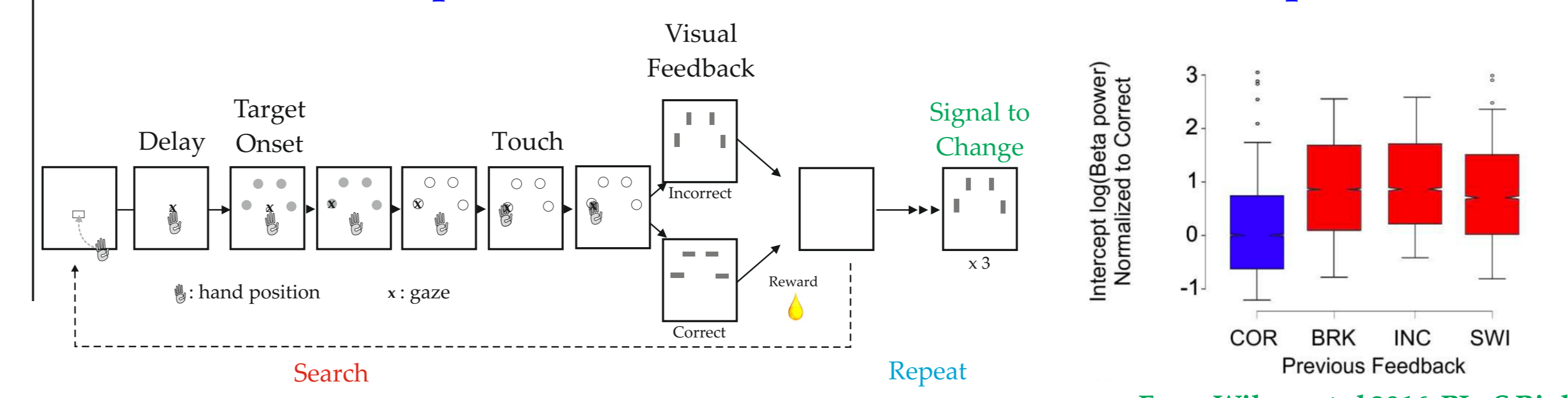
Duration and amplitude of recovered bursts from Power Threshold (PTA), Cycle-by-cycle (CC) methods, and bursts common to the two methods (CO), along with frequency distribution. Data from mouse (A), LFP (B), and ECoG (C) datasets. The distribution of CC bursts covers a wider range of amplitude and duration, despite the overlap.

5. The waveform of recovered bursts differs: detection methods are recovering different phenomena



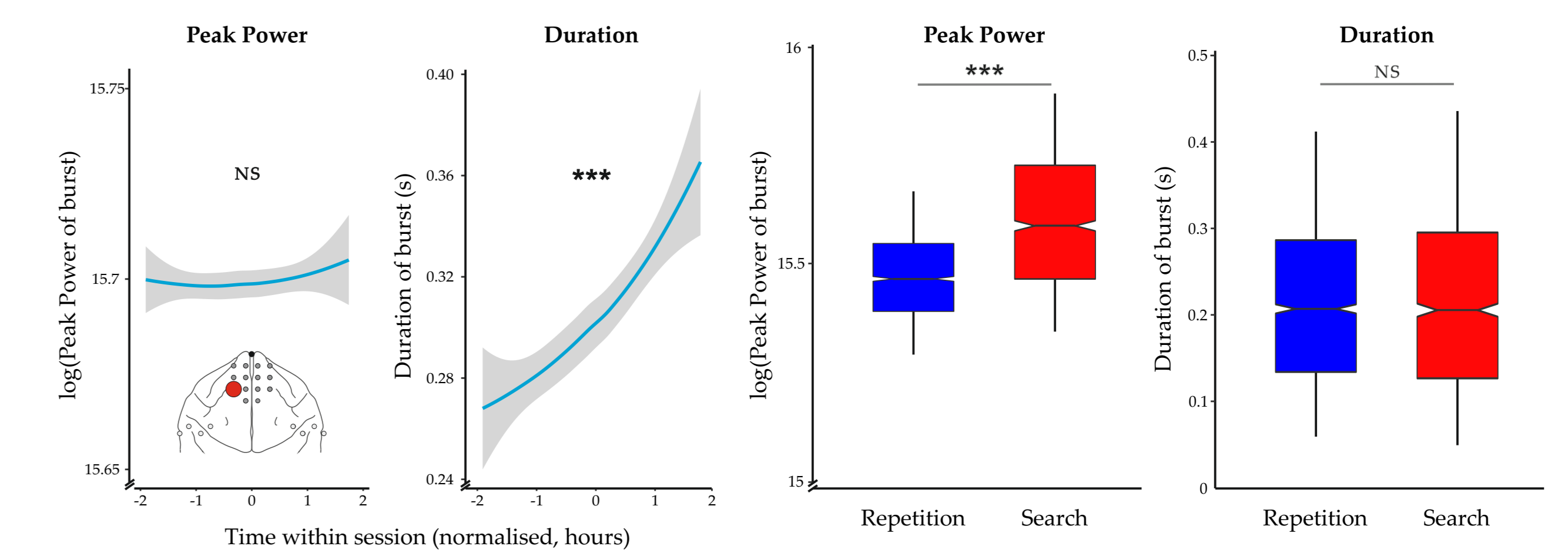
Cycle-by-cycle (CC) unique bursts have a much more consistent sinusoidal waveform. Power threshold (PTA) seems to capture more high-powered transients, with relative reduction of sinusoidal component around the peak amplitude. Data from mouse (A), LFP (B), and ECoG (C) datasets.

