PhD Program in "Cognitive and Cultural Systems"
Track in "Cognitive, Computational and Social Neurosciences"
(CCSN)

Course List - A.Y. 2020/21

CCSN PhD students are required to take all the following COMPULSORY COURSES:

Course	Lecturer(s)	Hours
Basic Principles and Applications of Brain Imaging Methodologies to Neuroscience	Emiliano Ricciardi	22
Basic Principles and Applications of Brain Imaging Methodologies to Neuroscience	Luca Cecchetti	30
Basic principles and Applications of Electrophysiology and Stimulation Tecniques	Giulio Bernardi	24
Basic principles and Applications of Electrophysiology and Stimulation Tecniques	Luca Turella	8
Basic principles and Applications of Electrophysiology and Stimulation Tecniques	Simone Rossi	8
Introduction to Consciousness and Sleep	Giulio Bernardi	16
Neurobiology of Emotion and Behavior	Pietro Pietrini	12
Neuroscience of Perception and Experience-Dependent Plasticity	Emiliano Ricciardi	22
Neuroscience of Perception and Experience-Dependent Plasticity	Davide Bottari	24
Principles of Brain Anatomy and Physiology	Luca Cecchetti	30

The following ELECTIVE COURSES are also available for CCSN PhD students:

Course	Lecturer(s)	Hours
Advanced Neuroimaging	Giacomo Handjaras, Nicola Vanello, Mauro Costagli	26
Advanced Topics in Network Theory: Algebraic Concepts in Network Theory	Guido Caldarelli	10
Advanced Topics in Network Theory: Brain Networks	Guido Caldarelli	10
Advanced Topics in Network Theory: Dynamical Models in Network Theory	Guido Caldarelli	10
Advanced Topics in Network Theory: Research Topics in Network Theory	Guido Caldarelli	10
Advanced Topics in Network Theory: Topological Concepts in Network Theory	Guido Caldarelli	10
Basic Elements of Cybersecurity	Rocco De Nicola	10
Basic Linear Algebra and Statistics for Neuroscience	Giorgio Gnecco, Francesco Serti	30
Basic Programming for Neuroscience	Monica Betta	20
Biosignals, Bionics and Neuroscience (long seminar without exam)	Michele Emdin, Graziella Orrù, Enzo Pasquale Scilingo, Silvestro Micera, Antonio Bicchi	28
Clinical Psychopathology and Psychiatry	Pietro Pietrini	16

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Cognitive Economics	Gustavo Cevolani, Luca Polonio	20
Computer Programming and Methodology	Mirco Tribastone	30
Contextual Analysis and Individual Objects: Arts, Sciences, Techniques, Beliefs	Linda Bertelli	30
Critical Thinking (no exam)	Gustavo Cevolani	20
Decision-Making in Economics & Management	Massimo Riccaboni	10
Forensic and Legal Psycology	Pietro Pietrini	16
Foundations of Probability and Statistical Inference	Irene Crimaldi	30
Funding and Management of Research and Intellectual Property (no exam)	Marco Paggi	10
Game Theory	Ennio Bilancini	20
Introduction to Cognitive and Social Neuroscience	Pietro Pietrini, Emiliano Ricciardi	24
Introduction to Network Theory	Guido Caldarelli	10
Introduction to Neuro-Linguistics	Alessandra Rampinini	12
Introduction to Psychophysics	Davide Bottari	12
Machine Learning	Giorgio Gnecco	20
Management of Complex Systems: Approaches to Problem Solving	Andrea Zocchi Simone Gerola	40
Matrix Algebra	Giorgio Gnecco	10
Neuroeconomics	Luca Polonio	12
Numerical Methods for the Solution of Partial Differential Equations	Marco Paggi	20
Philosophical and Ethical Themes in Neuroscience (no exam)	Mirko Daniel Garasic	10
Philosophy and Neuroscience in Moral Reasoning	Gustavo Cevolani	12
Philosophy of Science (no exam)	Gustavo Cevolani	20
Research Seminars (no exam)	Pietro Pietrini Emiliano Ricciardi	30
Scientific Writing, Dissemination and Evaluation (no exam)	TBD	8

Compulsory Courses

Basic Principles and Applications of Brain Imaging Methodologies to Neuroscience
Emiliano Ricciardi, Luca Cecchetti
52 Hours

Learning Outcomes:
At the end of the course, students are expected to have a general background knowledge of the basic principles, methodologies and applications of the most important brain functional techniques and to be prepared to evaluate the applicability of, and the results provided by these methodologies for different problems in cognitive and clinical neuroscience.

