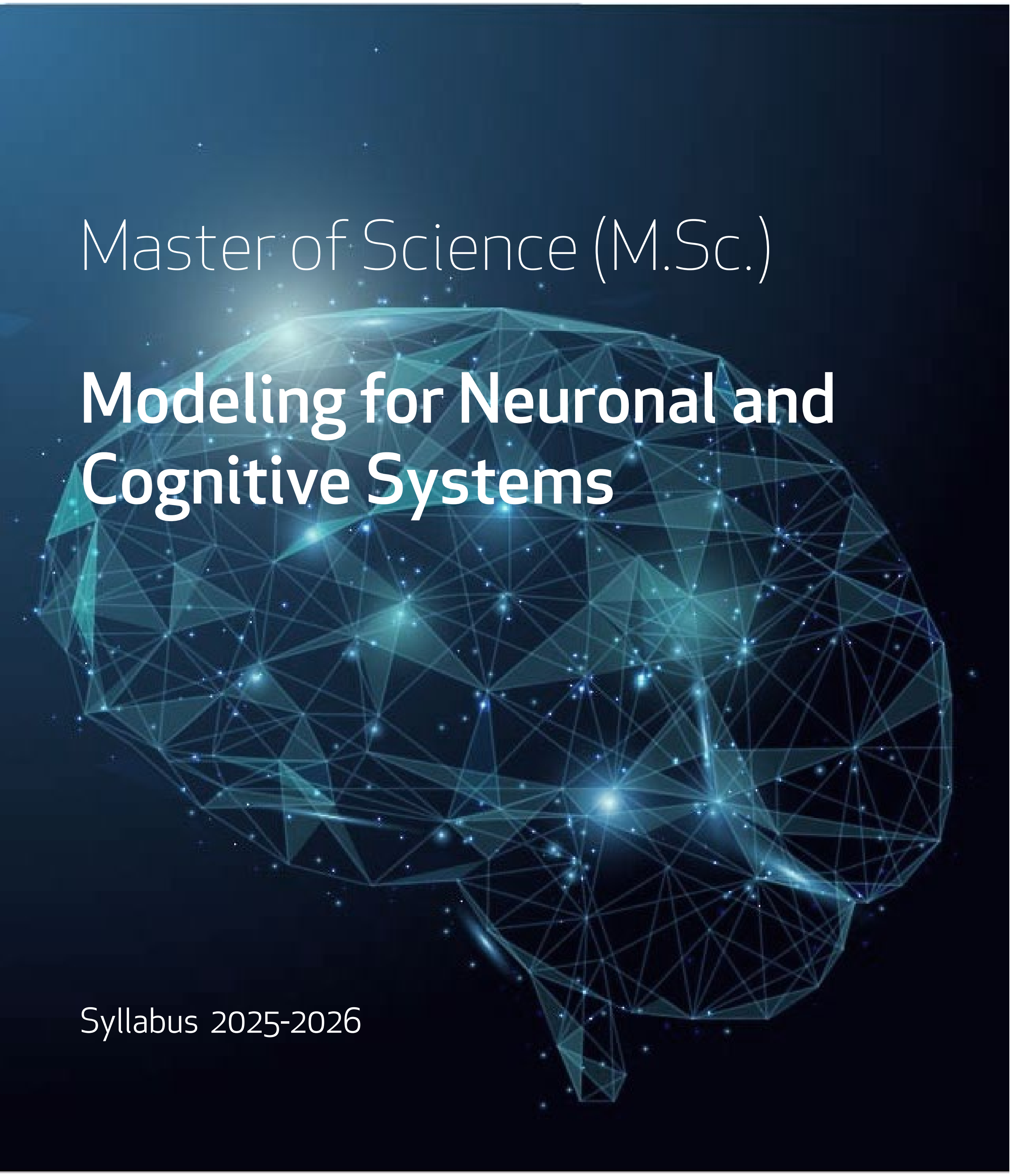
UNIVERSITÉ CÔTE D'AZUR



Master of Science (M.Sc.)

