

Spike-field coherence (and cross-covariance)

Computing the coherence (Part 2)

Instructor: Mark Kramer

Coherence: words

A constant phase relationship between two signals, at the same frequency, across trials.

Note

- *“same frequency”*

- *“across trials”*

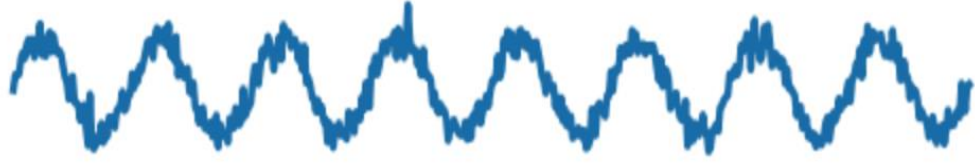
Coherence: idea

Ex: Record data simultaneously from two sensors, across multiple trials

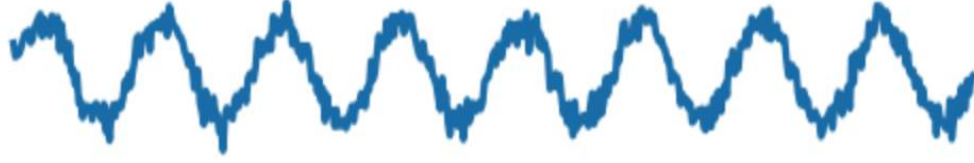
x (field: EEG, LFP, ...)

y (field: EEG, LFP, ...)

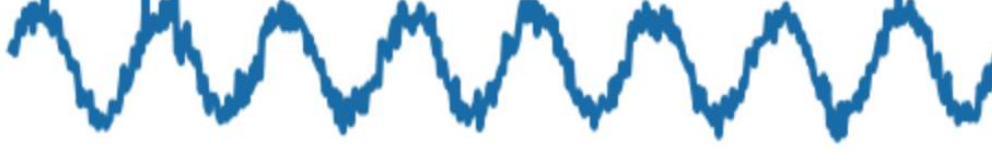
Trial 1



Trial 2



Trial 3



Is there a *constant phase relationship* between x & y , at the same f , across trials?

Coherence: equations

Remember:

$$K_{xy, j} = \frac{|\langle S_{xy, j} \rangle|}{\sqrt{\langle S_{xx, j} \rangle} \sqrt{\langle S_{yy, j} \rangle}}$$

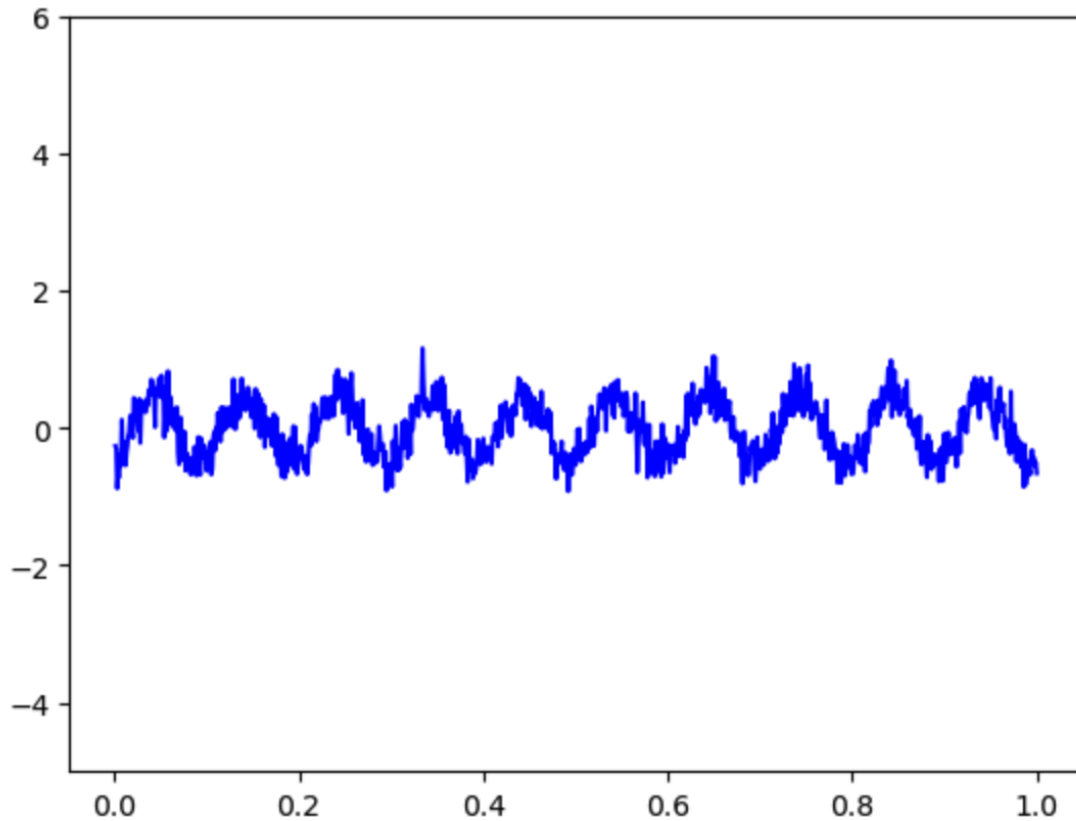
$S_{xy, j}$ = Cross-spectrum at frequency index j