Abstract:
The course aims at introducing the fundamentals of brain metabolism and brain imaging methodologies. Neuroimaging techniques provided cognitive and social neuroscience with an unprecedented tool to investigate the neural correlates of behavior and mental functions. Here we will specifically review the basic principles, research and clinical applications of positron emission tomography (PET) and functional magnetic resonance imaging (fMRI). Solid background in the concepts common to many types of neuroimaging, ranging from study design to data processing and interpretation, will be discussed to address neuroscientific questions. In particular, we will first review the basics of neurophysiology to understand the principles of brain imaging. Then, methodologies of data processing for the main brain imaging tools will be provided to the students with hands-on sessions: students will become familiar with the main pipelines for PET and fMRI data reconstruction, realignment, spatio- temporal normalization, first and second-level analyses.

Lecture Contents:
- Introduction to behavioral and cognitive neurosciences: definition and overview of main applications. The contribution of neuroimaging to cognitive neuroscience
- Principles of in vivo brain metabolic and functional exploration. Basics of brain metabolism: the concepts of neurovascular unit, neurovascular coupling, glucose and oxygen metabolism, synapses.
- Introduction to Positron Emission Tomography, basics of PET functioning and application. PET applications for clinical and research purposes. Examples of neurological cases of PET imaging. Indications for running a PET experimental protocol.
- Introduction to functional magnetic resonance imaging. Introduction to nuclear magnetic resonance imaging and its application in brain functional imaging
- Introduction to functional magnetic resonance imaging: definition of T2* and origin of the BOLD signal. Experimental design for fMRI protocols. Introduction to fMRI data preprocessing (image registration, realignment, smoothing, motion correction, etc.). Statistical approaches for group analysis in fMRI.
- Resting state protocols and the default mode network

Teaching Method:
The course includes theoretical and methodological face-to-face lessons with the help of slides. E-learning platform are used to share learning materials (slides, data, etc.). Hands-on lessons will be promoted.

Bibliography:

Slides of the course

Poldrack, R. A., Mumford, J. A., & Nichols, T. E. (2011). Handbook of functional MRI data analysis. Cambridge University Press.

Final Exam:

Knowledge is verified through oral presentation of selected papers on the theoretical and methodological aspects of neuroimaging, and through the completion of an analytical pipeline relative to an assigned fMRI dataset.

Prerequisites:

None

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Basic principles and Applications of Electrophysiology and Stimulation Tecniques
Giulio Bernardi, Luca Turella, Simone Rossi
40 Hours

(Giulio Bernardi - 24 Hours)

Learning Outcomes:
Knowledge of procedures for the acquisition of electroencephalographic activity in humans. Knowledge of common procedures for the preprocessing and analysis of electroencephalographic recordings.

Abstract:
The course will provide an introduction to the use of standard and high-density electroencephalography (EEG) for the study of brain activity in humans. In particular, the course deals with the following topics:

a) Principles of electroencephalography;
b) Preprocessing of EEG recordings;
c) Basic approaches for the analysis of EEG data.

Lecture Contents:
Part 1. Principles of electroencephalography. Standard and high-density EEG systems. Introduction to the preparation of an EEG recording in humans (Lectures).

Part 2. Preprocessing of EEG recordings. Identification of the most common artifacts. Procedures for the exclusion or reduction of common artifacts. Basic principles of source modeling (Lectures).

Part 3. Step-by-step preparation of high-density EEG recordings (Lab practical lesson or video tutorial).

Part 4. Procedures for the visualization and inspection of EEG recordings in MATLAB. Use of the EEGLAB toolbox for data visualization and analysis (Practical lesson).

Part 5. Procedures for basic data preprocessing, including data filtering and data inspection for the identification and rejection of electrodes and epochs containing physiological or non-physiological artifacts (Practical lesson).

Par 6. Use of independent component analysis (ICA) for the reduction of ocular, muscular, and electrocardiographic artifacts in EEG signals (Practical lesson).

Part 7. Analysis of EEG data: power spectral density, power in conventional frequency bands, time-frequency representation. Principles of connectivity analysis.

