Transient beta and gamma bursts in the mouse basolateral amygdala during the open field test

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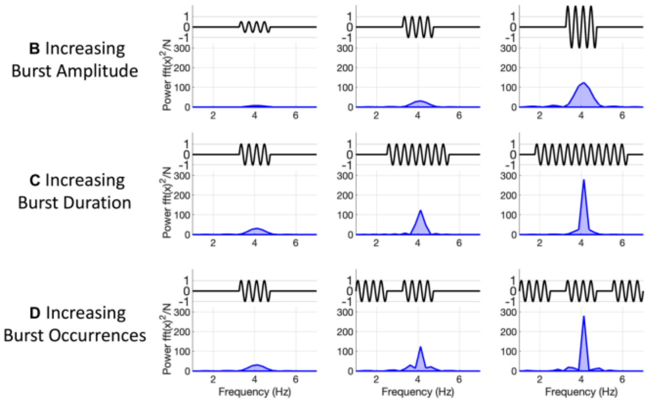
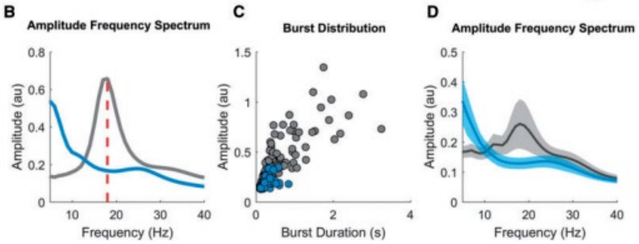
Introduction

Single bursts affect static power estimates



Quinn et al., *Brain Topography*, 2019

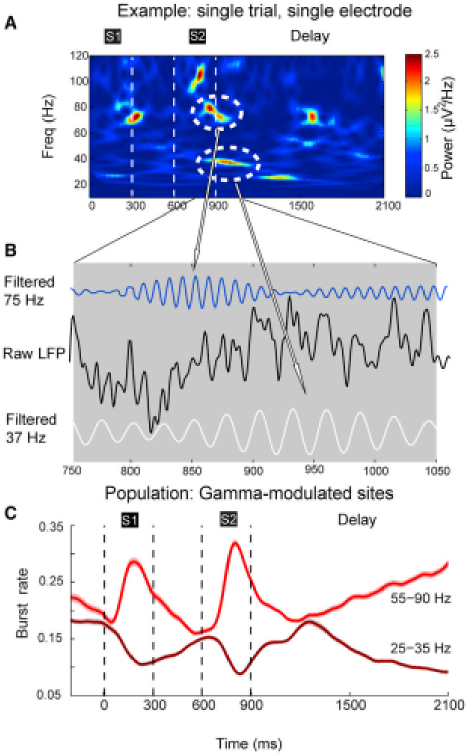
Burst durations correlate with motor impairments