6. Frontal beta power is modulated across trials in adaptive tasks

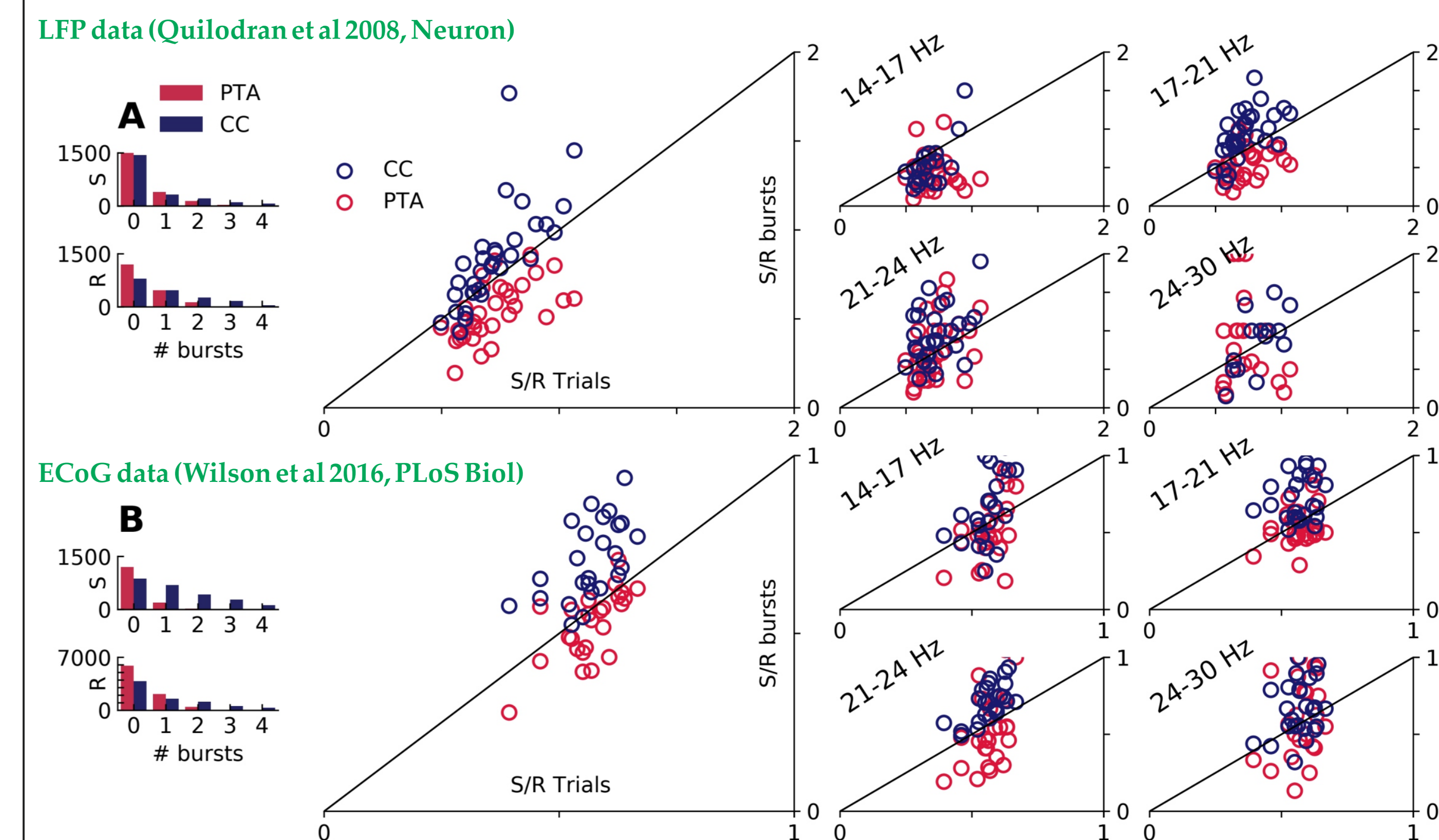


From Wilson et al 2016, PLoS Biol

7. This modulation is reflected in burst properties: power and duration of the bursts vary in a dissociated manner



8. The behavioural role of the bursts varies depending on waveform, therefore on detection method



CC bursts are more likely to be found in the search epoch, and PT burst more likely in the repetition epoch. LFP (A), and ECoG (B) datasets.

PTA is picking out lower frequency bursts, but on the right we see that this difference is not sufficient to explain the whole difference from the right panel - elements of this effect are present across overlapping frequency bands in both datasets.

Conclusions

- Single trial analysis is critical to understand information carried by beta oscillations. Oscillations occur in discrete bursts.
- Phenomena considered "beta bursts" by different detection methods have strikingly different oscillatory & temporal properties
- They may have very different functional implications and should not all be grouped together
- *High powered transients* are preferentially detected by power thresholding; *Consistent sinusoidal oscillations* are preferentially detected with a cycle-by-cycle approach
- Both are found in macaque LFP and ECoG, with potentially contrasting functional implications.

Author Contributions

- Zachary Langford performed all analyses, simulations and made figures
- Emmanuel Procyk provided data, funding and project design
- Charlie Wilson provided data, funding, project design, and is presenting the poster