Modeling for Neuronal and Cognitive Systems

Syllabus 2025-2026

Introduction

Program Structure

Year 1

SEMESTER 1 (SEP-FEB)

Core Courses

- **Bootcamp** – intensive refresher module
- **Behavioral and Cognitive Neuroscience**
- **Introduction to Modeling and Simulation**

Elective Courses

Pick 3 out of 9 (such as: functional neuroimaging, Reasoning and decision-making, Mathematical modeling at the molecular and cellular level…)

Optional

Cognitive neuroscience in Education – online module provided by the M.Sc. SmartEdTech

SEMESTER 2 (MAR-JUNE)

Core Courses

- **Prospective Research and Innovation**
- **Computational Modeling and Simulation of Neurocognitive Systems**

Mini-project

Mini-internship of 6 to 9 weeks in a laboratory at Université Côte d'Azur

Optional

Personal Initiative – a scientific project you would like to carry out

Year 2

SEMESTER 3 (SEP-FEB)

Core Course

- **Scientific Communication**

Elective Courses

Pick 2 out of 10 (for example: Text analysis, deep learning and statistics, Language…)

5 Months Internship

In a laboratory at Université Côte d'Azur

Optional

Methods and Tools for Technical and Scientific Writing - provided by the M.Sc. DSAI

SEMESTER 4 (MAR-AUG)

Core Course

- **Simulation and Analysis Tools for Neural Data** (Online)

5-6 Months Internship

Private or public sector, preferably abroad

French Grading System

In France, grades are given on a 20-point scale, which may differ from the system in your home country. The table below will help you better understand how your results are assessed.

Number of Points /20	Appreciation
1-5	Fail – *you have to retake the exam*
6-9	Unsatisfactory – *grade can be compensated*
10-11	Pass
12-13	Satisfactory
14-15	Good
16-18	Very good
19-20	Excellent

To pass a course and validate your academic year (M1 or M2), you need a minimum average of **10/20**. However, grades can be compensated between courses. For example:

If you receive 8/20 in *Introduction to Modeling and Simulation*, but 14/20 in *Behavioral and Cognitive Neuroscience*, the higher grade will compensate for the lower one, since your final average is calculated across all courses.

⚠ **Important rule**: Any grade of **5/20** or below is eliminatory and cannot be compensated. In such cases, you must retake the course or exam, and you cannot validate your academic year with that grade.

Retake Sessions (Second Session)

In France, a second session (resit) is only granted if you miss an exam for a valid, documented reason, such as:

- Medical reasons (with a medical certificate),
- Serious personal emergencies (e.g., family bereavement).

A second session will <u>not</u> be organized for the following reasons:

- Not showing up to the exam without justification,
- Receiving a grade below 10 and wanting to improve it,
- Forgetting to answer or submit part of an assignment.

Failing the Year

If your yearly average is below 10/20, or if you receive an eliminatory grade, you will have to retake the entire M1. Please note that this is not automatic: the decision rests with the MSc jury, who will evaluate your situation and decide whether you are allowed to repeat the year.

FIRST YEAR - MSc 1

SEMESTER 1 — 51 ECTS

Refresher Module (Bootcamp) — 15 ECTS

Statistics and Probability	3 ECTS
Programming and Simulation	3 ECTS
Linear Algebra	3 ECTS
Dynamical Systems	3 ECTS
Introduction to Neuroscience and Cognitive Science	3 ECTS

Core Courses — 18 ECTS

Behavioral and Cognitive Neuroscience	9 ECTS
Introduction to Modeling in Neuroscience and Cognition	9 ECTS

Elective Courses (3) — 18 ECTS

Stochastic Models in Neurocognition and their Statistical Inference	6 ECTS
Multiple Timescale Dynamics in Neuroscience	6 ECTS
Functional Neuroimaging and Data Processing	6 ECTS
Language	6 ECTS
Knowledge, Intelligence and Expertise	6 ECTS
Reasoning and Decision-Making	6 ECTS
Data Collection Methods and Statistical Analysis	6 ECTS
Mathematical Modeling at the Molecular and Cellular Level	6 ECTS
Text Analysis, Deep learning and Statistics	6 ECTS

SEMESTER 2 — 33 ECTS

Mini-project (internship) — 18 ECTS

9 full weeks of internship in a laboratory at UniCA

Core Courses — 15 ECTS

Prospective Research and Innovation	6 ECTS
Computational Modeling and Simulation of Neurocognitive Systems	9 ECTS