Blue: ON dopaminergic medication
Grey: OFF dopaminergic medication

Tinkhauser et al., *Brain*, 2017

Gamma bursts underlie working memory



Lundqvist et al., *Neuron*, 2016

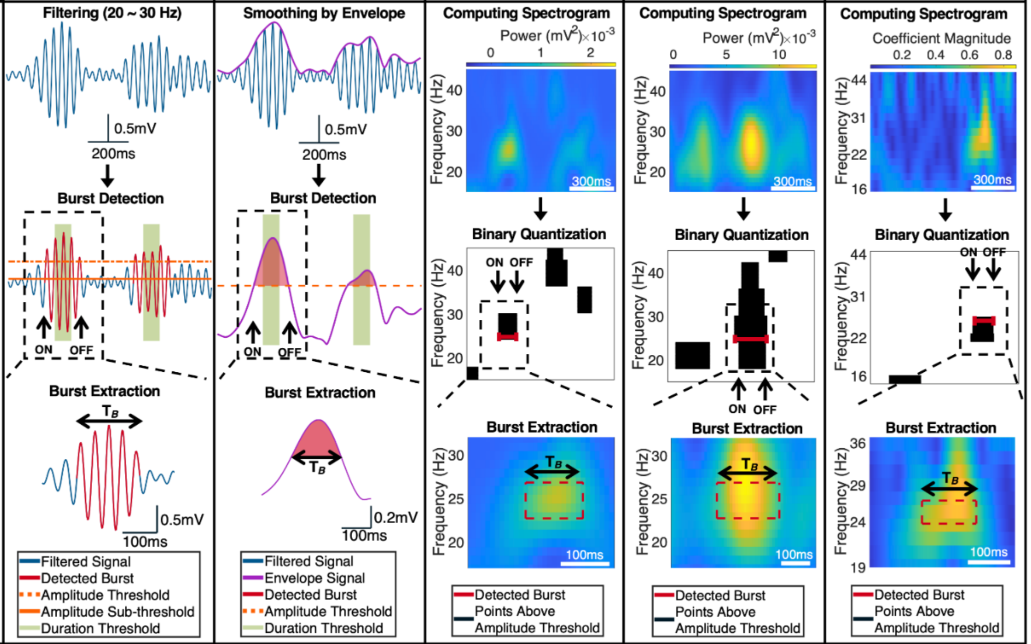
Table of Burst Detection Algorithms

Schematics of Algorithms

ON : onset of burst detection

OFF : offset of burst detection

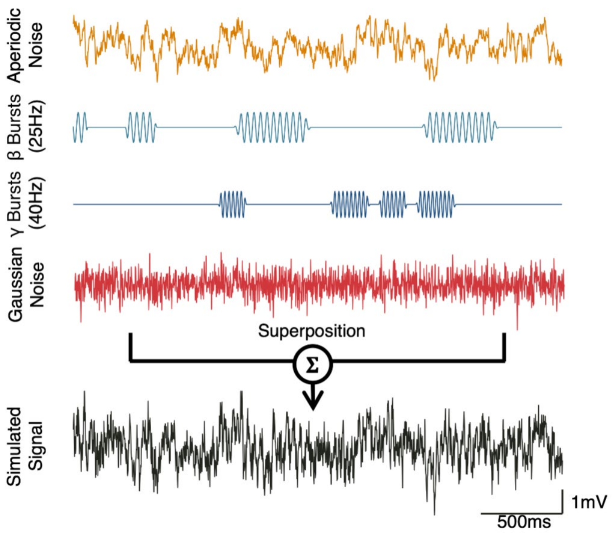
T_B : detected burst time interval



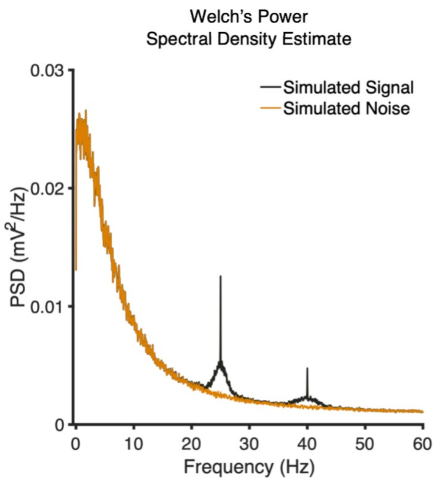
Methods / Properties	A: Bandpass Filtering	B: Envelope-Based	C: Single Taper	D: Multitaper	E: Wavelet
Domain	Time	Time	Time-Frequency	Time-Frequency	Time-Frequency
Transformation Type	None	Hilbert transform	Fourier transform	Fourier transform	Continuous Wavelet Transform
Time-Frequency Tradeoff	None Applicable	None Applicable	$\Delta f = ENBW_{Hanning} \cdot \left(\frac{f_s}{L}\right)$	$\Delta f = 2TW \cdot \left(\frac{f_s}{L}\right)$	$\sigma_{\psi(t)} = \sigma_{\hat{\psi}(w)} = \frac{1}{\sqrt{2}}$ $\sigma_t = s\sigma_{\psi(t)}$ and $\sigma_w = \frac{\sigma_{\hat{\psi}(w)}}{s}$ (wavelet dilation given by the scale s)

Schematics of Neural Signal Simulations

Simulation signal components



Power estimates of simulated bursts



Bursts

- Modelled with Tukey windows
- Duration from 3 – 12 cycles
- SNR_{dB} levels from -10 – 10 dB
- Amplitude constant of β=0.630 mV and γ=0.551 mV

