Introduction to Time Series Analysis

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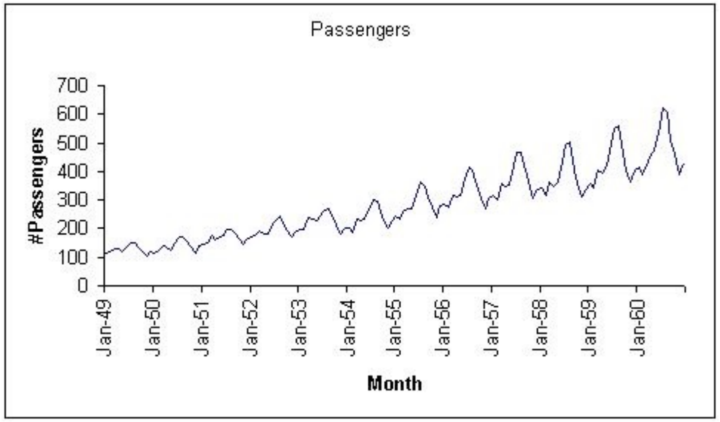
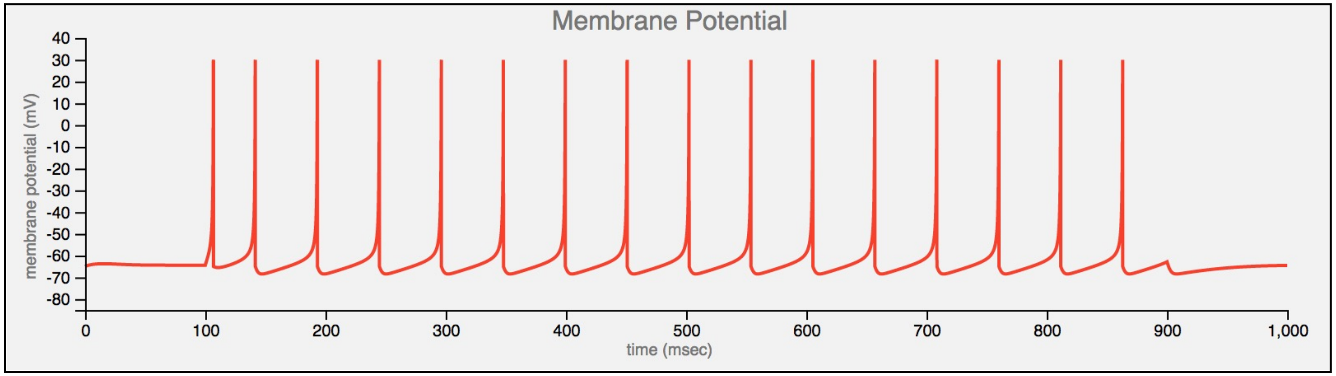
*For neuroscience basics.
Time series models (e.g. economic, climate forecasts) go beyond our scope

Introduction to Time Series Analysis

What are time series?

~~Any variable sampled at regular intervals across time~~





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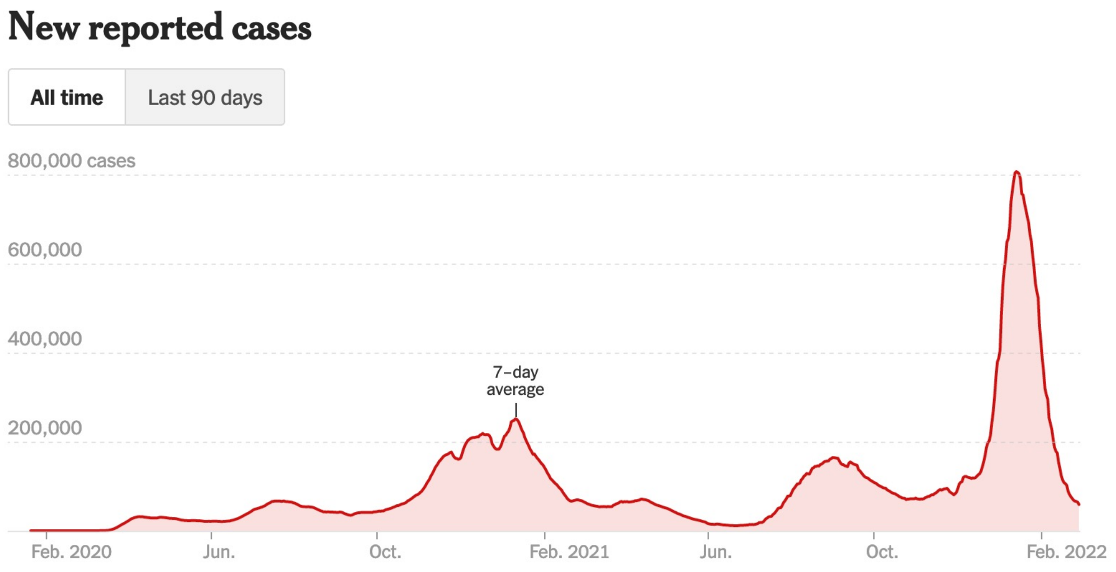

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What are time series?

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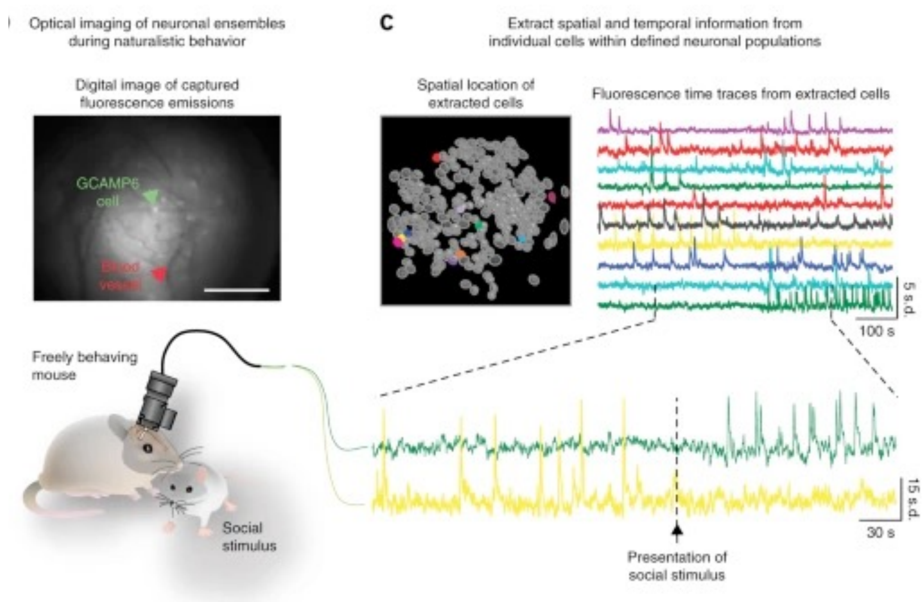
- Neural data: neuron spikes, LFPs, Ca++ signals (neurons, fiber photometry), neurochemical measures (eg. voltammetry), EEG, fMRI BOLD



Resendez et al., 2016

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- Other physiology: heart/respiratory rate, GSR, pupil dilation