Teaching Method:
Lectures, Practical lessons, Practical lesson in the EEG laboratory (or video tutorial)

Bibliography:
Riitta Hari, Aina Puce. MEG-EEG Primer. 2017
Mike X Cohen. Analyzing Neural Time Series Data. 2014

Final Exam:
Yes (practical and oral exam)

Prerequisites:
None

Basic principles and Applications of Electrophysiology and Stimulation Tecniques
Giulio Bernardi, Luca Turella, Simone Rossi
40 Hours

(Luca Turella - 8 Hours)
Course description will be available soon.

Basic principles and Applications of Electrophysiology and Stimulation Tecniques
Giulio Bernardi, Luca Turella, Simone Rossi
40 Hours

(Simone Rossi -8 Hours)

Learning Outcomes:
Basic knowledge of non invasive brain stimulation techniques for research and treatment uses

Abstract:
The course will provide the neurophysiological basis of how non invasive brain stimulation techniques may interact with cortical neurons and networks. The following topics will be covered: Examples of how the different techniques can be used to get causal evidences on the role of different brain regions in cognitive tasks (memory, intelligence); Examples on how corticospinal motor synergies can be studied; A survey on the safety of non invasive brain stimulation techniques; uses of these techniques with therapeutic purposes.

Lecture Contents:
TMS, TMS-EEG coregistration, tDCS, tACS, tRNS, EEG, Combination of techniques

Teaching Method:
Frontal lessons with video support; Interaction with students

Bibliography:
https://scholar.google.it/citations?user=1YEh9q4AAAAJ&hl=it

Final Exam:
No

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Introduction to Consciousness and Sleep
Lecturer: Giulio Bernardi
Hours: 16

Learning Outcomes:
Knowledge of the main approaches for the study of consciousness in humans. Identification of main states of vigilance based on electroencephalographic activity. Knowledge of the impact of homeostatic and circadian factors on brain structure and function.

Abstract:
The course will provide an introduction to fundamental concepts and current experimental approaches related to the study of the functional and anatomical basis of consciousness. In particular, the course deals with the following topics:

a) Definition of consciousness and identification of its fundamental properties;
b) The neuroanatomical bases of consciousness;
c) Main experimental paradigms and methodological approaches to the study of consciousness;
d) Altered states of consciousness: sleep, anesthesia, seizures, coma and related conditions;
e) Sleep as a model for the study of consciousness: local aspects of sleep and wakefulness.

Lecture Contents:
Part 1. Definition of consciousness and identification of its fundamental properties. The neuroanatomical basis of consciousness.

Part 2. Conscious access and experimental approaches for the study of visual consciousness. Electrophysiological and functional signatures of distinct states of vigilance. Impact of changes in vigilance state on neuroimaging investigations.

Part 3. Behavioral and functional differences between sleep and wakefulness. Sleep scoring and analysis of sleep structure. Sleep as a model for the study of consciousness. Local aspects of sleep and wakefulness. The neural correlates of dreaming.

Part 4. Altered states of consciousness: sleep, anesthesia, coma, unresponsive wakefulness syndrome (or vegetative state), minimally conscious state, seizures. Measures of the level of consciousness in physiological and pathological conditions.

Teaching Method:
Lectures

Bibliography:
Steven Laureys Olivia Gosseries Giulio Tonon. The Neurology of Consciousness (2nd Edition) - Cognitive Neuroscience and Neuropathology. 2015

Stanislas Dehaene. Consciousness and the brain: Deciphering how the brain codes our thoughts. 2014

Hans Dringenberg. Handbook of sleep research (1st Edition). 2019

Final Exam:
Yes (short seminars)

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Neurobiology of Emotion and Behavior
Pietro Pietrini
12 Hours

Learning Outcomes:

By attending this Course, students will learn the fundamentals of the neurobiological correlates of emotion and behavior and their evolutionary meaning under physiological conditions. Neurobiological correlates and effects of altered mental conditions on emotion and behavior also will be discussed.

Abstract:

The body of knowledge gained in the field of neuroscience in the last quarter of century have changed the way we conceptualize mind, behavior and even human nature. Since the 19th century it has been known that lesions to the cerebral cortex may lead to impairments in specific cognitive functions and in the ability to modulate behavior. The recent development of modern methodologies for investigating brain functions, including positron emission tomography and functional magnetic resonance imaging has made it possible to investigate the neural circuits implicated not only in cognitive processes such as perception, attention, memory and language, but also in more elusive mental functions, including emotion and behavior. In addition, molecular biology and genetics have led to the decoding of the human genome and are now investigating the role that the genetic endowment plays in shaping not only physical, but also personality features, behavior and vulnerability to mental disorders.