Optional modules

Cognitive Science in Education (Sem.1)	2 ECTS
Personal Initiative (Sem. 2)	2 ECTS

SECOND YEAR - MSc 2

SEMESTER 3 — 42 ECTS

Internship 1 — 24 ECTS

5 months internship at UniCA

Core Course — 6 ECTS

Scientific Communication	6 ECTS

Elective Courses (2) — 12 ECTS

Stochastic Models in Neurocognition and their Statistical Inference	6 ECTS
Multiple Timescale Dynamics in Neuroscience	6 ECTS
Functional Neuroimaging and Data Processing	6 ECTS
Language	6 ECTS
Knowledge, Intelligence and Expertise	6 ECTS
Reasoning and Decision-Making	6 ECTS
Data Collection Methods and Statistical Analysis	6 ECTS
Mathematical Modeling at the Molecular and Cellular Level	6 ECTS
Text Analysis, Deep learning and Statistics	6 ECTS
Foundations of Deep Learning	6 ECTS

Optional Course

Methods and Tools for Technical and Scientific Writing

SEMESTER 4 — 33 ECTS

Internship 2 — 30 ECTS

5 to 6 months internship

Core Course — 3 ECTS

Simulation and Analysis Tools for Neural Data (Online)	3 ECTS

SEMESTER 1

Refresher Module
Bootcamp

SEMESTER 1
15 ECTS
190 hours face to face
Code: AIUMOD11

Description

The students arrive with different academic backgrounds. To fill in the gaps in their mathematical, statistical and programming skills, the first 2 months of the first year are devoted to a complete refresher program. An additional novel feature of this very intensive educational approach is to place students in a situation where they rapidly work together and help each other in an independent way (without the teacher). They also learn (and hopefully appreciate) to work in an open space. This is very important for achieving one of our goals: by the end of the Master's program, participants with very different backgrounds are used to interacting with each other and intensively working together. During these 8 weeks, they will have different teachers and focus on different topics: linear and bilinear algebra, complex numbers, Fourier analysis, basic probability, basic statistics and programming in R, differential equations, PDE, simulation, modeling, simulation and implementation of basic systems and object-oriented programming, basics in experimental protocol set-ups…

Subjects

Statistics and Probability — **3 ECTS**

Professor: Patricia REYNAUD-BOURET — 42 hours

Learning outcomes:

- Elementary probability
- Random variables and models Elementary statistics
- Linear models
- Tests and p-values
- Elementary use of R and Rmarkdown.

Description: Elementary introduction to probability, statistics, R(studio) and Rmarkdown, with an emphasis on neuroscience and cognition examples

Programming for Modeling and Simulation — **3 ECTS**

Professors: Samuel DESLAURIERS-GAUTHIER, Romain VELTZ — 42 hours

Learning outcomes:

- Use and modify the variables of models using operations/instructions
- Follow a method to design the algorithm corresponding to a simulation model
- Follow a method to implement the program corresponding to the algorithm
- Design programs as interacting objects
- Carry out your object-oriented programming projects

Description: Nowadays, understanding complex systems, like the neurocognitive one, requires the use of computer programs for modeling and simulating their behaviors. As a computational neuroscientist, you need to be able to understand the basics of hardware and

Refresher Module
Bootcamp

SEMESTER 1
15 ECTS
190 hours face to face
Code: AIUMOD11

software architectures of computers and to develop, organize and connect programming objects. This class will provide you a method to carry out your programming projects in the context of modeling and simulation. You will learn how to describe programs as algorithms and how to design these programs as interacting objects. Both algorithms and object-oriented designs will be implemented in Python programming language. All along the bootcamp, you will apply the concepts learned to a research project of neuronal network model.

Linear Algebra — 3 ECTS

Professor: Martin KRUPA — 30 hours

Learning outcomes:

- Apply linear algebra methods in the analysis of models
- Use linear algebra in some aspects of modeling

Dynamical Systems — 3 ECTS

Professor: Martin KRUPA — 30 hours

Introduction to cognitive science and neuroscience — 3 ECTS

Professors: Ingrid BETHUS, Raphaël FARGIER, Emilie Gerbier — 24 hours

Learning outcomes in cognitive science with Emilie Gerbier: Have a general idea of the scientific milestones in the history of cognitive science and of the different disciplines that constitute the cognitive sciences / Distinguish the levels of analysis at which a cognitive "problem" is tackled (computational, algorithmic, architectural, implementational; Marr's or Dawson's levels).