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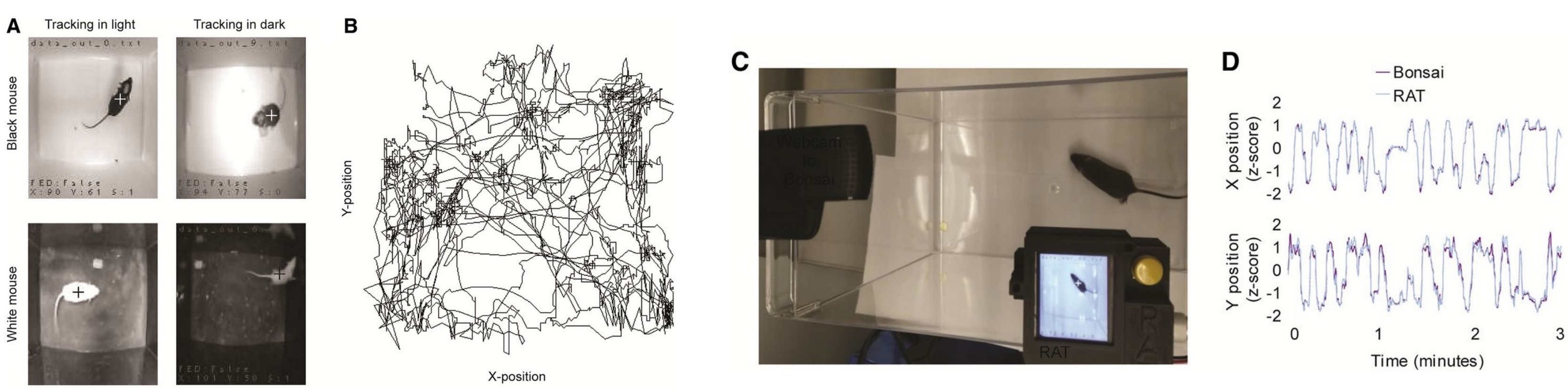

Krynitsky et al., eNeuro 2020

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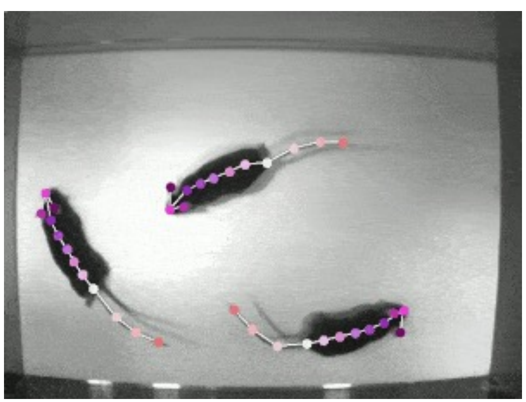

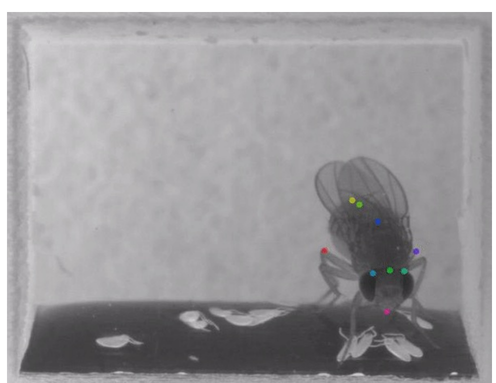

www.mackenziemathislab.org/deeplabcut

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- Other physiology: heart/respiratory rate, GSR, pupil dilation
- Behavior measures: position (x,y coordinates), speed, heading, gaze position, responses (e.g. lever presses)
- Size or counts of something growing or shrinking
- Temperature
- Image pixels in an animation
- Anything!

Introduction to Time Series Analysis

What are time series?

~~Any variable sampled at regular intervals across time~~

Regular intervals = equally spaced!!

Introduction to Time Series Analysis

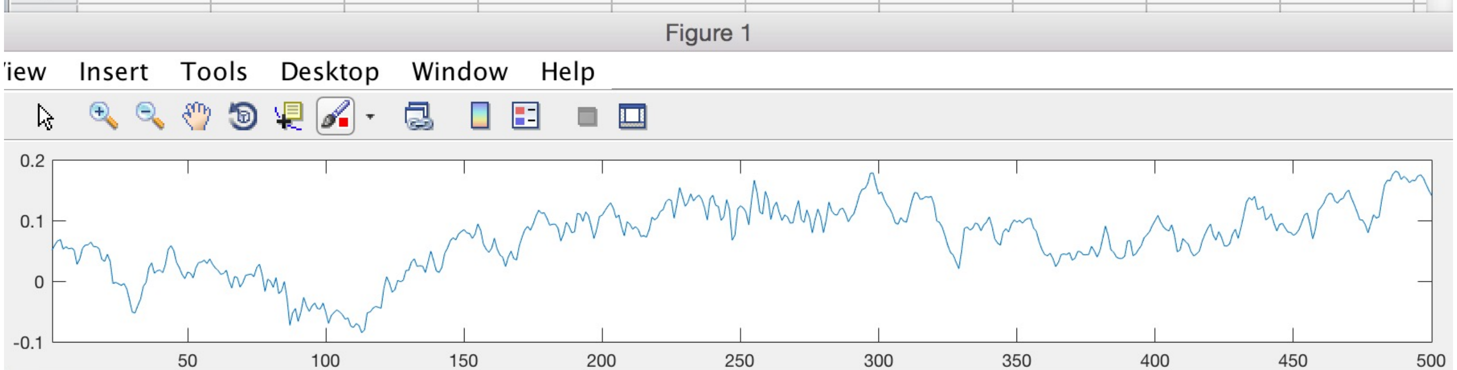
What are time series?

~~Any variable sampled at <u>regular intervals</u> across time~~

Regular intervals = equally spaced!!

This means you are discretizing time

	1	2	3	4	5	6	7	8	9	10
1	0.0513	0.0596	0.0664	0.0684	0.0525	0.0566	0.0532	0.0544	0.0510	0.0273
2										
3										



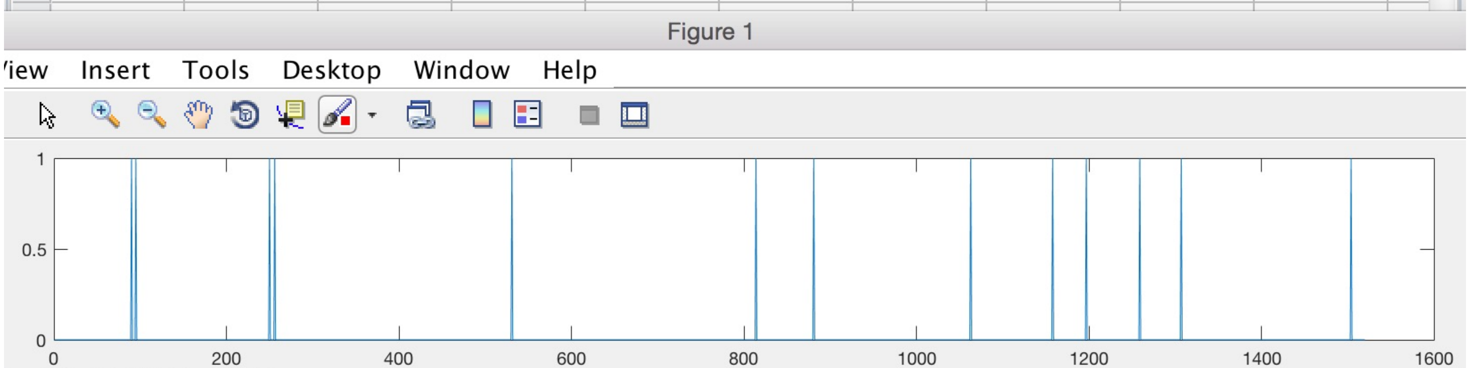
Events (e.g. neuron spiking, lever pressing) can be turned into a time series

