DEPARTMENT OF NEUROSCIENCE

C4F6132, Signals and States: Quantitative Time-Series Analysis in Neuroscience and Biology, 1.5 credits (hec)

Signaler och tillstånd: Kvantitativ tidsserieanalys inom neurovetenskap och biologi, 1,5 högskolepoäng

Third-cycle level / Forskarnivå

Approval

This syllabus was approved by The Committee for Doctoral Education on 2026-09-04, and is valid from spring semester 2027.

Responsible department

Department of neuroscience, Faculty of Medicine

Prerequisite courses, or equivalent

Basic familiarity with biological research and quantitative reasoning is expected. Basic programming experience in Python, MATLAB, R, or an equivalent language is required. Advanced programming proficiency is not required.

Purpose & Intended learning outcomes

Purpose

The purpose of the course is to develop doctoral students' ability to use quantitative approaches to address scientific questions involving time-resolved data in neuroscience and biology. The course aims to strengthen students' ability to choose appropriate analytical strategies, interpret quantitative results in their biological context, and critically assess the strength and limitations of conclusions drawn from complex datasets.

Knowledge and understanding

Intended learning outcomes

After completing the course, the student should be able to explain key concepts and analytical challenges associated with time-resolved neural and biological data, including high-dimensional

representations, temporal dynamics, and relationships between biological signals.

Competence and skills

After completing the course, the student should be able to:
• select and apply an appropriate quantitative approach to a time-resolved neural, behavioral, or other biological dataset;
• visualize and interpret high-dimensional structure, temporal dynamics, or relationships between biological signals in relation to a clearly formulated scientific question.

Judgement and approach

After completing the course, the student should be able to:
• critically evaluate the suitability and robustness of a quantitative analysis in relation to the data, experimental design, and biological question;
• distinguish between association, prediction, and causal interpretation, and identify important limitations or alternative explanations when interpreting quantitative results.

Course content

A. Time-resolved data in neuroscience and biology
Characteristics of electrophysiological, imaging, behavioral, physiological, and other biological time-series data. Temporal alignment, sampling, noise, drift, missing data, and basic considerations in preparing time-resolved datasets for analysis.

B. High-dimensional representations
Population and multivariate data, dimensionality reduction, clustering, distributed representations, and interpretation of high-dimensional biological measurements.

C. Dynamics and state
Trajectories, state-space representations, manifolds, state transitions, and dynamical concepts used to describe changing neural and biological systems.

D. Linking biological signals and behavior
Quantitative behavioral analysis and approaches for relating neural, behavioral, physiological, and other biological variables, including encoding and decoding frameworks.

E. From quantitative analysis to scientific inference
Model fitting and validation, overfitting and generalization, robustness and reproducibility, and critical interpretation of statistical relationships. The course concludes by considering the distinction between association, prediction, directed temporal relationships, and causal interpretation.

Forms of teaching and learning

The course combines conceptual lectures, scientific discussions, and guided hands-on practical

sessions. Lectures introduce analytical concepts through examples from neuroscience and biology, and practical sessions allow students to apply these concepts to representative time-resolved datasets on their own computers.

The practical work emphasizes analytical reasoning, interpretation, and common limitations rather than mastery of individual software packages. Exercises are structured so that the principal analytical work is completed during scheduled course time. Group discussions are used to connect analytical choices to scientific conclusions.

Language of instruction

The course is given in English

Grading scale

Pass (G) /Fail (U)

Compulsory components & forms of assessment

Practical sessions and the final examination are compulsory. Absence from a compulsory practical session must be compensated through an equivalent individual assignment determined by the course director.

The examination consists of a short individual oral presentation based on an analysis carried out during the course practical sessions. The student will present the scientific question, justify the selected analytical approach, interpret the principal result, and discuss important limitations of the analysis.

The examination assesses the intended learning outcomes by evaluating the student's ability to select and apply an appropriate analytical approach, interpret quantitative results in their biological context, and critically assess the robustness and limitations of the conclusions.

Course literature

All course literature is recommended; no literature is mandatory. Selected chapters and sections will be indicated for individual course topics, and no textbook is expected to be read in full.

Recommended reference texts include:
- Cohen, M. X. Analyzing Neural Time Series Data: Theory and Practice. MIT Press.
- Shumway, R. H. & Stoffer, D. S. Time Series Analysis and Its Applications: With R Examples. Springer.
- Izhikevich, E. M. Dynamical Systems in Neuroscience: The Geometry of Excitability and Bursting. MIT Press.

Selected contemporary research articles and methodological resources will also be provided in connection with individual course topics.