Evaluation and assessment

Minimum two exams/graded assignment per subject. The grades of each subject can be compensated. An average grade will be calculated for the entire Bootcamp and count for 15 ECTS.

Core Course
Introduction to Modeling in Neuroscience and Cognition

SEMESTER 1
9 ECTS
45 hours face to face
Code: AIUMOD12

Professor: Bruno CESSAC

Description

The nervous system is composed of multiple subsystems interacting in parallel, across different spatial scales—from molecules to the whole brain—and temporal scales—from milliseconds to years. Understanding these subsystems and their interactions is essential to interpret experimental data (multi-electrode recordings, optical imaging, EEG, MEG, etc.) and to explain how cognitive functions emerge from cortical dynamics.

Because the nervous system constantly interacts with a changing environment, we also aim to understand how the multi-scale dynamics of neural assemblies adapt so quickly and reliably. This requires appropriate theoretical models and analytical tools, grounded in experimental neuroscience.

This course provides a practical and operational introduction to brain dynamics at different scales: from neurons and synapses, to neural networks, to neural masses, up to the emergence of cognitive processes. Biological, physical, mathematical, computational, and cognitive aspects will be addressed in parallel. Acquisition techniques (multi-electrodes, optical imaging, EEG, MEG, etc.) will be presented alongside experimental protocols linking behavior to in vivo recordings during cognitive tasks.

Learning Outcomes

In this course, the students will learn how to combine fundamental knowledge in physics, biology, mathematics and computer science, to better understand the multi-scale dynamics of neural assemblies. They will also develop their critical thinking: How can I check if a model or a simulation of neural assemblies is correct ? How to reproduce experimental results ? Are the physical units coherent ? How to make testable predictions ?

Requirements

Students are expected to attend classes, complete exercises, actively participate in discussions, and read the assigned materials.

Evaluation and assessment

- Tutorials (25%): Regular assignments with written reports.
- Scientific article review (75%): Students choose a research article, write a detailed report, and present it orally.

Core Course
Behavioral and Cognitive Neuroscience

SEMESTER 1
9 ECTS
45 hours face to face
Code: AIUMOD13

Professor: Paula POUSINHA, Ingrid BETHUS, Fabrizio CAPITANO, Benjamin AZOULAY

Description

Neuronal and cognitive systems cannot be modeled without knowing the basics of neurosciences, from the molecular to the integrated level, involved in cognition and behaviors. The first part of the course focuses on elementary neurophysiology and neuroanatomy. What are the different subparts constituting the nervous system and what are their main roles? How are neurons constituted? How do they generate activity and communicate with other neurons?

The second part of the course explores, with an integrative perspective, the neurobiological basis for higher mental functions through several examples. Sensorimotor functions are at the root of all the other processes. So the study of feeding behaviors is a good way to learn about the bio-logic of elementary behaviors, starting from the physiology of the autonomic nervous system and ending with neuroethological issues. Learning and memory are the basic processes of higher mental functions and also hot topics with applications in many domains. In addition to all these fundamental aspects, the course also explains the materials and methods used in cognitive neuroscience to obtain data at the different levels of organization of nervous, cognitive and behavioral systems.

Evaluation and assessment

Minimum two graded assignments. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Optional Course (M.Sc. SEdTech)
Cognitive Science in Education

SEMESTER 1
2 ECTS
30 hours online
Code: AIUSMA24

Professor: Victoria PROKOFIEVA

Description

The main objective of this course is to know how the learner's brain works, in order to propose an adapted learning environment. This course is offered by the M.Sc. *Smart Educational Technologies* and is entirely online.

Advances in neuroscience and cognitive psychology allow us to optimize learning by understanding how the brain works and by proving or disproving the effectiveness of certain techniques and the truthfulness of certain beliefs (i.e., neuromyths).

This course therefore presents the main learning mechanisms and concrete examples of application in learning situations. Students will have to think about their teaching posture and/or their way of creating pedagogical tools in the light of the elements presented.

The course is organized into 3 main topics:

1. Cognitive neuroscience for learning,
2. Executives functions,
3. Memory systems.

Evaluation and assessment

Minimum two graded assignments. The grade obtained in this course can not be compensated.