$S_{xx, j}, S_{yy, j}$ = Auto-spectra at frequency index j

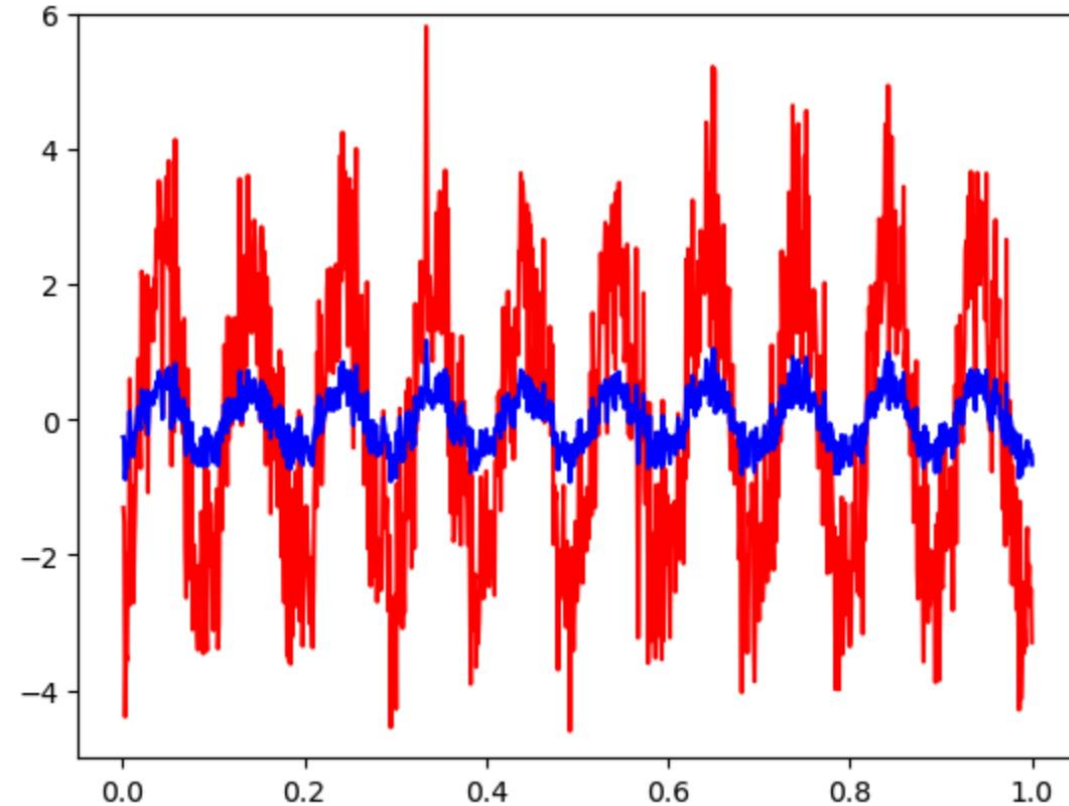
$\langle S \rangle$ = Average of S over trials

Coherence: impact of scaling

Q. How does scaling x or y impact the coherence?



multiply
by
5



Q. Impact on coherence between x and y?

Coherence: impact of scaling

Scale: $A_{j,k} \rightarrow 5A_{j,k}$

$$\kappa_{xy, j} = \frac{\left| \sum_{k=1}^K 5A_{j,k} B_{j,k} \exp(i\Phi_{j,k}) \right|}{\sqrt{\sum_{k=1}^K (5A_{j,k})^2} \sqrt{\sum_{m=1}^K B_{j,m}^2}}$$

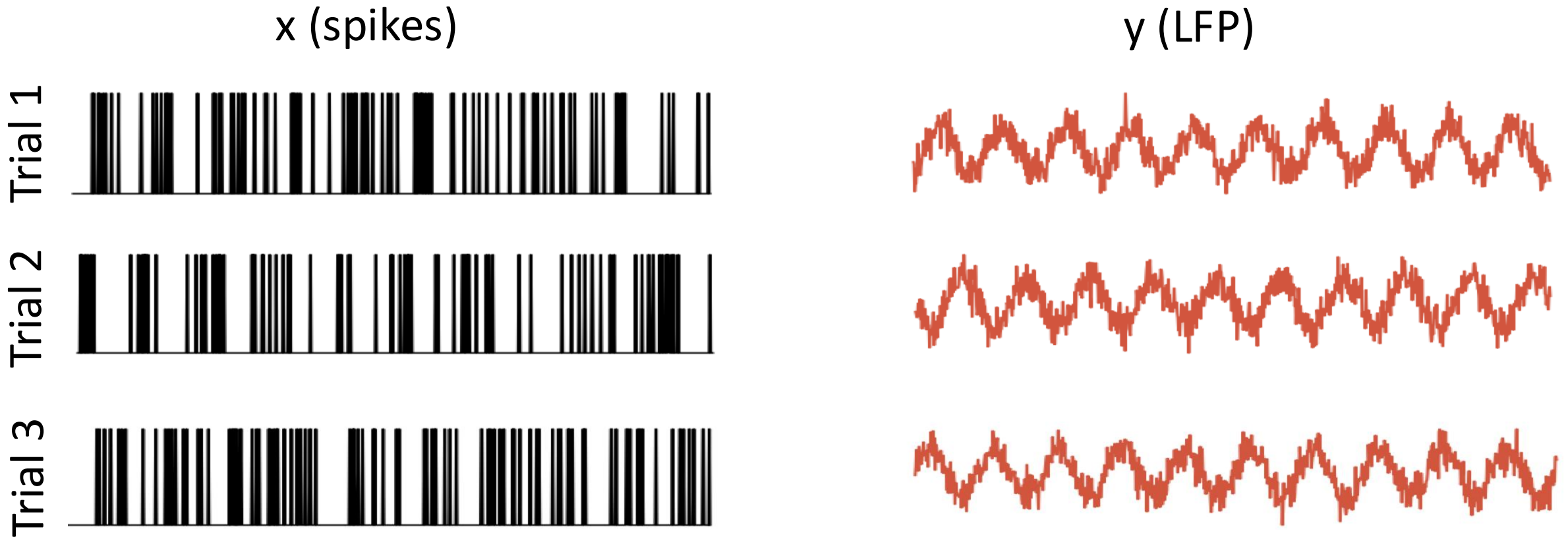
The 5's cancel \rightarrow no impact on coherence