"samples" are short time windows

0 = no event in the time window

1 = event occurred

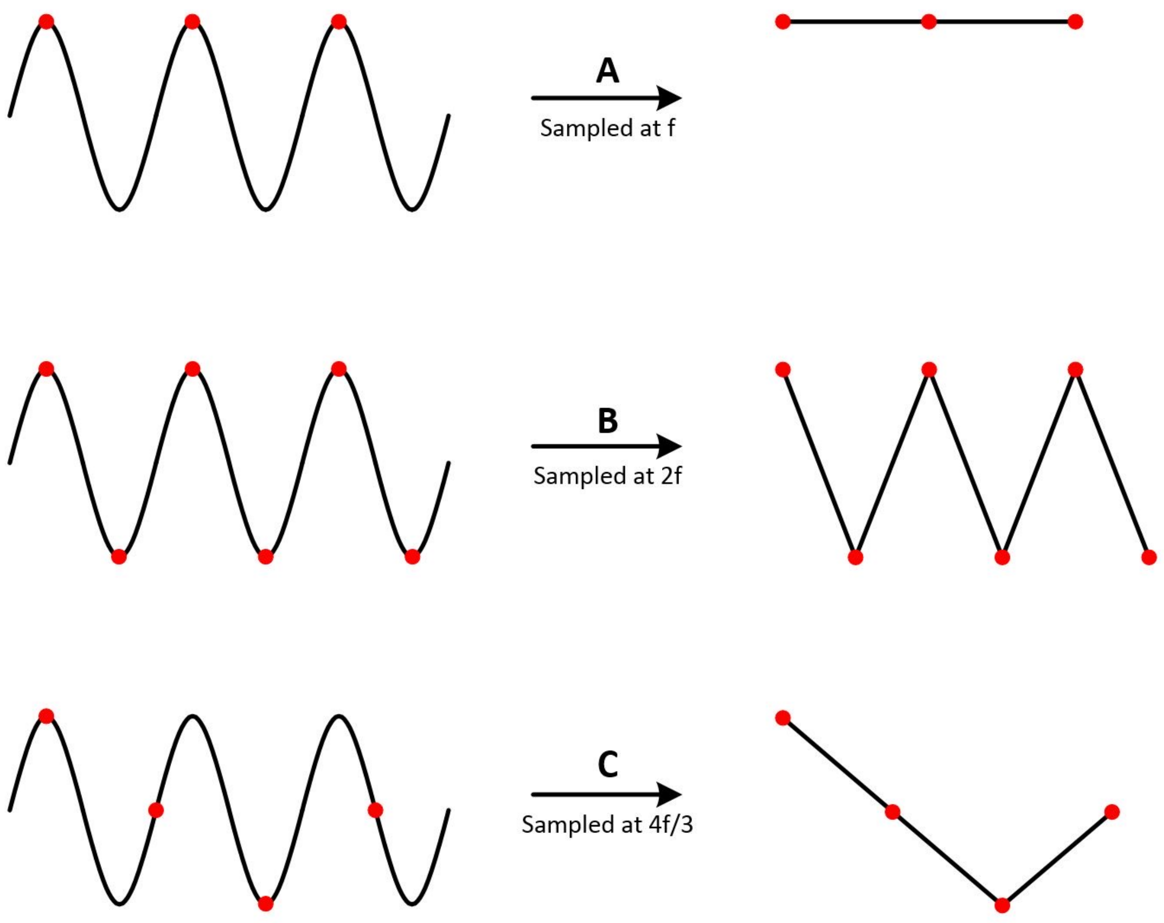
	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2										
3										



Considerations in time series sampling:

*You must have a concept of relevant timescales for your measure

- sampling rate too low -> you will not optimally capture trends in the data



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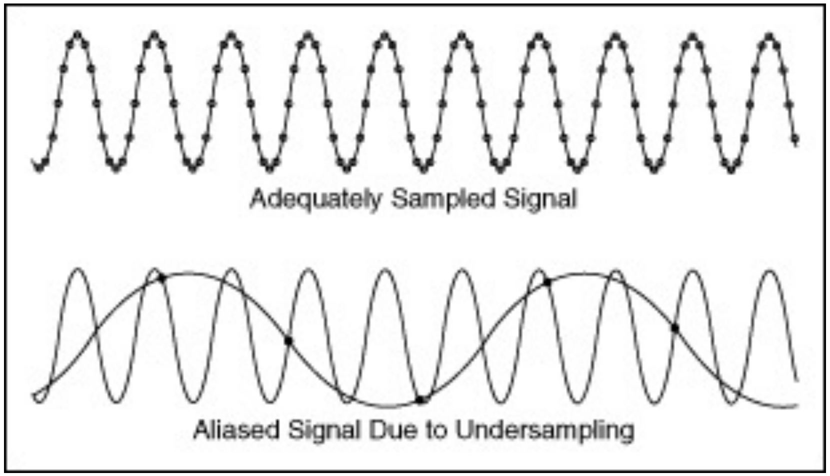
Aliasing



<u>Nyquist theorem for periodic signals</u>: the sampling rate for a periodic signal must be >= 2x the highest frequency of interest

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- sampling rate too high -> file sizes explode

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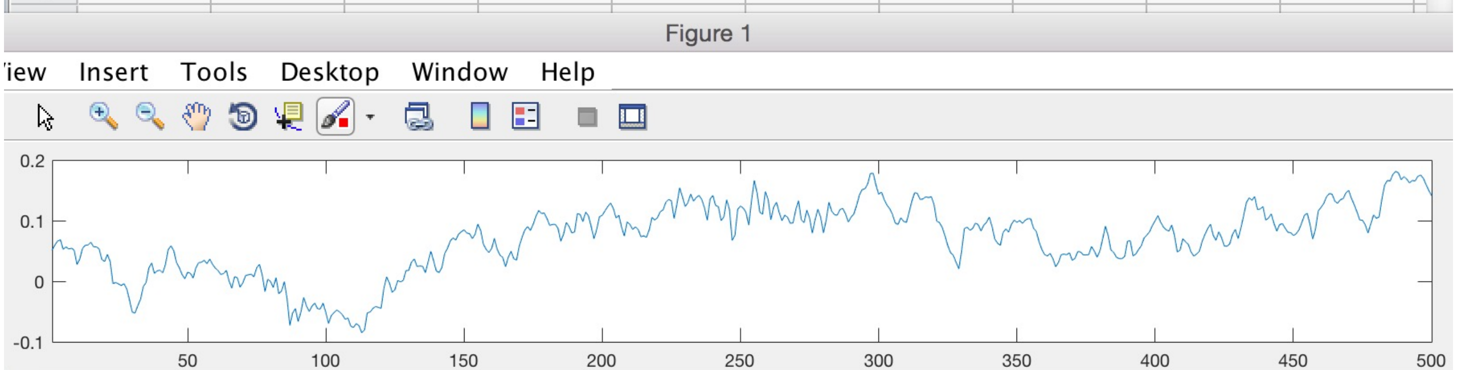
* Each observation has a *time stamp*
  - these time stamps are necessary to align different streams of data