SEMESTER 2

Core Course
Computational Modeling and Simulation of Neurocognitive Systems

SEMESTER 2
9 ECTS
45 hours face to face
Code: AIUMOD22

Professors: Evgenia KARTSAKI, Laurent RODRIGUEZ, François DELARUE

Description

The recent and ongoing increase of computer computational power offers new exciting possibilities for modeling and simulating neurocognitive systems. Thanks to this power, more and more different complex models can be simulated. To guide you over the set of choices of models and parameters, you will learn the mathematical system theory to formalize the computational modeling of a neurocognitive system and its simulation.

In the first part of the course, a state of the art of the computational modeling and simulation of the neurocognitive system and its learning capabilities will be provided, pinpointing the hot research questions in the domain.

In the second part, the formal concepts will be provided. All along the course, you will apply the concepts learned to conduct a research project at both neuronal activity and behavioral activity levels in a learning context.

Evaluation and assessment

Minimum two graded assignments. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Core Course
Prospective Research and Innovation

SEMESTER 2
6 ECTS
30 hours face to face
Code: AIUMOD23

Professors: Benoit MIRAMOND, Laurent RODRIGUEZ, Jean MARTINET + guest lecturers

Description

The spectacular advances made in cognitive science and neuroscience during the last decades have led to more and more applications in medicine and technologies used in everyday life. A wide range of applications are open to students in fundamental, applied and biomedical research, and in the different fields of application of neuro-inspired systems (e.g. neurostimulation, deep learning, bio-inspired sensors, autonomous systems, developmental robotics and neuromorphic electronics, etc.).

Students need to develop an informed and critical eye to determine the most relevant advances in the future and set priorities. In addition, as the future players in the field, they also need to develop an ethical perspective on these questions. These different topics are addressed by researchers, physicians and industrial partners, working together in applied research or innovation projects.

Evaluation and assessment

Minimum two graded assignments. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Optional Module
Personal Initiative Project

SEMESTER 2
3 ECTS
Code: AIUMFD24

Supervisor: Ingrid BETHUS

Description

Students choosing this Master's program should have a natural curiosity for neuroscience and cognition. Given that it is not possible to cover all the subjects of interest, especially in the first year, we leave room for students to acquire a new perspective in a self-designed study.

The aim of this module is to let students (in groups or individually) identify a topic they would like to explore and subsequently design and carry out a project. We will provide the necessary resources to acquire tools and find contacts. A small budget (around 500€) is reserved especially for this purpose, and expenses are supervised by the coordinator. The funds can be used for equipment, softwares (...), inviting researchers from other universities to give a course, etc.

Evaluation and assessment

None.

SEMESTER 3

Core Course
Scientific Communication

SEMESTER 3
6 ECTS
20 hours face to face
Code: AIUMOD34

Professors: Patricia REYNAUD-BOURET & Raphaël FARGIER

Description

The aim of the course is to practice scientific communication through various individual presentations that are graded by the other students and the teachers. This is a unique opportunity in a scientific life to have real feedbacks on the talks you give and to improve the way you are perceived by your audience. Three talks will be given by each student: one on bibliography, one on data or simulations, one as if it was for a PhD grant interview.

Evaluation and assessment

Minimum two graded assignments. The grade obtained in this course can be compensated.

Optional Course
Methods and Tools for Technical and Scientific Writing

SEMESTER 3
15 hours face to face
Code: AIQDSC15

Professors: Marco WINCKLER

Description

This class is dedicated to methods and tools for supporting technical and scientific writing. By following this class, students are expected to become capable writers using common tools used for professional scientific publications.

Contents and program of the course:

- Reading a scientific article
- Tool for bibliography
- Markup Languages and Latex
- Benchmarking, Systematic Literature Review

SEMESTER 4

Core Course
Simulation and Analysis Tools for Neural Data

SEMESTER 4
3 ECTS
30 hours online
Code: AIUMOD42

Professor: TBA

Description

TBA

Evaluation and assessment

Minimum two graded assignments. The grade obtained in this course can be compensated.