Noise Processes

- Aperiodic noise with an all-pole IIR filter
- Gaussian noise sampled from $z\sim\mathcal{N}(\mu,\sigma^2)$ where $\mu = 0$ and $\sigma = 0.630/\sqrt[20]{10^{\mathrm{SNR_{dB}}}}$

Trials

- 11,000 trials (1000 signals of varying lengths of bursts per each SNR_{dB} level)
- Total duration per signal: 300 s

Burst Detection Efficiency

Definitions of Statistical Metrics

$$\text{Precision, } P = \frac{TP}{(TP+FP)}$$

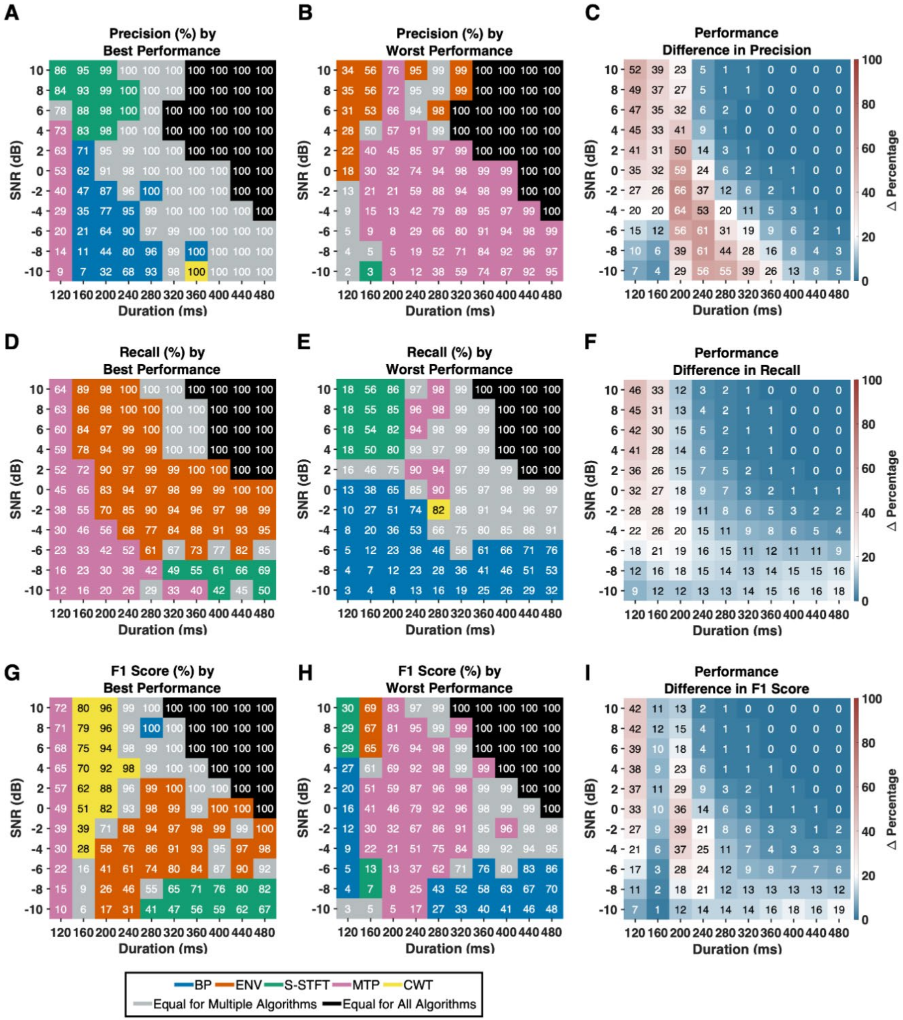
$$\text{Recall, } R = \frac{TP}{(TP+FN)}$$

$$\text{F1-Score, } F_1 = \frac{2PR}{P+R}$$

TP: True positives
FP: False positives
FN: False negatives

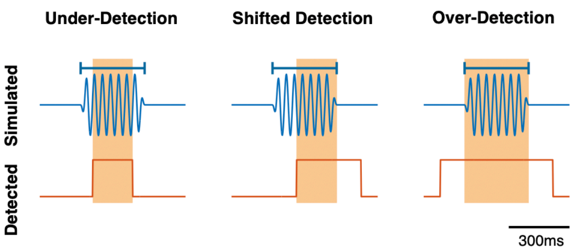
Note

- The bursts of shorter durations are relatively more dependent on the selected algorithms (C, F, I).
- MTP and CWT resulted with best performances for the most transient bursts (G).