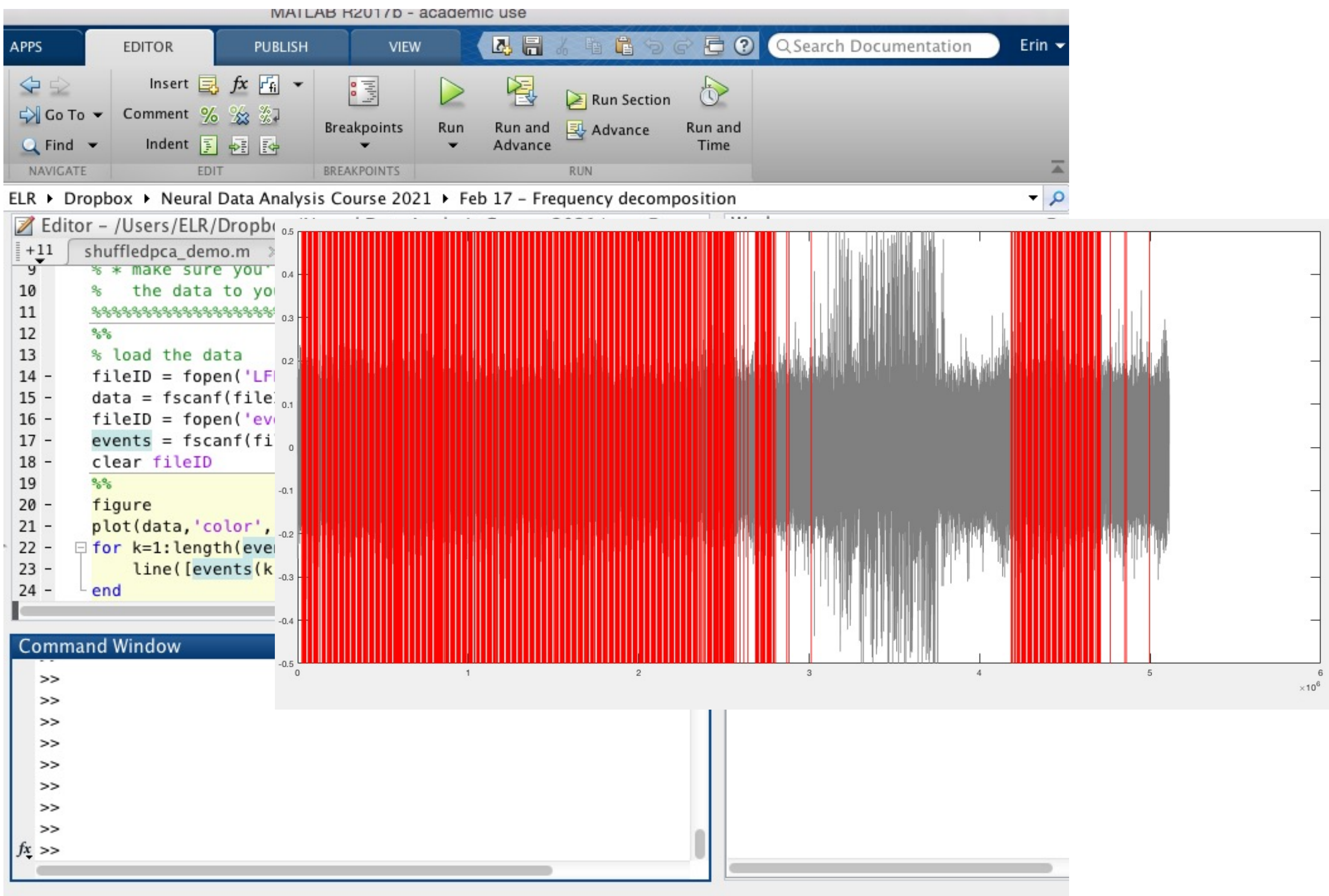
This means you are discretizing time

	1	2	3	4	5	6	7	8	9	10
1	0.0513	0.0596	0.0664	0.0684	0.0525	0.0566	0.0532	0.0544	0.0510	0.0273
2										
3										



Example: Aligning time series to an event

See *TimeSeriesDemoScript.m* or Time Series Demo in R



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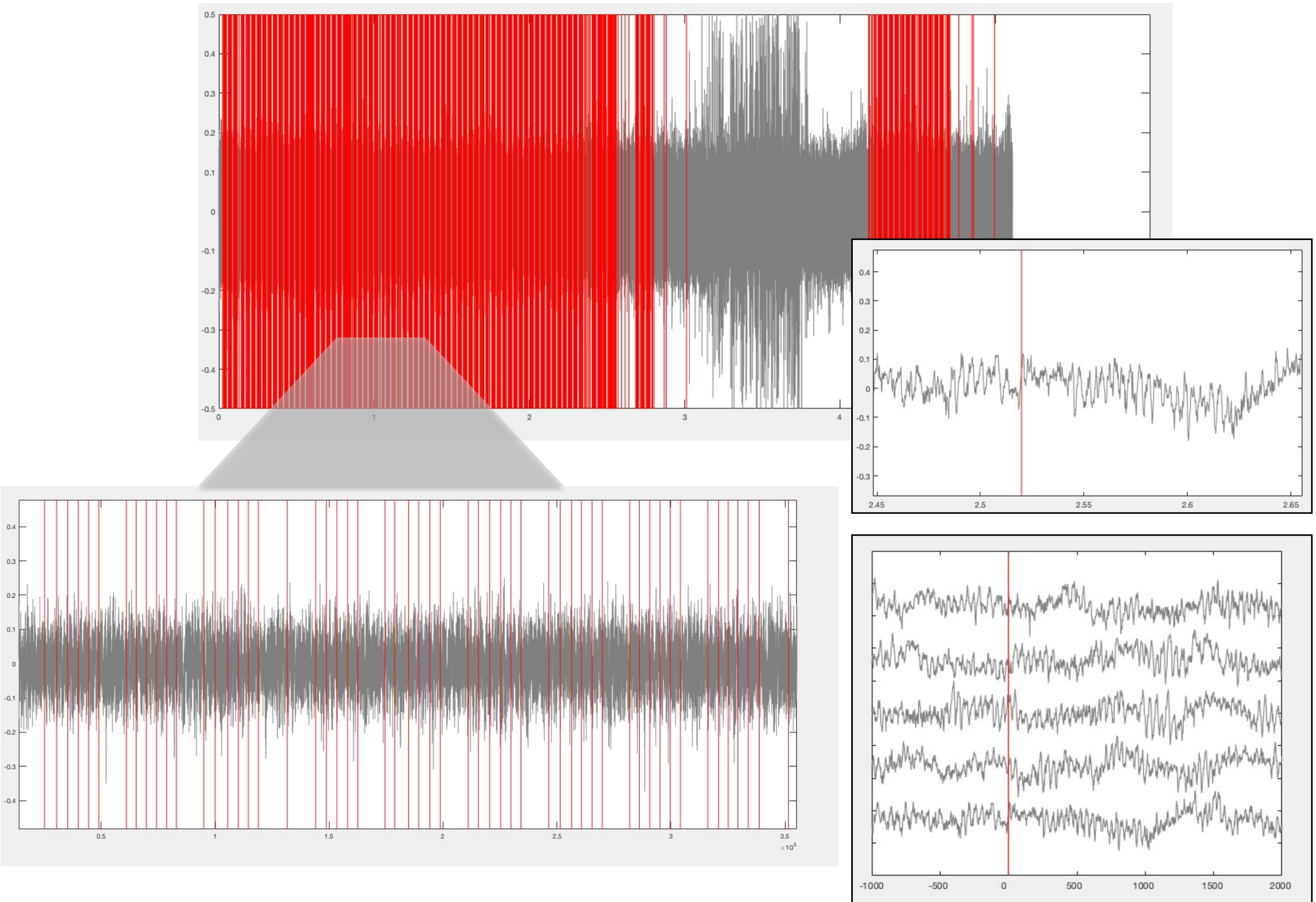
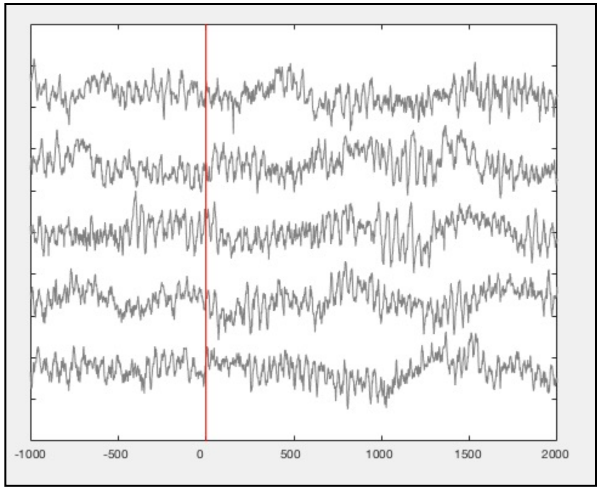
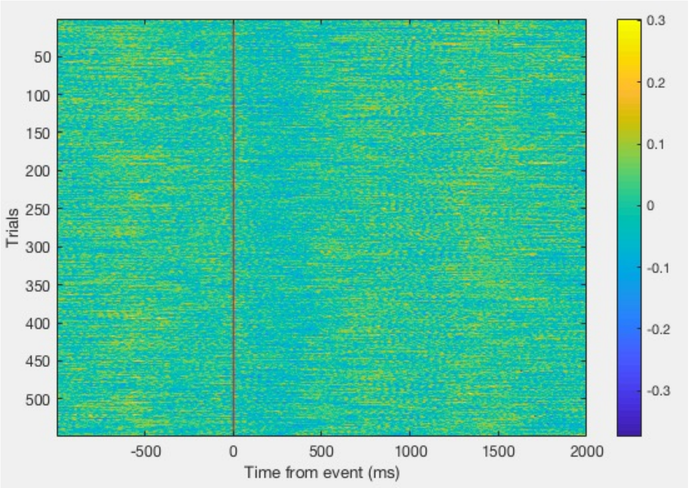
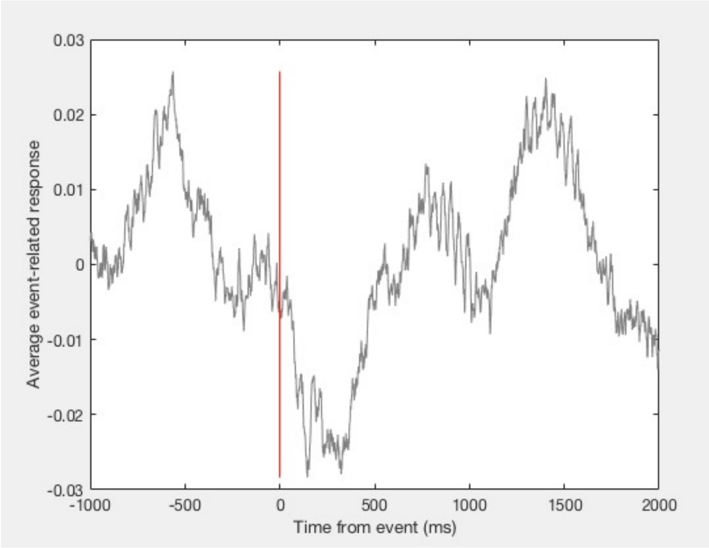