Q. How does scaling x or y impact the coherence?

A. It doesn't.

Spike-field coherence: idea

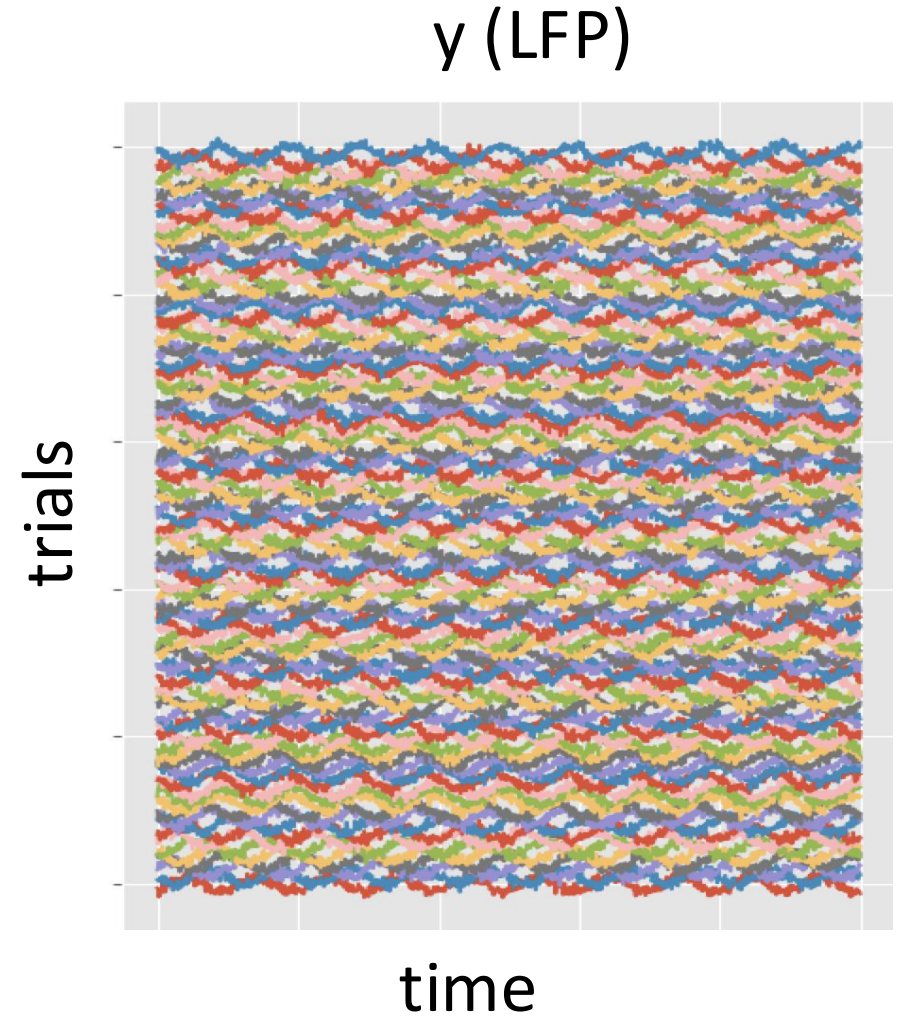
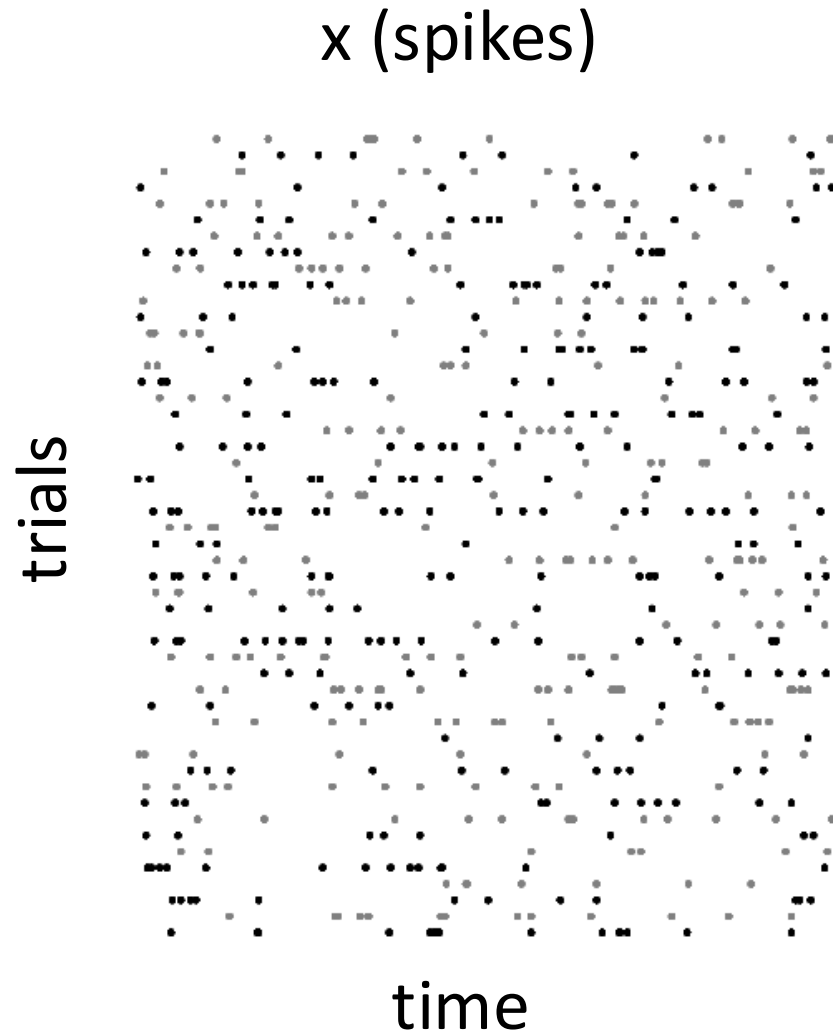
Example: Record data simultaneously from two sensors, across multiple trials



Is there a *constant phase relationship* between x & y , at the same freq, across trials?