Lecture Contents:

* Brain structures involved in emotion and behavior in humans, non humans primates and other vertebrates. Why it is important to study the neurobiological correlates of emotion and behavior in the human brain
* Brain functional and structural correlates of emotion and behavior in humans. How structural and functional brain imaging methodologies can be applied to the in vivo study of human emotion and behavior
* Brain response to fearful stimuli. The role of amygdala. Emotions as a way to enhance signal-to-noise ratio in information processing. Evolutionary meaning of emotional processing
* Mood influence on emotional brain response. Effects of priming on amygdala response to neutral and sad stimuli. Implications for the understanding of the effects of environmental factors on mood balance
* Effects of negative life events on brain structures. Implications for the neurobiology of depression. Effects of meditation on brain structure and function
* Cognitive and emotional determinants in behavioral modulation. From instinct to decision making. The neural correlates of aggressive control in the healthy human brain. Altered structural and functional cortical and subcortical factors in behavioral dysfunctions: implications for mental insanity in the forensic context
* The human genome. Genetic alleles involved in emotional processing and behavior. Genetic vulnerability to mood disorders
* Moral behavior. Cognitive and emotional aspects. The genetic factors that may influence human moral decisions

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* Genes and environmental factors in shaping individual social behavior and vulnerability to psychological distress and depression
* Implications of recent neuroscience acquisitions about human emotion and behavior for the social sciences and the law

Teaching Method:
The course includes theoretical and methodological face-to-face lessons, with the help of slides and experimental research publications. E-learning platform are used to share learning materials (slides, data, publications, etc.)

Bibliography:
Lesson slides; selected papers of studies and case reports discussed in class

Final Exam:
Knowledge will be verified throughout the course by student's engagement into discussion in class; a written examination with open questions and multiple choice questions will be administered at the end of the course

Prerequisites:
Basic knowledge of brain imaging methodologies.It is strongly suggested, though not mandatory, that students have followed the following courses prior to enrolling in this one: Introduction to Cognitive and Social Psychology; Basic Principles and Applications of Brain Imaging Methodologies to Neuroscience.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Neuroscience of Perception and Experience-Dependent Plasticity
Lecturer: Emiliano Ricciardi, Davide Bottari
Hours: 46

Learning Outcomes:
At the end of the course, students are expected to have specific knowledge of the neurophysiology of perception and of the applications of the most important brain functional techniques toward the investigation of the neuronal basis of perception across different sensory modalities. Students will be also introduced to the topic of sensory deprivation and to the comprehension of how (the lack of) visual experience shapes brain development and function. Moreover, students will learn how neural plasticity and its dependence from environmental input changes along the development.

Abstract:
The course will review the neurophysiological bases of perception in humans. In particular, for each sensory modality, the basic neurophysiology of perception will be described and evaluated with an experimental perspective. The course will consequently detail the neural bases of unimodal, multisensory and supramodal perception. The course will review the literature concerning early and late sensory-deprived individuals to understand how the lack of sensory experience affects brain functional and structural development. Moreover, the course will review the specificity of neural plasticity in early phases of the development, describing sensitive and critical periods from a functional and structural perspectives. Finally the course will review studies showing the differences between the neural plasticity occurring during childhood and in adulthood.

Lecture Contents:
- Introduction to perception and sensory experience; definition perception vs. sensation and sensory modalities; common features across sensory modality; perception and imagery.
- Perception: methodological approaches, advantages and pitfalls.
- The bodily senses: definition, subtypes, the skin and mechanoreceptors, physiology of bodily senses, central pathways, neural correlates of active and passive touch, brain imaging approaches applied to touch-based experimental design.
- Pain and nociception, physiology and central processing of pain (‘pain matrix’). Brain imaging of pain perception, pain anticipation and pain modulation.
- The Auditory system: anatomy, auditory perception, functional organization (anterior/posterior), computational neuroscience of auditory perception.
- Chemical senses. Physiology of olfaction and taste. Brain imaging applied to the assessment of the neural correlates of chemical senses.
- The visual system. Physiology of vision, the eye and the central visual pathways. Brain imaging approaches to the investigation of the visual system. The functional organization of the ventral and dorsal extrastriate patterns. Maps and modules in the ventral stream. Neural basis of face perception.
- Multisensory I and II. What is multisensory processing, behavioral and neural correlates.
- Cross-modality I and II. Heteromodal responses in sensory deprived models (animal and human) and in typical development.