Example: Aligning time series to an event

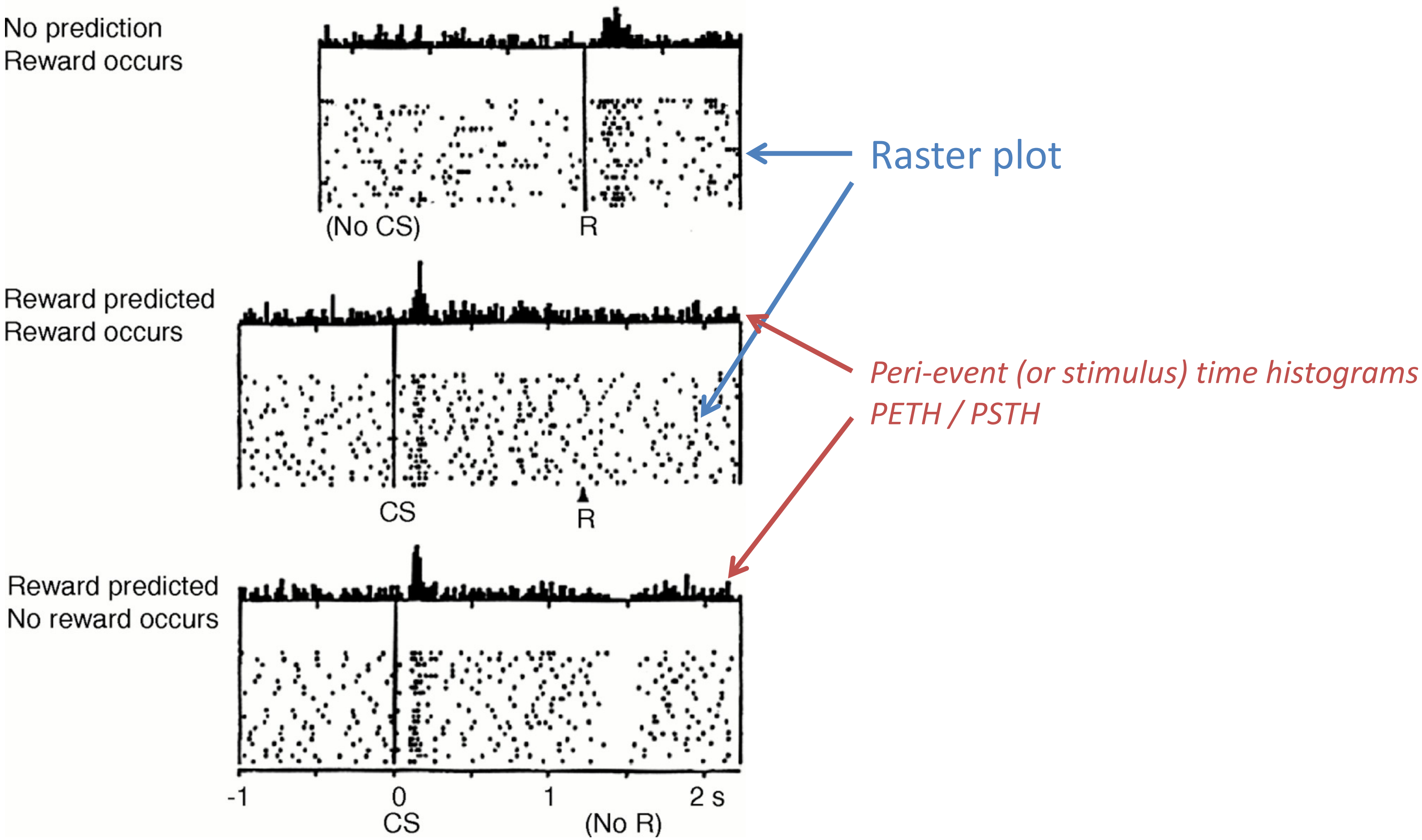


all trials





This also works for time series of discrete observations



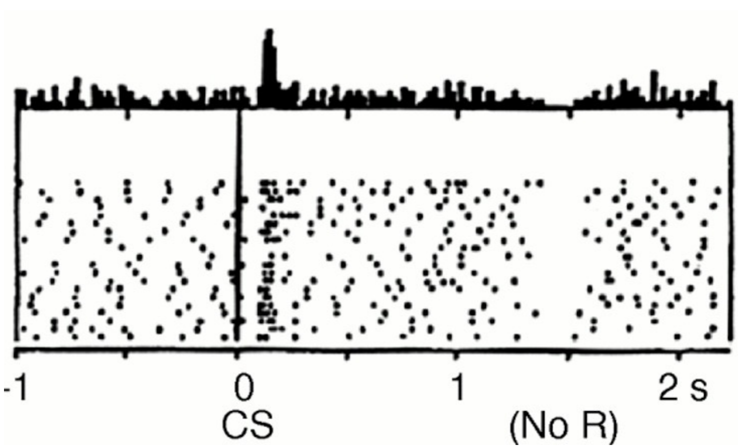
Schultz et al., 1997 Science

Why do this?