Spike-field coherence

Consider the data:

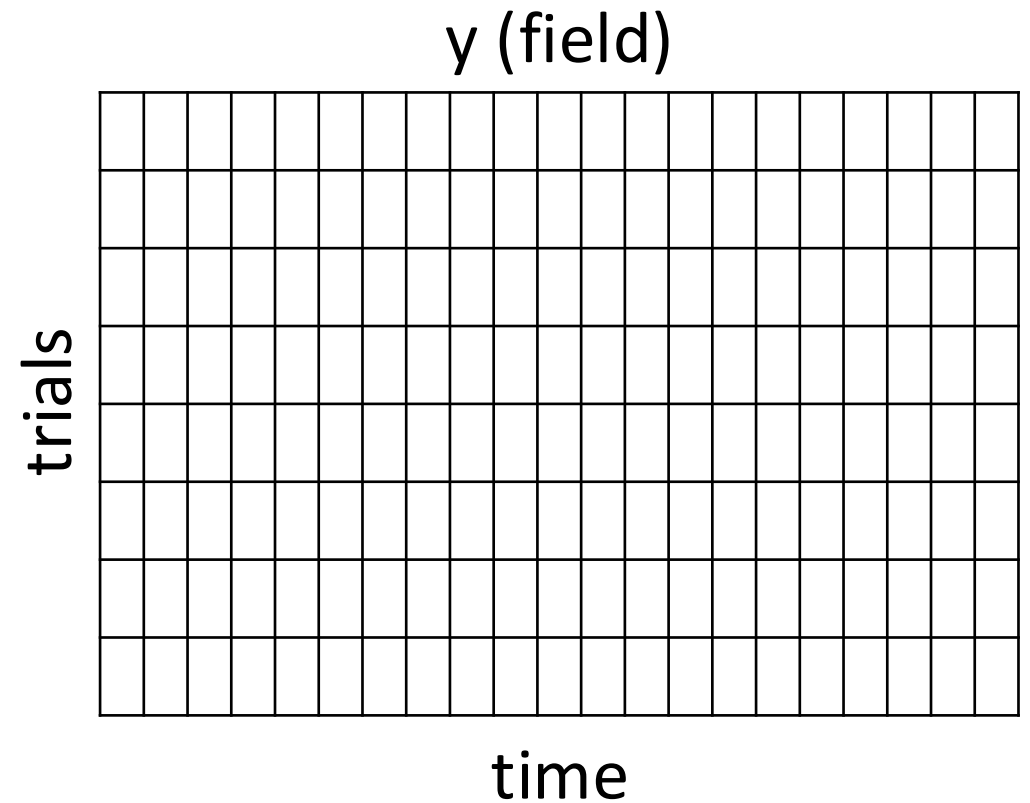
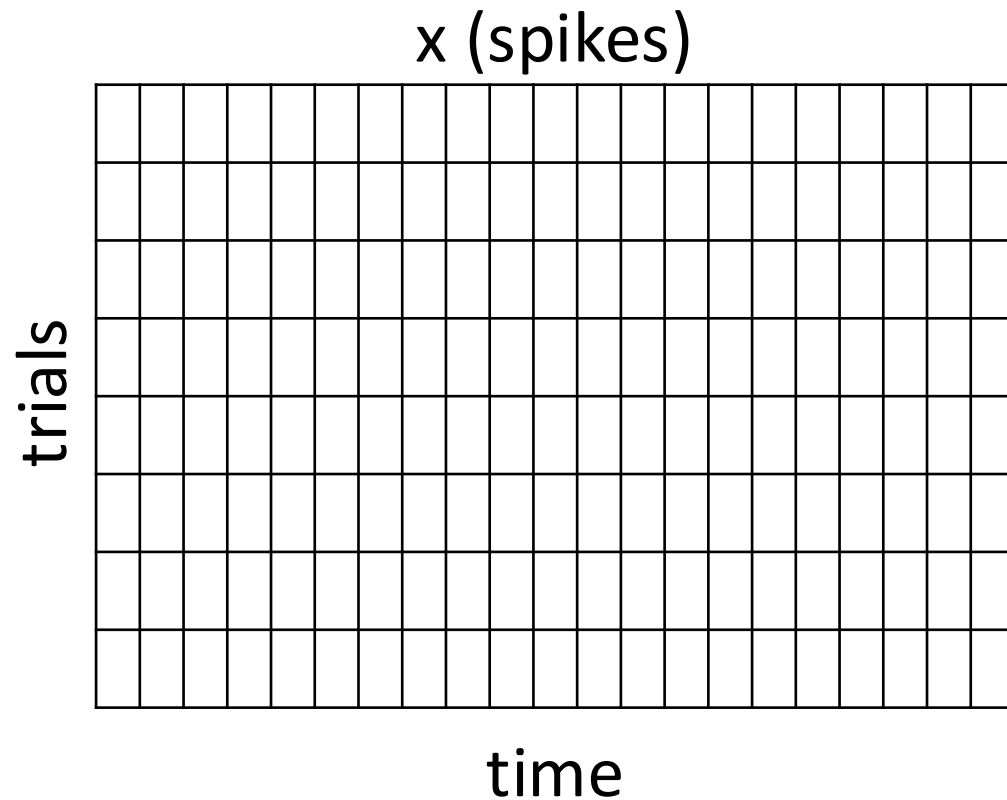


We want a measure of consistent neural spiking at a specific phase of the field ...

Spike-field coherence : idea

Example: Record data simultaneously from two sensors, across multiple trials

Organize the data ...



Each row is a trial, each column is a time point, organize data in matrices.