ELECTIVE COURSES

Elective Course
Stochastic Models in Neurocognition and their Statistical Inference

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD51

Professors: Patricia REYNAUD-BOURET & Etienne TANRE

Description

The objective is to describe the main stochastic models (Markov Chains, Integrate and Fire, point processes [...]) and their main mathematical properties. The pros and cons of each of them is discussed especially in terms of the modeling and the statistical inference of real data.

Evaluation and assessment

Minimum two graded assignments/exams. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Elective Course
Multiple Timescale Systems in Neuroscience

ELECTIVE
6 ECTS
30 hours face to face
Code: AIQMOD16

Professor: Emre BASPINAR

Description

This course focuses on computational modeling of neural population dynamics through three main approaches: neural fields, neurogeometry, and whole-brain models.

We begin with an introduction to the concept of scale in computational models, followed by neural fields, including the coarse-grained limit and the classical Wilson–Cowan and Amari models.

The second part explores neurogeometric approaches. After a brief overview of human visual perception, we examine the functional architecture of the primary visual cortex (V1), covering concepts such as receptive profiles, pinwheel structures, and connectivity. We then study the geometric modeling of V1 based on the work of Petitot, Citti, and Sarti.

The final part presents The Virtual Brain, a whole-brain simulation platform. We will build networks of population models to simulate large-scale brain dynamics and study applications such as cortical wave propagation (e.g., in migraine/epilepsy), visual perception, and brain state transitions (awake vs. sleep). Practical work will be carried out using Python notebooks.

Learning outcomes

By the end of the course, students will:

- Understand and implement neural field models, both local and spatial, and analyze patterns of population dynamics.
- Master key concepts such as connectivity, transfer functions, and activity patterns.
- Apply geometric tools to study the functional architecture of the visual cortex and link them to perceptual tasks.
- Gain practical experience with The Virtual Brain, learning to construct and simulate brain networks to explore large-scale dynamics and brain states.

Requirements

The students must attend classes regularly and read the references provided throughout the course.

Evaluation and assessment

The assessment will take place in three stages:

Steps 1 & 2 (25%): Students will complete homework assignments at the end of the first and second thirds of the course. These exercises will cover both theoretical and practical aspects of the material. Collaboration in groups is allowed at this stage.

Step 3 (75%): Each student will independently select one of the proposed research papers related to the course, and prepare a written report on it.

Elective Course
Functional Neuroimaging and Data Processing

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD53

Professors: Samuel DESLAURIERS-GAUTHIER & Theodore PAPAPOULO

Description

This course deals with brain functional imaging and its application to create brain computer interfaces using two non-invasive techniques used to estimate brain activity:

- M/EEG which measures the electro-magnetic field created by cortical currents,
- Functional and diffusion MRI which respectively measures:
  - A signal (BOLD) linked to energy consumption in the brain.
  - Brain connections (mostly in the white matter), which are linked to brain activity.

Learning outcomes

By the end of this course in functional neuroimaging, students will have developed a critical understanding of the principles and applications of both M/EEG and fMRI for studying human brain function. They will be able to explain the physiological and physical bases of these techniques, evaluate their respective strengths and limitations in terms of spatial and temporal resolution, and apply appropriate analysis methods to real datasets. In addition, students will gain hands-on experience in data preprocessing, signal interpretation, and image processing.

Requirements

Students are expected to have a fundamental background in neuroscience, psychology, cognitive science, or a related biomedical field. Prior coursework should include fundamental neuroanatomy and neurophysiology. Basic knowledge of statistics and signal processing is required, as well as proficiency in the Python programming language. Familiarity with linear algebra, Fourier analysis, and probability theory will be highly beneficial.

Evaluation and assessment

25%: a short quizz at the start of every class (9 in total);

75%: final written exam.

Elective Course
Language

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD54

Professor: Raphaël FARGIER

Description

This course explores current knowledge on the linguistic, cognitive, and neural architecture of language. It emphasizes an experimental and interdisciplinary approach, drawing on psycholinguistics, neuroscience, linguistics, psychology, and artificial intelligence. Students will learn how neuroscientific methods are applied to language research and how interdisciplinary integration contributes to contemporary models of language processing.

The module is divided into two parts:

- Block 1 (5 sessions): Lectures combining ex-cathedra teaching with interactive problem-solving.
- Block 2 (5 sessions): Critical reading and discussion of scientific articles, fostering both individual and group analytical skills.

