Analyzing time-series data in neuroscience

All the most important stuff I’ve learned

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2025

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This mini-course

Comprehensive guide to analyzing time-series data in neuroscience

For

Anyone interested in working with modern neuroscience data

Whether you want to

Analyze data collected to address a specific question

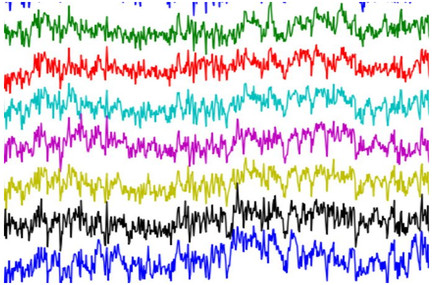
Extract new scientific results from existing data

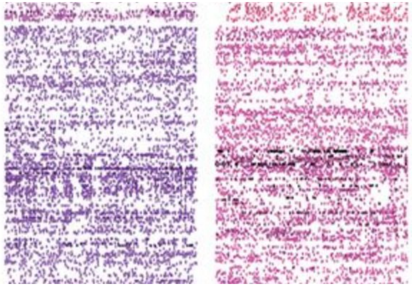
Note

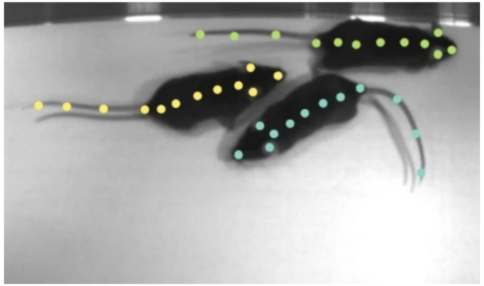
Designed to be comprehensive yet concise.
To be used as both course and guidebook/reference.

Why is analyzing time-series data important?

Default output of most modern measurement devices







Crucial to understand how to work rigorously with such data, but not easy.

Generally requires both technical and domain knowledge

Goals of this course

<u>Fast-track your way to expertise in time-series analysis in neuroscience</u>

- Understand fundamental concepts in time-series analysis
- Understand both canonical and state-of-the-art methods
- Understand common challenges and solutions
- Learn to efficiently transform data into trustworthy scientific results
- Learn to design new analyses to ask new questions

The complete outline: everything you need to hit the ground running

Fundamental concepts
- Common data types in neuroscience
  - Intracellular voltage
  - Spike trains
  - LFP/ECoG
  - Calcium imaging
  - fMRI/EEG/MEG
  - Fiber photometry?
  - Video/tracked behavior
  - Stimuli/other sensors
  - Simulation data
- Challenges of time-series analysis
- Modeling as analysis
- Model fitting
  - Parameters
  - Loss functions
  - Training/test data
  - Overfitting/bias-variance tradeoff
  - Model comparison
- Random processes perspective
- Dynamical systems perspective

Philosophy
- What you see depends on how you look
- Frameworks/theories/models
- Descriptive/mechanistic/normative levels
- Measurable vs important quantities
- Importance of making predictions
- Transforming data into scientific results

Methods survey I: Canonical methods
- Common pre-processing steps
  - Spike sorting
  - Image processing/ROI extraction
  - Estimating firing rates
  - Tracking
  - Smoothing
  - Detrending
  - Creating artificial trials
- Classical signal processing
  - Correlation functions
  - Fourier transforms/power spectra
  - Linear filters/impulse response
- Canonical neural data analyses
  - Raster plots and ISIs
  - PSTHs and tuning curves
  - LNP/spike-triggered average

Methods survey II: Modern methods
- Dimensionality reduction
- Clustering/segmentation
- Statistical models
- Latent variable models
- Dynamics/state-space models
- Mechanistic models
- Spatiotemporal analyses
- Neural networks/VAEs/ELBO
- Learning/inference techniques
- Information theoretic methods

Common issues
- Multicollinearity
- Controlled vs naturalistic data
- Nonstationarity and long timescales
- Trials/Sessions/Animals/Conditions
- Binning
- Missing data
- Too much data
- Gotchas: normalization, correlated training/test data, what is N? etc.
- Interpreting data-driven analyses

Practical tips
- Approaching/vetting a new dataset
- Data pre-processing
- Statistics
- Data munging/storage
- Null/control datasets
- Deconstructing fit models
- How to not make mistakes
- Leveraging AI
- Designing custom analyses
- Coding strategies
- Reproducibility/data sharing

Miscellaneous
- Other methods
- Common software
- Other resources