Spike-field coherence: equation

$$\kappa_{ny, j} = \frac{\text{trial averaged } \underline{\text{cross}} \text{ spectrum}}{\sqrt{\text{trial averaged } \underline{\text{spike}} \text{ spectrum}} \sqrt{\text{trial averaged } \underline{\text{field}} \text{ spectrum}}}$$
$$\kappa_{ny, j} = \frac{|\langle S_{ny, j} \rangle|}{\sqrt{\langle S_{nn, j} \rangle} \sqrt{\langle S_{yy, j} \rangle}}$$

trial averaged spike spectrum

trial averaged field spectrum

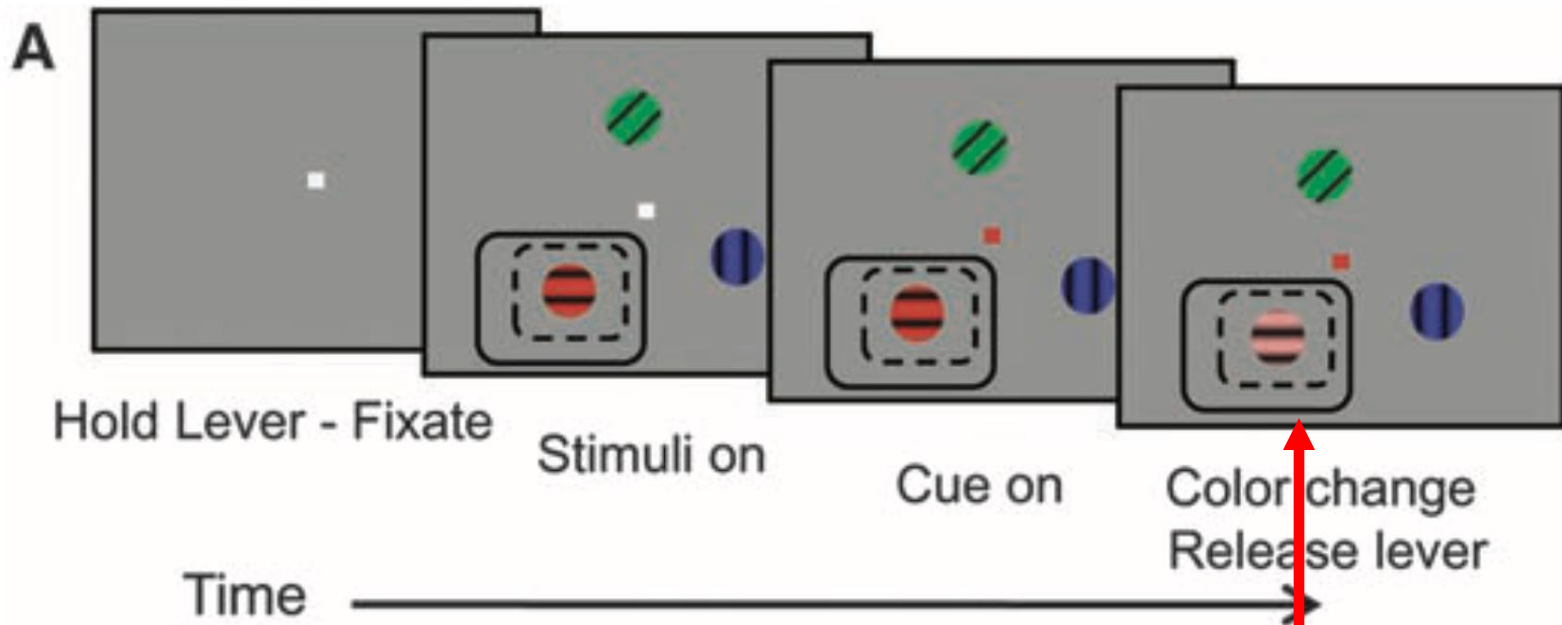
y = field signal (e.g., EEG, MEG, LFP, ...)

n = spike train (e.g., [0 0 0 0 0 0 1 0 0 0 0 0 0 0 ...])

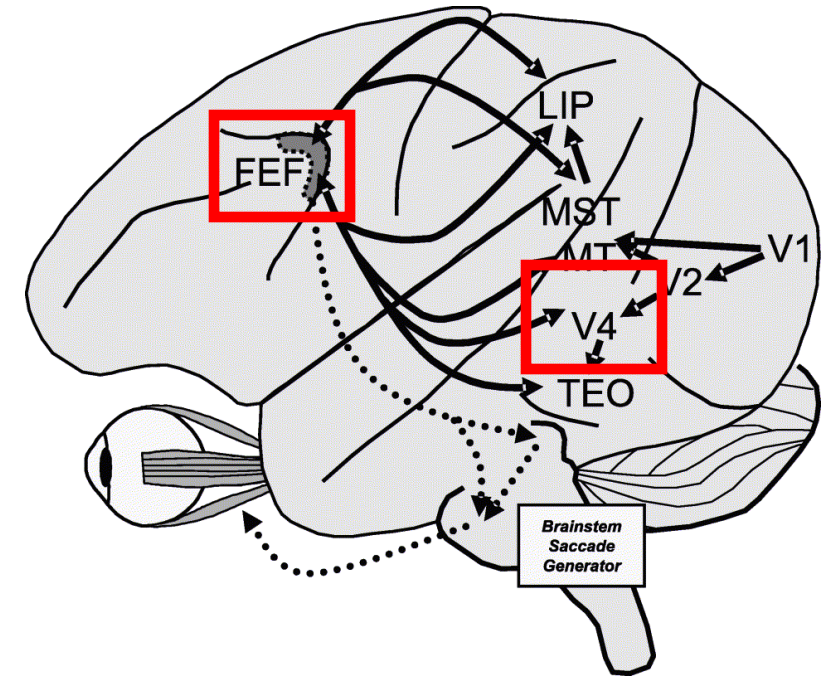
Same equations ... but new problems ...

Spike-field coherence: example

[Gregoriou et al., Science, 2009]