- Supramodality, definition and indications from the research in blind individuals. Functional features of supramodality and discussion on the open questions on the topic.
- Functional and Structural Development I and II. Definition and examples of sensitive and critical periods. Physiological basis. Review of sensitive periods in vision. Perceptual narrowing. Unisensory and multisensory functional development.
- Experience dependent plasticity I and II. Developmental and adulthood experience dependent plasticity. Probabilistic learning and perceptual training in animal and human models.

Teaching Method:
The course includes theoretical and methodological face-to-face lessons with the help of slides. E-learning platform are used to share learning materials (slides, data, etc.).

Bibliography:
Slides of the course and scientific papers that are relevant to the presented topics.
Suggested readings:
Cognitive Neuroscience: The Biology of the Mind - Michael S. Gazzaniga, Richard B. Ivry, George R. Mangun
Principles of neural science - Eric R. Kandel, James H. Schwartz, Thomas M. Jessell, Steven A. Siegelbaum, A.J. Hudspeth

Final Exam:
Learning outcomes are verified through oral presentations on selected topics.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Principles of Brain Anatomy and Physiology
Luca Cecchetti
30 Hours

Learning Outcomes:
At the end of the course, students will be able to recognize major anatomical landmarks of the human brain, both in volume and surface space. They will also be able to analyze structural brain data using several neuroimaging tools (e.g., FSL, Freesurfer, TrackVis).

Abstract:
The course aims at introducing the fundamentals of brain anatomy and physiology. In the first part of the course we will revise cell types and cytoarchitectonic of the cortical mantle, with particular regards to visual, auditory, somatosensory and motor systems. We will then focus on gross neuroanatomy: gyri and sulci of the cortex, subcortical structures, brainstem nuclei and major white matter fasciculi. The second part of the course will be devoted to the study of functional neuroanatomy, with insights on the relationship between specific brain structures and human cognition, collected using functional and lesion studies. In the last part of the course we will review structural brain imaging methods: voxel-based and surface-based (e.g., thickness, folding) morphology, diffusion weighted imaging and tractography. Students will be also involved in the analysis of structural imaging datasets.

Lecture Contents:
- Useful terms to "navigate" the brain (e.g., dorsal, caudal, rostral) and how they relate to viewing planes (axial, coronal, sagittal); overall description of grey and white matter, as well as of the ventricular system. General description of brain development.
- Examples coming from comparative neuroanatomy on brain volume and cortical folding. General organization of white matter (associative, commissural and projection fibers). Brain morphology: to what extent is inherited and how it relates to gender and ethnicity. Changes in brain volume related to development, ageing and to circadian rhythms.
- Brainstem structure and function (pons, midbrain and medulla oblongata). Description of major pathways (e.g., corticopontocerebellar fibers, cerebral and cerebellar peduncles) and nuclei (inferior and superior olive, red nucleus, substantia nigra).
- Cerebral hemispheres and lobes. Identification of major sulci and gyri of the frontal lobe using Surfice and FSL. Frontal lobes functions with examples coming from lesion studies (e.g., impulse control, speech production, motor planning). Identification of white matter tracts connecting distinct regions of the frontal lobes using Trackvis.
- Identification of major sulci and gyri of the parietal lobe. Parietal lobes functions with examples coming from lesion studies (e.g., spatial and somatosensory processing). Dissection of white matter tracts connecting distinct regions of the parietal lobes. Temporal lobes functions with examples coming from lesion studies (e.g., speech comprehension, auditory processing). Dissection of white matter tracts connecting distinct regions of the temporal lobes.
- Identification of major sulci and gyri of the occipital lobe. Occipital lobes functions with examples coming from lesion studies (e.g., visual processing and multisensory integration). Dissection of white matter tracts connecting distinct regions of the occipital lobes using. Limbic lobe functions with