Temporal Concurrence between Simulated and Detected Bursts

Schematics of temporal concurrence

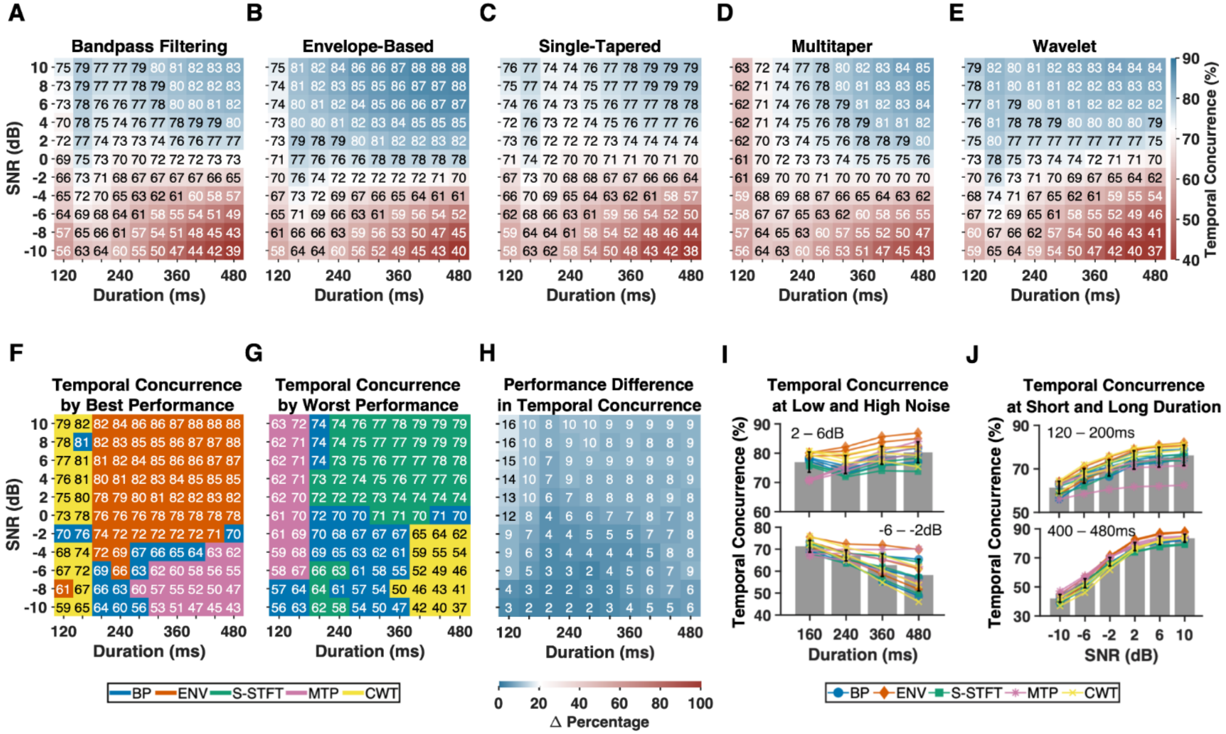


Temporal Concurrence =

$$\frac{1}{N_{TP}}\sum_{n=1}^{N_{TP}}\frac{\min(s_{n,stop},\ d_{n,stop})-\max(s_{n,start},\ d_{n,start})}{\max(s_{n,stop},\ d_{n,stop})-\min(s_{n,start},\ d_{n,start})}$$

where N_{TP} is the number of TP bursts and $\vec{S}_n = (s_{n,start}, s_{n,stop})$ and $\vec{D}_n = (d_{n,start}, d_{n,stop})$ for n^{th} *TP* burst indicate the onset and cessation of a real burst *S* and a detected burst *D*, respectively.