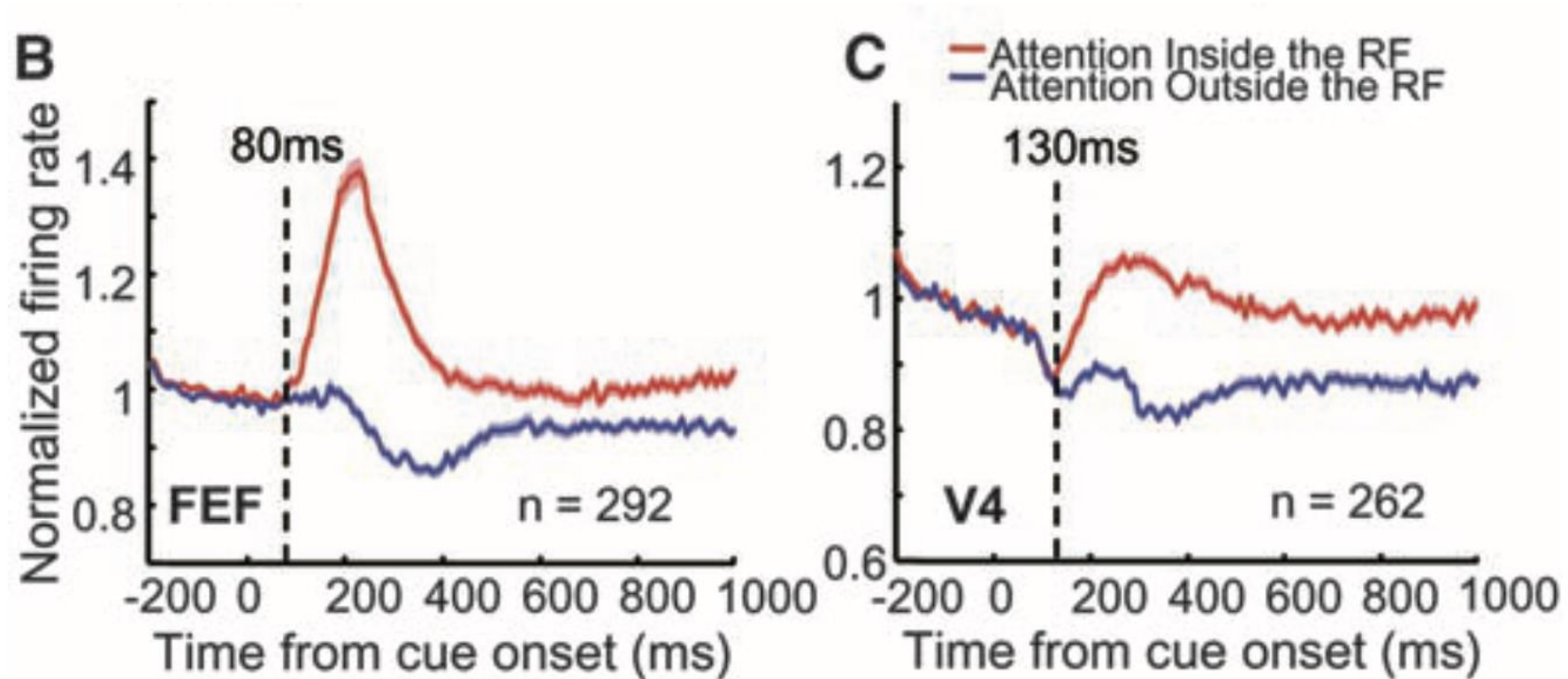
in the receptive field (RF) of FEF & V4



[Thompson & Bichot, Prog. Brain Res, 2005]

Spike-field coherence: example

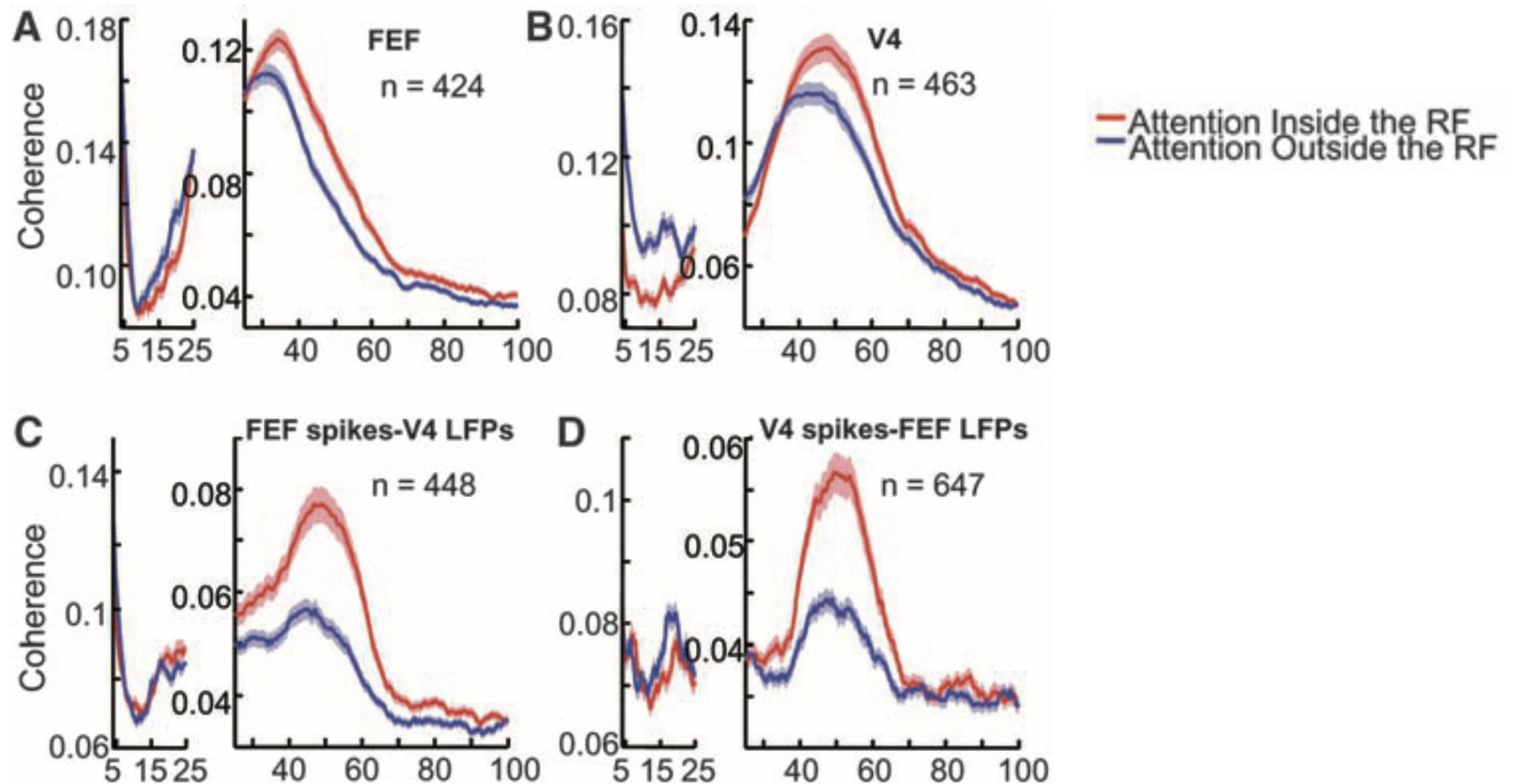
[Gregoriou et al., Science, 2009]