examples coming from lesion studies (e.g., emotional and salience processing). Dissection of white matter tracts connecting distinct regions of the limbic lobe.
- Identification of subcortical structures. Basal ganglia, thalamus, hippocampus and amygdala functions with examples coming from lesion studies (e.g., memory, motor control). Dissection of white matter cortico-subcortical tracts.
- Spatial normalization, AC-PC alignment, Talairach and MNI152 templates. Linear and Nonlinear spatial registration techniques: algorithms, cost functions (e.g., mutual information), degrees of freedom (e.g., affine vs rigid body) and interpolation (e.g., trilinear, spline, nearest neighbour). How to implement spatial transformations in FSL and how to deal with abnormal brains (e.g., lesions, atrophy).
- How to measure structural properties of the white matter: the diffusion weighted imaging. How does DWI works and which type of measures we can obtain (e.g., fractional anisotropy, mean diffusivity).
- Use of Freesurfer for cortical morphology and FSL for voxel-based morphology. Examples of structural covariance.

Teaching Method:
The course includes theoretical lectures with the help of slides. Practical lectures will cover the application of analysis tools to structural imaging data.

Bibliography:
Slides of the course

Final Exam:
Knowledge is verified through an interview on functional neuroanatomy and gross brain morphology (using both volumetric and surface-based representations).

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Elective Courses

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Neuroimaging
Giacomo Handjaras, Nicola Vanello, Mauro Costagli
26 Hours

(Giacomo Handjaras - 12 Hours)

Learning Outcomes:
The course is aimed to introduce basic concepts and to provide the basis of practical applications on bivariate and multivariate analyses of neuroimaging data.

Abstract:
Early neuroimaging studies focused on univariate analyses in which the activity of each voxel (MRI) or channel (EEG/MEG) is processed independently from each other. Nowadays, multivariate machine learning techniques have been developed to model complex, sparse neuronal populations. This course will provide an introduction to new approaches to handle and model bivariate and multivariate interactions between voxels or channels. Specifically, the course focuses on functional connectivity and its derivatives, Representational Similarity Analysis and machine learning decoding and encoding perspectives. A comprehensive review of model validation and statistical inference is provided. The course also discusses the transdisciplinary approach combining different neuroimaging techniques and the advent of ultrahigh field neuroimaging.

Lecture Contents:
Part 1. Bivariate analyses: functional and effective connectivity and its derivatives (e.g., dynamic functional connectivity). Brief recap of graph measures used in neuroimaging.
Part 2. Decoding approach.
Part 3. Encoding models.
Part 4. Representational Similaity Analysis.
Part 5. Trending methodologies to handle complex experiments (e.g., laminar fMRI, inverted encoding models).
Part 6. Hands-on lesson using real data.

Teaching Method:
slides and working in groups on pc

Bibliography:
O'Reilly, J. X., Woolrich, M. W., Behrens, T. E., Smith, S. M., & Johansen-Berg, H. (2012). Tools of the trade: psychophysiological interactions and functional connectivity. Social cognitive and affective neuroscience, 7(5), 604-609.
Bastos, A. M., & Schoffelen, J. M. (2016). A tutorial review of functional connectivity analysis methods and their interpretational pitfalls. Frontiers in systems neuroscience, 9, 175.
Hutchison, R. M., Womelsdorf, T., Allen, E. A., Bandettini, P. A., Calhoun, V. D., Corbetta, M., ... & Handwerker, D. A. (2013). Dynamic functional connectivity: promise, issues, and interpretations. Neuroimage, 80, 360-378

Haxby, J. V. (2012). Multivariate pattern analysis of fMRI: the early beginnings. Neuroimage, 62(2), 852-855.
Mitchell, T. M., Hutchinson, R., Niculescu, R. S., Pereira, F., Wang, X., Just, M., & Newman, S. (2004). Learning to decode cognitive states from brain images. Machine learning, 57(1-2), 145-175.
Haynes, J. D. (2015). A primer on pattern-based approaches to fMRI: principles, pitfalls, and perspectives. Neuron, 87(2), 257-270.
Pereira, F., Mitchell, T., & Botvinick, M. (2009). Machine learning classifiers and fMRI: a tutorial overview. Neuroimage, 45(1), S199-S209.
Naselaris, T., Kay, K. N., Nishimoto, S., & Gallant, J. L. (2011). Encoding and decoding in fMRI. Neuroimage, 56(2), 400-410.
Kriegeskorte, N., Mur, M., & Bandettini, P. A. (2008). Representational similarity analysis-connecting the branches of systems neuroscience. Frontiers in systems neuroscience, 2, 4.
Cichy, R. M., & Pantazis, D. (2017). Multivariate pattern analysis of MEG and EEG: A comparison of representational structure in time and space. NeuroImage, 158, 441-454.