*Aligning data repeatedly samples changes in your data relative to ongoing events

e.g.

- look for event-related responses



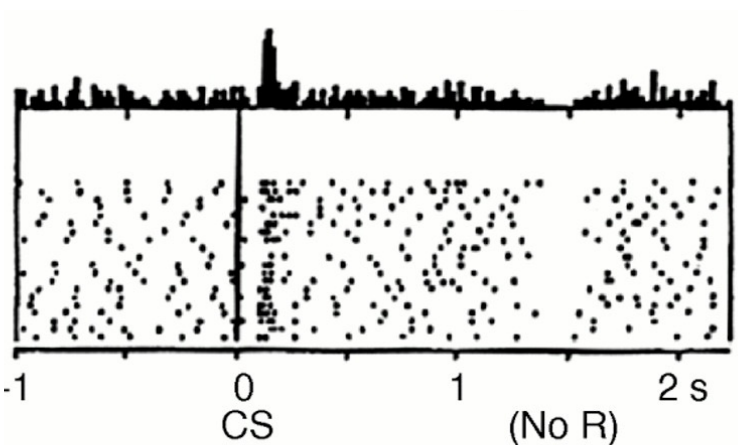
Schultz et al., 1997 Science

Why do this?

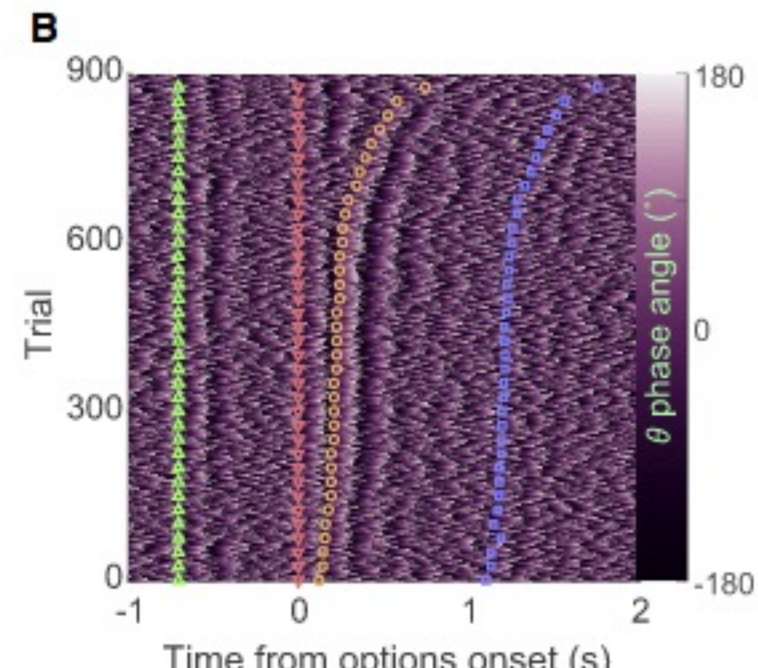
*Aligning data repeatedly samples changes in your data relative to ongoing events

e.g.

- look for event-related responses
- contrast responses to different events
- consider if data are aligned to the wrong event



Schultz et al., 1997 Science



Knudsen and Wallis, 2020

Optional steps to consider…

Preprocessing = steps taken to “clean up” the data before further analysis

Examples:

- normalizing (mean-subtraction, z-scoring, normalizing to a baseline, etc.)

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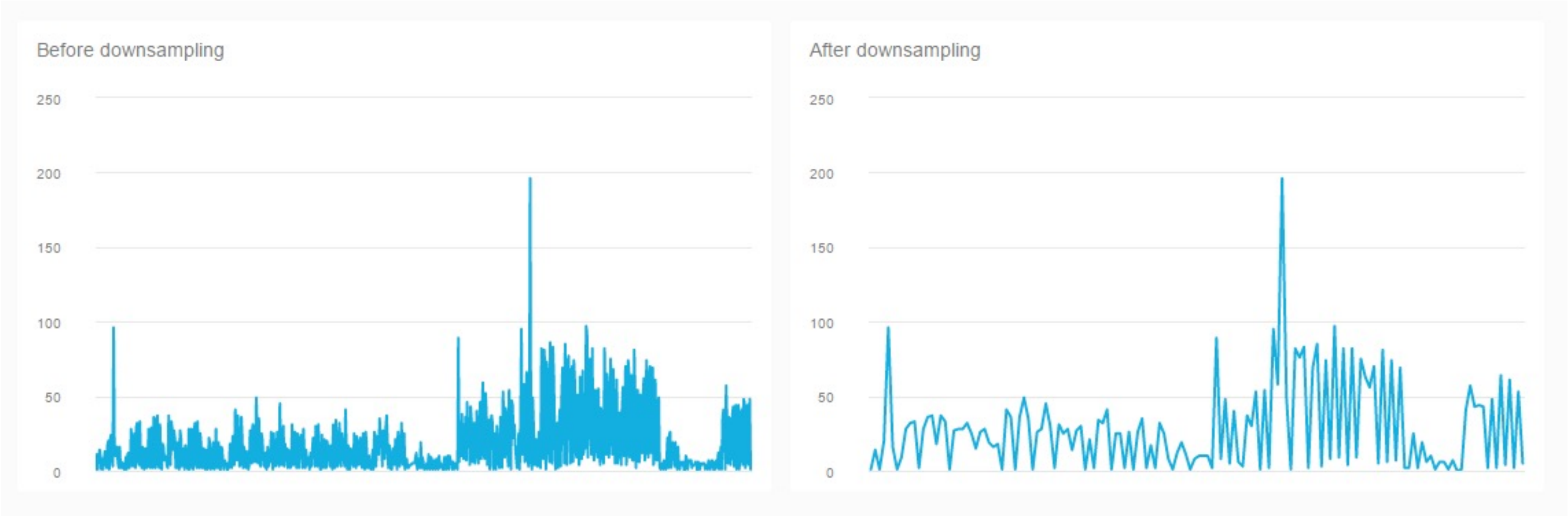
- downsampling



Optional steps to consider…

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Examples:

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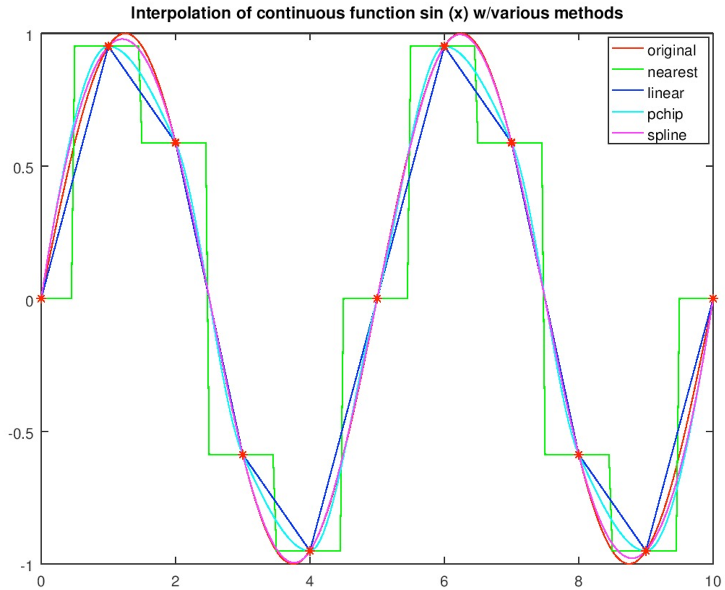
- interpolating



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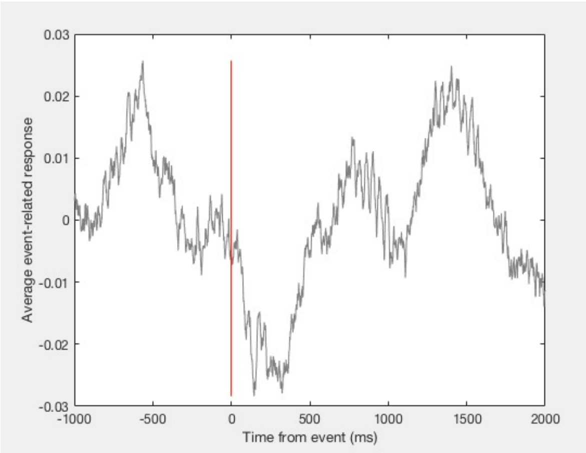
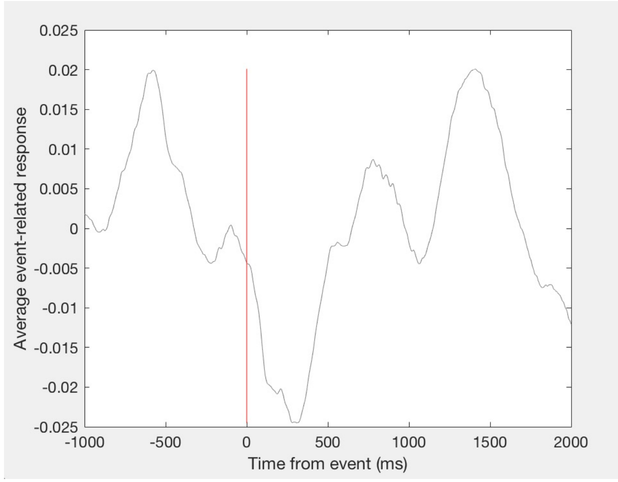
Examples:

- normalizing (mean-subtraction, z-scoring, normalizing to a baseline, etc.)
- downsampling
- interpolating
- smoothing



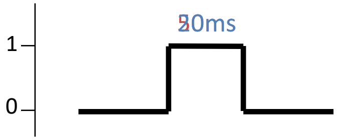
100ms moving average →



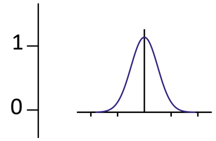
Data smoothing

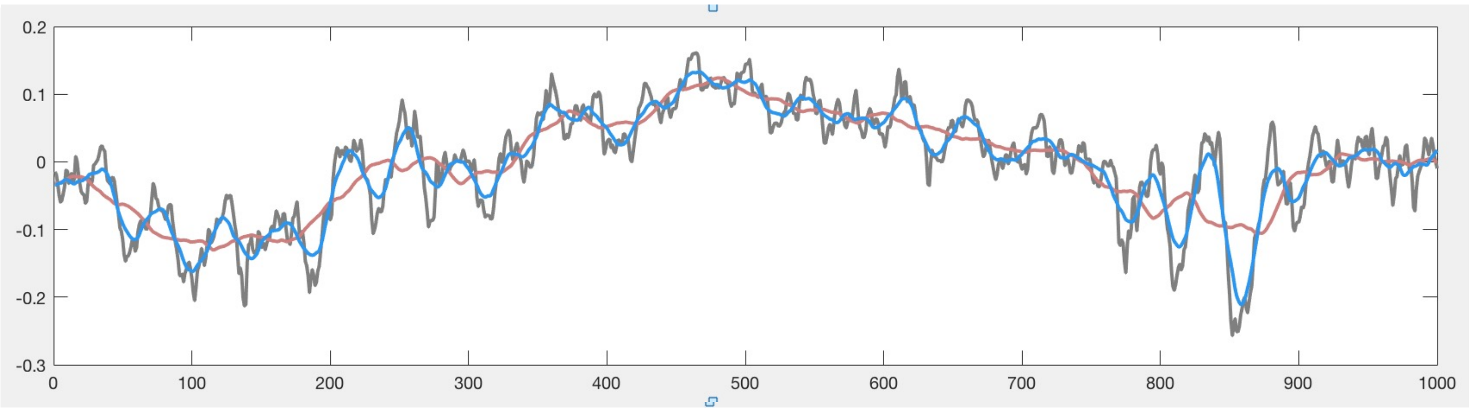
- These techniques *convolve* the time series with another function

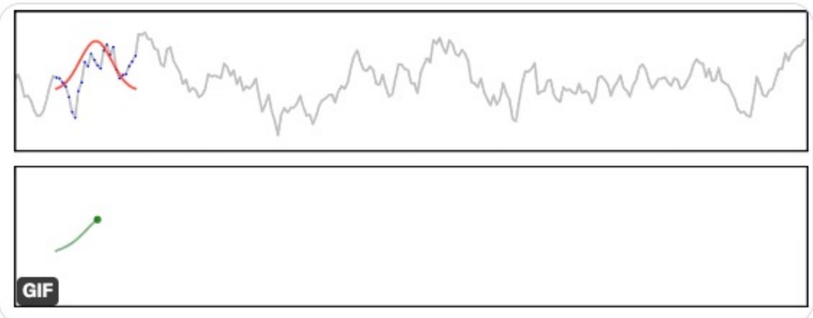
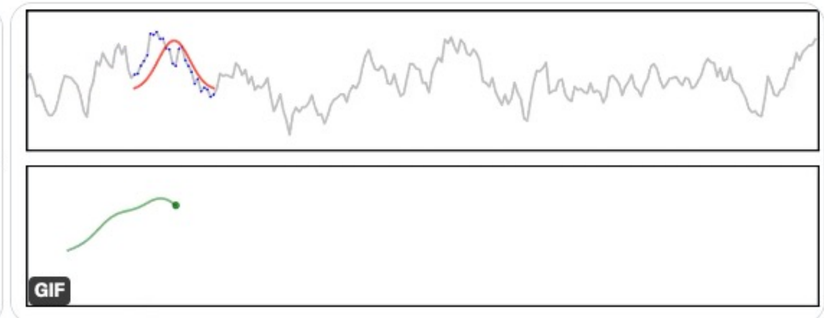
e.g. moving average aka “boxcar”