Firing rate increases when attending to stimulus in receptive field

Spike-field coherence: example

[Gregoriou et al., Science, 2009]



Spike field coherence increases when attending to stimulus in receptive field

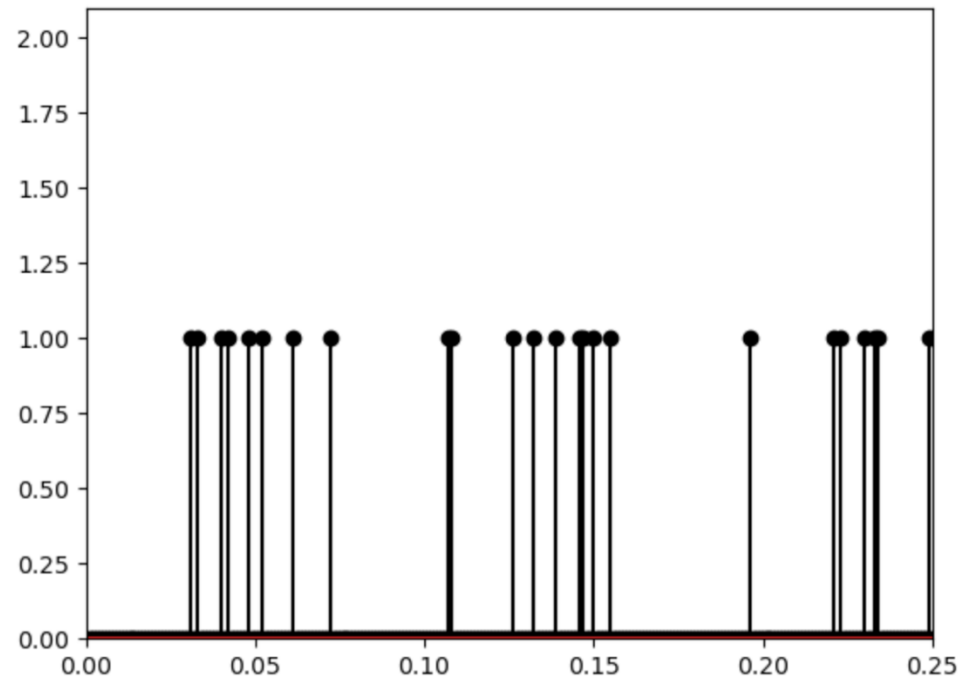
Spike-field coherence: dependence on rate

So, firing rate & spike-field coherence increase.

Q. Confounds?

Q. How does scaling the spikes (x) impact the spike-field coherence?

Q: How do you scale a spike train?