Learning outcomes

By the end of the course, students will:

- Acquire a solid understanding of current knowledge in the cognitive science of language.
- Be able to design and justify new approaches or experimental protocols to address open questions and major debates on the (neuro)cognitive architecture of language.

Requirements

Active participation and class attendance are expected. Additional readings will be provided to support and extend course content.

Evaluation and assessment

- Continuous assessment: Short in-class quizzes.
- Final exam (Block 1): Written synthesis report.
- Final exam (Block 2): Scientific poster presentation proposing a new experiment or approach to investigate a key research question in the field.

Elective Course
Knowledge, Intelligence and Expertise

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD55

Professors: Frédéric LAVIGNE & Fernand GOBET

Description

This course addresses the issue why constraints linked to cerebral capacity tend to inflect the induction of concepts. In this class, the idea that limitation of capacity offers benefits for efficient learning in humans is developed to show that expertise is a product of both complexity and simplicity. Occam's razor is a key idea to link human and artificial intelligence. The course also describes the differential contribution of the three different layers: phylogeny, sociogeny, and ontogeny.

We then review the Flynn effect (the debate as to whether the rise in IQ scores truly corresponds to higher general intelligence in the recent evolution), the relation between working memory capacity and intelligence, memory training, deliberate practice, individual differences, and cultural effects. Computational models (e.g., CHREST) are studied and bridges are made to AI.

Learning outcomes

- Describe different learning theories and their relation to intelligence, memory and educational strategies.

Evaluation and assessment

Minimum two graded assignments/exams. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Elective Course
Reasoning and Decision-Making

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD56

Professors: Eric GUERCI & Paul PEZANIS-CHRISTOU

Description

In this course, we introduce the field of behavioral and experimental economics from a historical and methodological perspective. We then discuss various models of decision making in both non-strategic and strategic environments. The former will be based on the literature and recent advancement of Decision Theory, the latter will be based on Game Theory. In discussing these models, we will refer to the experimental literature that has tested the implications of these models, and motivated new theoretical developments. Furthermore, we will also discuss findings from the literature on heuristics used in decision making. The course adopts a hands-on training approach. Some lectures will be given at the CoCoLab experimental laboratory. Students will participate to ad hoc laboratory experiments and will be encouraged to discuss the outcomes of these experiments.

Learning outcomes

- Understand how economists deal with cognition and decision making;
- Understand how economists design, run and analyze data coming from simple economic experiments;
- Discover new trends in economic thinking (role of emotions...).

Requirements

- Notions of game theory;
- Notions of statistics and probability.

Course plan

1. History and evolution of the relation between psychology and economics.
2. Economic experiments: methodological issues and debates.
3. Behavioral economics: theoretical foundations and their operationalization into public policies.
4. Psychological bias and heuristics in choice under risk.
5. Psychological bias and heuristics in choice under ambiguity.
6. Social preferences in strategic decision making.
7. The three major types of reasoning: deductive / inductive / abductive.
8. Trade-off between stability and variability in the decision making and the role of emotions.
9. Human vs Artificial: from prediction to decision-making.

Evaluation and assessment

Group assignment (group task) with a presentation (25% of final mark) + Written exam (75% of final mark).

Elective Course
Data Collection Methods and Statistical Analysis

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD57

Professors: Seçkin ARSLAN & Vincent VANDEWALLE

Description

This course will provide a comprehensive overview of main data collection and statistical data analysis procedures over five major modules (see below). The course will take 10 weeks in total and in each lecture, we will be mostly using data collection and analysis procedures for language and cognitive processing data, but at the end of the course, students are expected to be able to apply these procedures to data from other domains as well. In all sessions (except for single case studies), we will be using PsychoPy and R studio. Relevant packages, sample datasets and codes will be provided to students. Students are strongly advised to bring their personal computers with PsychoPy and R studio installed. The structure of lectures will be organized in such a way that students will first follow step-by-step tutorials and then be given some time for tutor-supervised lab-sessions, during which there will be opportunities for students to immerse themselves into the experimental data collection and/or statistical procedures they have just learned.