Final Exam:
Knowledge is verified through oral presentation of selected papers on the theoretical and methodological aspects of neuroimaging.

Prerequisites:
None

Advanced Neuroimaging
Giacomo Handjaras, Nicola Vanello, Mauro Costagli
26 Hours

(Nicola Vanello - 8 Hours)
Course description will be available soon.

Advanced Neuroimaging
Giacomo Handjaras, Nicola Vanello, Mauro Costagli
26 Hours

(Mauro Costagli - 6 Hours)
Course description will be available soon.

SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics in Network Theory: Algebraic Concepts in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
THE STUDENT WILL ACQUIRE THE ALGEBRAIC SKILLS TO OPERATE WITH NETWORKS

Abstract:
We shall provide the definitions of the algebraic concepts lying at the core of network theory and shall introduce the principles of network analysis with Python. This module is propedeutic for modules 3, 4, 5.

Lecture Contents:
LECTURE 11 Graph Representation
LECTURE 12 Graph Representation
LECTURE 13 Exercises in Python
LECTURE 14 Graph Laplacian
LECTURE 15 Graph Spectral properties
LECTURE 16 Exercises in Python
LECTURE 17 Exercises in Python
LECTURE 18 Exercises in Python
LECTURE 19 Exercises in Python
LECTURE 20 Exercises in Python

Teaching Method:
Powerpoint lectures

Bibliography:
Scale-Free Networks G. Caldarelli

Final Exam:
the candidate will work in the classroom and we shall assign a "pass" or "retake" vote at the end of course.

Prerequisites:
None

SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics in Network Theory: Brain Networks
Guido Caldarelli
10 Hours

Learning Outcomes:
Knowledge of the basis of Brain Networks

Abstract:
We shall provide the tools to measure and analyze the different kinds of networks that can be defined when studying the human brain (e.g. the functional and the structural one).

Lecture Contents:
Physics of Brain measurements. Networks from Functional Magnetic Resonance Imaging, applications to cohorts of patients

Teaching Method:
Powerpoint slides

Bibliography:
Scale-Free Networks G. Caldarelli

Final Exam:
the candidate will work in the classroom and we shall assign a "pass" or "retake" vote at the end of course.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics in Network Theory: Dynamical Models in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
Being able to use models for network theory

Abstract:
We shall review the most popular growth models for networks, the details of the most studied dynamical processes on networks and their implementation in Python. This module requires module 2.

Lecture Contents:
LECTURE 31 Models I
LECTURE 32 Models II
LECTURE 33 Models III
LECTURE 34-37 Epidemics
LECTURE 37-40 Exercises in Python

Teaching Method:
Powerpoint lectures

Bibliography:
Scale-Free Networks G. Caldarelli

Final Exam:
the candidate will work in the classroom and we shall assign a "pass" or "retake" vote at the end of course.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics in Network Theory: Research Topics in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
Being aware of the state of the art

Abstract:
We shall review the latest developments in research concerning the field of network theory. This module requires module 2. The course "Advanced Methods for Complex Systems I" is suggested as a prerequisite.

Lecture Contents:
The Exponential Random Graph Model: constrained entropy maximization; parameter estimation; computing expectations and errors; a quick look at perturbation theory for networks (2h)
Hypothesis testing on networks: projecting and filtering bipartite networks; early-warning signals detection; community detection techniques for correlation matrices (asset graph, MSF, dendrogram-cutting, the Masuda approach, random matrix theory-based techniques) (3h)
Network reconstruction; applications to the World Trade Web; comparison between network models and econometric models; applications to financial networks; link prediction (3h)
An overview of infrastructural networks (2h)

Teaching Method:
Powerpoint lecture

Bibliography:
Scale-Free Networks G. Caldarelli

Final Exam:
The candidate will work in the classroom and we shall assign a "pass" or "retake" vote at the end of course.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics in Network Theory: Topological Concepts in Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
knowledge of the topology associated to graphs

Abstract:
We shall introduce the definitions of the main topological quantities of interest in network theory and their implementation in Python. This module requires module 2 and is propedeutic for module 5.