Gaussian kernel






GIF

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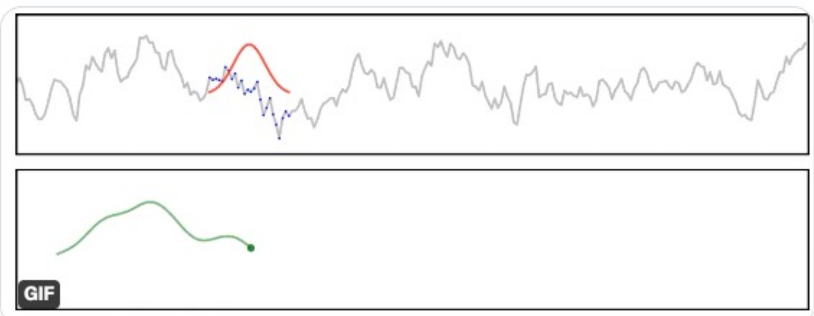
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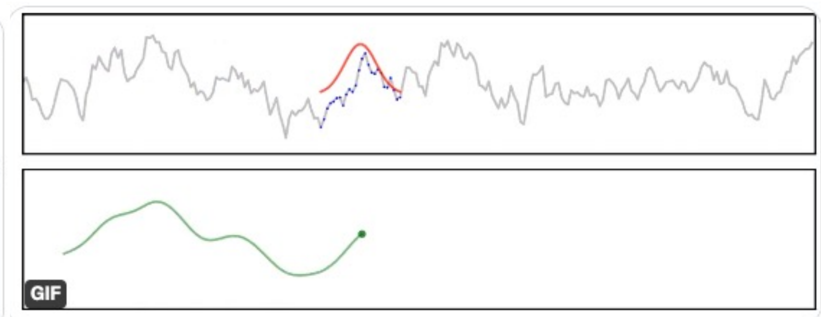
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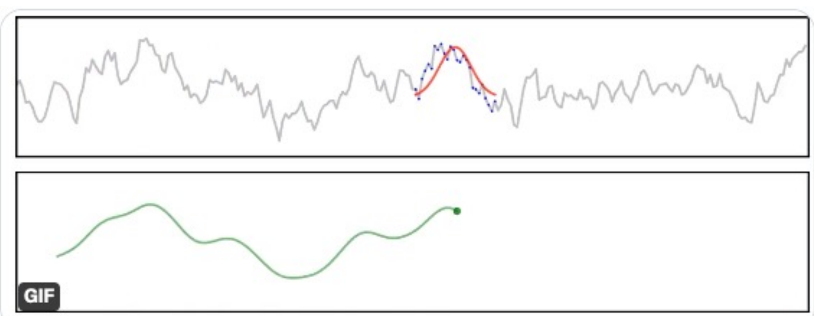
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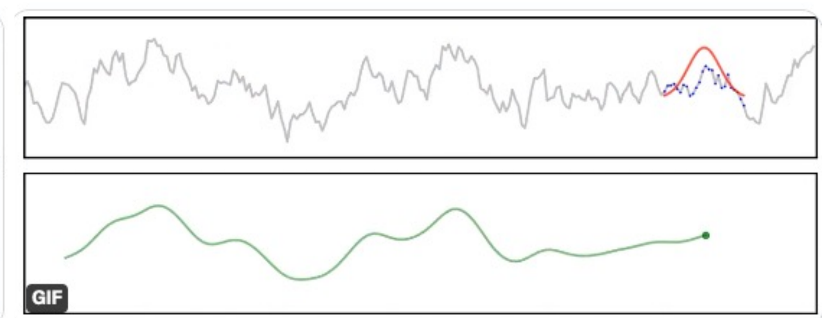
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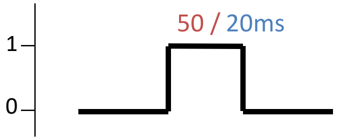

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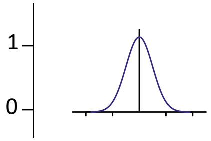

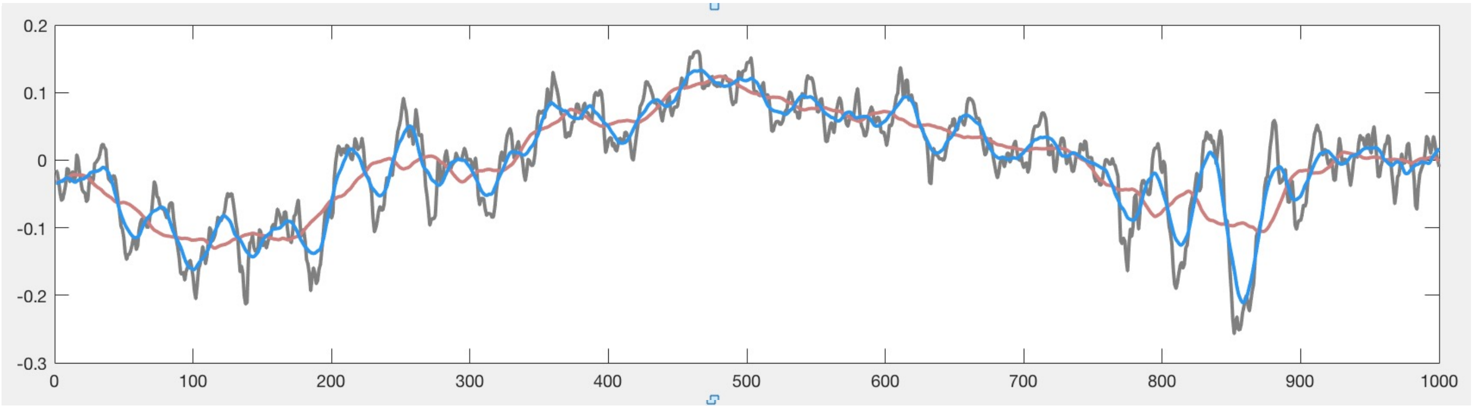

- Do this as a preprocessing step, i.e. *before* selecting epochs or trials, to avoid edge effects

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- downsampling
- interpolating
- smoothing
- var. de-noising steps

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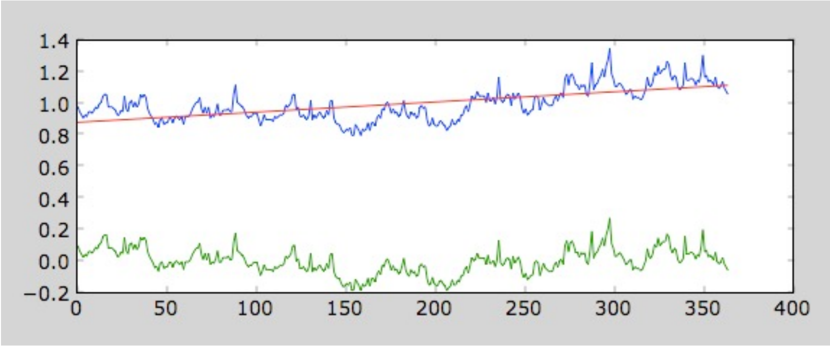

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Best practices: Know your data and which preprocessing steps are appropriate
Apply these steps consistently to *all* data
Best carried out in a "pipeline"

HW # 6

HW6: Introduction to Time Series Analysis

You have recorded two neurons with the following parameters:

Sampling frequency 1kHz
Recording duration 7127.914 sec (or 118.7986 min)

Each vector in the attached data set includes the timestamp *in ms* when the neuron fired an action potential, as well as a timestamp, also in ms, for a recurring event.

1. Make raster plots of the first 100 events for each neuron's response time-locked to the event. Include times from 500ms before the event to 1s after
2. Plot each neuron's average response over all 699 events as a lineplot or PETH in the same time epoch (make sure your x-axis indicates time relative to the event)
3. Smooth each neuron's time series using a 200ms moving average, and replot the lineplot from 2