Learning outcomes

- Develop a working idea of how scientists use experimental techniques in cognitive science focusing on some aspects in psychology and neuro/psycholinguistics.
- Generate a well-developed research question to study cognitive processing
- Program a simple experiment of their choice
- Analyze experimental data using mixed-effects regression models
- Interpret statistical outputs

Course plan

1. General introduction, Accuracy data
2. Response times data
3. Single case, patient and/or treatment studies
4. Eye movements data
5. Event-related potentials (ERP) data

Evaluation and assessment

Minimum two graded assignments/exams. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Elective Course
Mathematical Modeling at the Molecular and Cellular Level

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD58

Professor: Claire GUERRIER

Description

The goal of the class is to present methods in applied mathematics, modeling and simulations to study computational problems in neuroscience at the molecular and cellular level. We will study neuronal structures at different scales, form synapses to neural networks. From specific examples, we will develop mathematical models and their analysis to determine how the properties of neurons at the molecular level shape their activity and propagate to the network level. This change of scale will be formulated and analyzed using several tools such as partial differential equations, stochastic processes and numerical simulations. We will first consider the classical electrical circuit analogy for modeling signal propagation in neurons, and its limitations. We will mainly develop two examples: a model of neuronal network (the pre-Botzinger Complex), and a model for the myelinated axon. In a second part, we will develop a model for short-term plasticity at the pre-synaptic terminal. Using the mean first passage time theory, we will coarsely grain the problem, initially formulated using a reaction-diffusion system in a complex geometry, into fast stochastic simulations.

Learning outcomes

- Build a mathematical model from results coming from experiments. Choose the correct representation (deterministic, probabilistic), write the system of equations/any mathematical representation of the problem.
- Numerical simulations: write a code to solve a simple PDE, simulate a Brownian motion, code a Gillespie algorithm.
- Understand the math/physics behind diffusion/brownian motion, numerical schemes, chemical rate equations.

Course plan

- Signal transmission in myelinated axons: we will build a model for signal propoagation in myelinated axons. We will introduce the following: Hodgkin-Huxley formalism / Finite elements simulations / Fourier transforms and Fourier Series / Poission-Nernst-Planck / Tsodycks Markram model / Modeling short-term plasticity in the pre-synaptic terminal
- Modeling short-term plasticity in the pre-synaptic terminal: we will build a model of the pre-synatpic terminal to investigate what are the main effectors regulating short-term plasticity. We will introduce the following: Chemical master equation / GIllespie simulations / Mean first passage time theory and simulations / Conformal transforms / Matching asymptotics / Markov chains

Evaluation and assessment

Minimum two graded assignments/exams. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Elective Course
Text Analysis, Deep Learning and Statistics

ELECTIVE
6 ECTS
30 hours face to face
Code: AIUMOD59

Professor: Serena VILLATA

Description

This course aims to provide tools and methodology to do information extraction from textual data using two complementary approaches:

1) Statistical analysis based on historical methods and baseline calculations.

2) Deep learning, which proposes methods for classifying texts and identifying linguistic markers and patterns.

Statistics will mainly focus on the frequency analysis of words and their distributions in a corpus, through methods such as z-score, correspondence analysis or the calculation of co-occurrences. The deep learning part will focus on two standard text classification architectures: recurrent networks and convolutional networks. The study of the hidden layers of these networks (embedding, attention, TDS) will be considered in order to extract the linguistic information learned by these models and compare it to the information known in statistics.

Learning outcomes

At the end of the course, students will be able to:

- Create a corpus and define metadata related to a given working hypothesis
- Use appropriate statistical methods to fit any analytical needs
- Program a deep learning network for text classification
- Extract linguistic information from the hidden layers of a deep learning network

Requirements

Good notions of Python programming + baseline statistics and machine learning.

Evaluation and assessment

Minimum two graded assignments/exams. The final exam counts for 75% of the grade. The grade obtained in this course can be compensated.

Elective Course
Foundations of Deep Learning

ELECTIVE MSc 2 only
6 ECTS
30 hours face to face
Code:

Professors: François DELARUE, Patricia REYNAUD-BOURET, Remy SUN

Description

This course will open in 2026-27 and is only available to second year students who validated the course "stochastic models in neurocognition and their statistical analysis" during the first year.

Course plan

- Stochastic Gradient Descent and Diffusion Models – 10 hours
- Mathematical Foundations of Deep Learning – 10 hours
- Spiking Neural Networks – 10 hours

Evaluation and assessment

TBA.