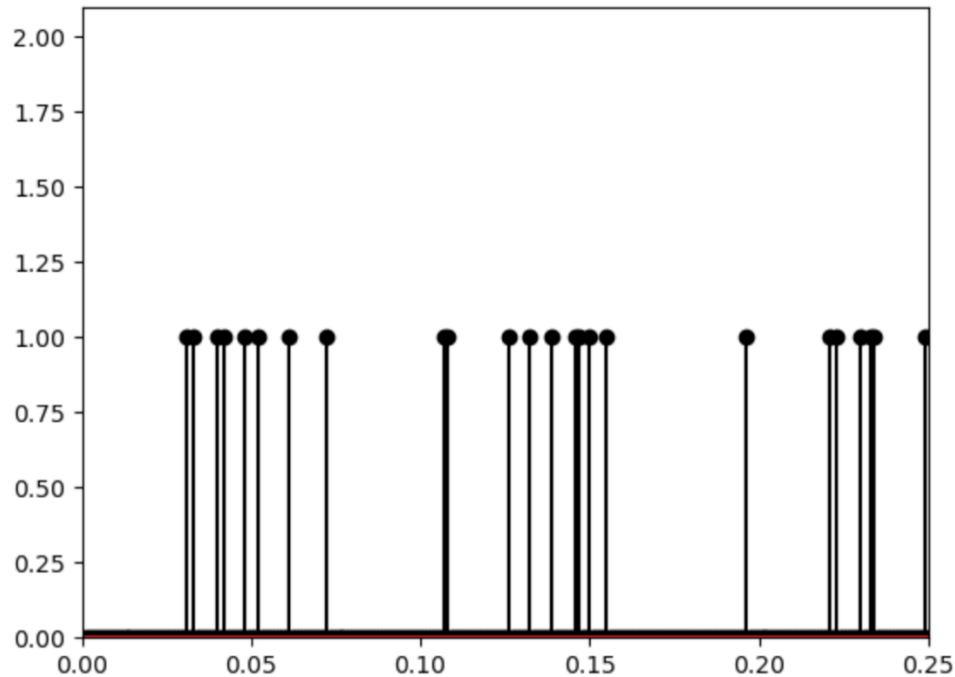
multiply
by
2



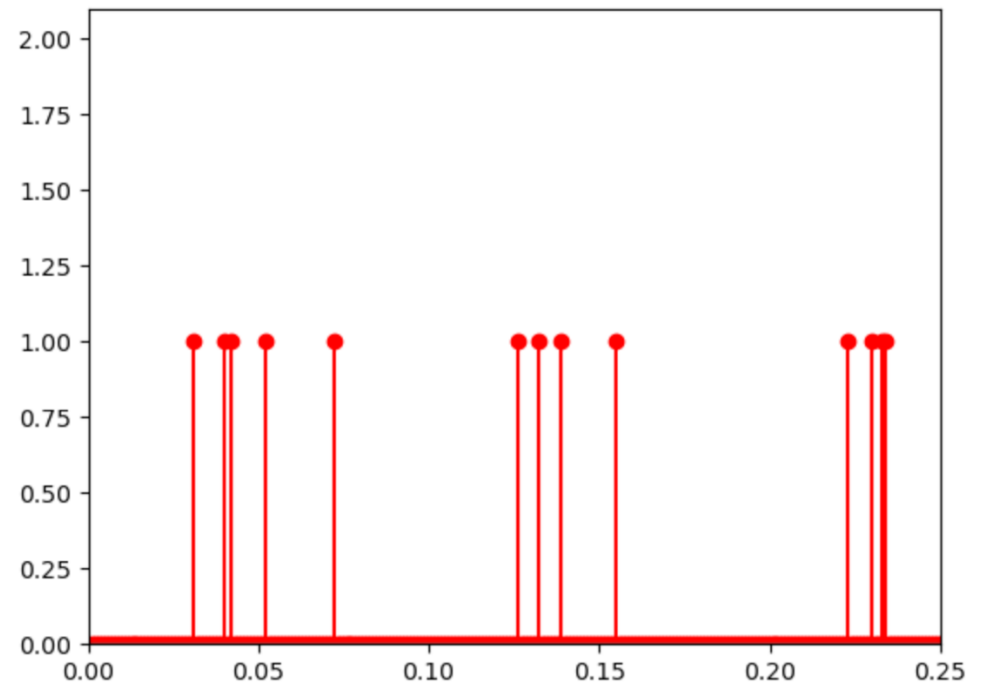
Spike-field coherence: dependence on rate

Q. How does scaling x or y impact the coherence?

Q: How do you scale a spike train?



thin
by
 $1/2$
→

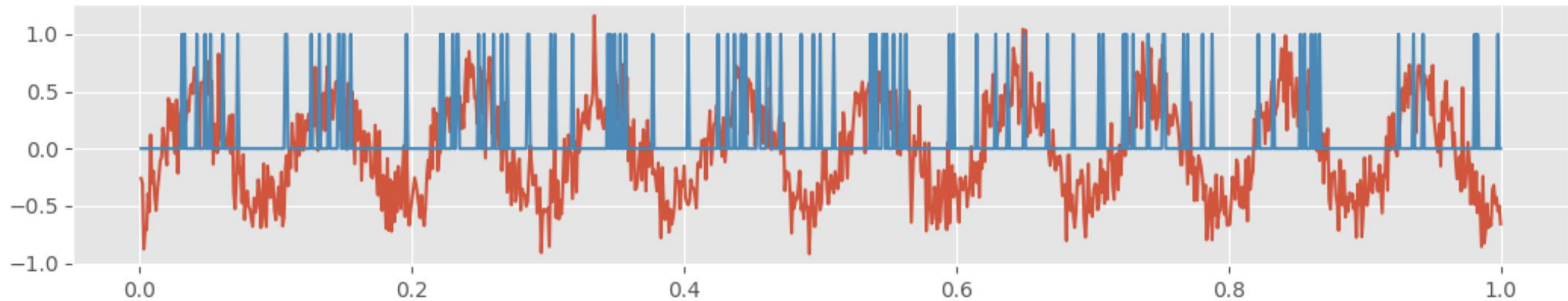


change the firing rate

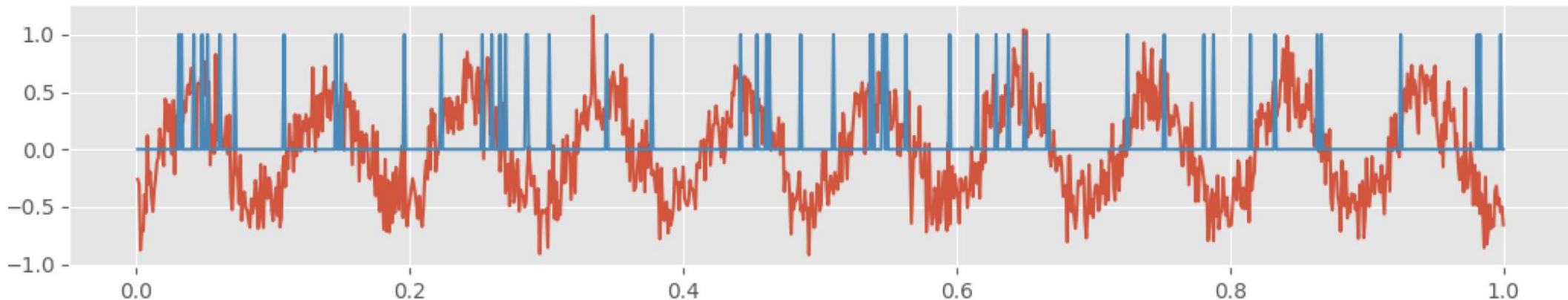
Spike-field coherence: dependence on rate

Q: Does the spike-field coherence depend on the firing rate of the neuron?

Original spike & field



Scale the spiking (remove 50% of spikes, chosen at random, “thinning”)



Spike-field coherence: dependence on rate

Q: Does the spike-field coherence depend on the firing rate of the neuron?

Here, rate: expected number of spikes in a given duration

Try it ...

Python

Spike-field coherence: dependence on rate

Q: Does the spike-field coherence depend on the firing rate of the neuron?

Observations:

greater thinning \rightarrow fewer spikes \rightarrow lower coherence

as the rate tends to 0, so does the spike-field coherence

The spike-field coherence reflects

- (1) the relationship between spiking activity and the phase of field, and
- (2) the mean firing rate.

Spike-field coherence: dependence on rate

Q: What next?

Q: If, in your experiment, the overall spike rate differs between two neurons, then how do you compare the spike-field coherence?

- include a rate adjustment factor in the coherence measure to account for rate dependence.
- build a generalized linear model to separate overall neural activity from spike train-LFP oscillatory coupling.

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Computational Neuroscience

Rate-adjusted spike–LFP coherence comparisons from spike-train statistics



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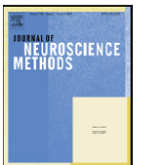
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Computational Neuroscience

A procedure for testing across-condition rhythmic spike-field association change

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