Detection of shorter transient bursts is algorithm-dependent



Applications of Algorithms on Beta Burst Detection in Open Field Test

Statistical Tests

Location occupancy: Two-Way ANOVA with Tukey's HSD

Burst rates

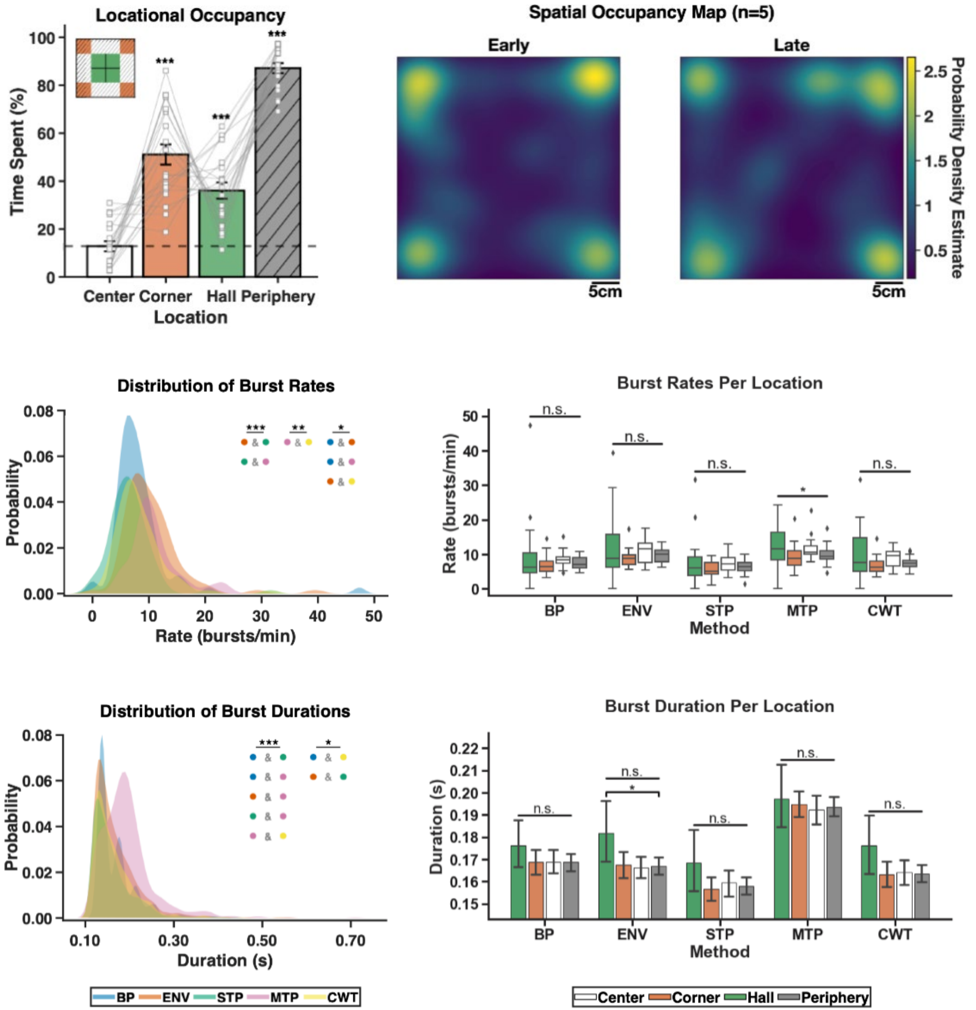
- **Algorithm dependency:** One-Way ANOVA with Tukey's HSD
- **Location dependency:** Kruskal-Wallis Test with Dunn's Test with Šidák Correction

Burst durations

- **Algorithm dependency:** Kruskal-Wallis Test with Dunn's Test with Šidák Correction
- **Location dependency:** One-Way ANOVA with Tukey's HSD

Note

- The burst detections and their signal properties are dependent on the selected algorithm.
- No statistically significant changes in burst rates and durations were reported with respect to the demarcated locations.



Conclusion

1. It is necessary to consider the **distinct advantages** of each method in relation to the burst properties one wants to study.

2. The burst-induced **dynamic changes in cognitive processes** were not observed in the open field test (i.e., non-trial based nature-like experiment), but we believe these observations will be seen from similar experiments in the future.

3. We encourage the **hybrid use of multiple methods** to maximize temporal precisions of burst detection, especially when cognition and behaviors have to be correlated.

Thank you for listening

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