Lecture Contents:
LECTURE 21 Centrality measures II
LECTURE 22 Centrality measures
LECTURE 23 Bipartite Networks
LECTURE 24 Ranking and Reputation
LECTURE 25 Mesoscale Properties
LECTURE 26 Exercises in Python
LECTURE 27 Exercises in Python
LECTURE 28 Trade Network data
LECTURE 29 Exercises in Python
LECTURE 30 Exercises in Python

Teaching Method:
Powerpoint lectures

Bibliography:
Scale-Free Networks G. Caldarelli

Final Exam:
The candidate will work in the classroom and we shall assign a "pass" or "retake" vote at the end of course.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Basic Elements of Cybersecurity
Rocco De Nicola
10 Hours

Learning Outcomes:
Basic knowledge of the risks when surfing the web and of the main tools for defending assets and privacy.

Abstract:
This introductory an introductory course that would be beneficial for any student and does not assume any prior technical knowledge. We will discuss cybersecurity in general and present techniques and tools for navigating securely and for defending assets and privacy.

Lecture Contents:
Introduction to Cybersecurity, examples of different kinds of attacks. Best practice for malware detection and for password management. Secure and privacy preserving Internet surfing and application usage. Introduction to Access Control methods. Basic notions of cryptography: Symmetric and Asymmetric Encryption, Public-Key Encryption, Message Authentication, Digital Signatures. Steganography.

Teaching Method:
Blackboard; slides.

Bibliography:
Handouts with the slides, introductory books,

Final Exam:
Final collective discussion about the importance of cybersecurity with short presentations by all students.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Basic Linear Algebra and Statistics for Neuroscience
Giorgio Gnecco, Francesco Serti
30 Hours

(Linear Algebra part - Giorgio Gnecco - 10 Hours)

Learning Outcomes:
The course is aimed to introduce basic notions of linear algebra and its applications to Neuroscience. It is focused more on applications than on theory.

Abstract:
This course provides a basic introduction to linear algebra to students with no (or minimal) background on it. The emphasis is on the description of some applications of linear algebra, including some of interest to students in neuroscience, such as basic image processing, principal component analysis, and spectral clustering. More advanced material will be provided upon request to students having already a solid bakground in linear algebra.

Lecture Contents:
- Historical introduction.
- Sum of two matrices, scalar multiplication, convex combination. Application to image processing.
- Vectors, vector norms, and transposition. Application to movie ratings and digit recognition.
- Product of a row vector and a column vector, cosine similarity. Application to movie ratings.
- Matrix product. Application to image processing.
- Linear systems, Gaussian elimination, Cramer's rule. Application to cryptography and to computed tomography.
- Least squares. Application to score prediction in races.
- Eigenvalues and eigenvectors. Application to graph centrality and spectral clustering.
- Matrix powers. Application to genetics.
- Principal component analysis, linear discriminant analysis, singular value decomposition. Application to image processing.
- Markov chains. Application to games and web surfing.
- Exercises on the blackboard on the following topics: sum of matrices, scalar multiplication, matrix product, Cramer's rule, Gaussian elimination, eigenvectors and eigenvalues, determinants.

Teaching Method:
The teacher will project slides on the screen (a copy of the slides will be provided to the students). He will also solve some exercises on the blackboard.

Bibliography:
Tim Chartier, When life is linear: from computer graphics to bracketology, MAA Press, 2015.
Timothy Hagle, Basic math for social scientists: concepts, SAGE Publications, 1995.
Timothy Hagle, Basic math for social scientists: problems and solutions, SAGE Publications, 1996.

Final Exam:
Final written examination (2 hours).

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Basic Linear Algebra and Statistics for Neuroscience
Giorgio Gnecco, Francesco Serti
30 Hours

(Statistics Part - Francesco Serti - 20 Hours)

Learning Outcomes:
To provide students with an introduction to probability and statistics.

Abstract:
This part of the course will provide students with an introduction to probability and statistics and it will be focused on topics that are particularly relevant to neuroscience. The lessons will be designed for students with a minimum knowledge of the subject.

Lecture Contents:
The topics covered will be:
- Introduction to probability: random variables, discrete and continuous distributions
- Introduction to statistics: definition of statistical model, estimate and estimator, point estimation and
- interval estimation
- Statistical tests: parametric and non parametric tests
- Analysis of Variance: one-way and two-way ANOVA
- Relation between variables: linear model, multiple regression

Teaching Method:
Each class will consist of a first introductory part with basic notions of statistics and of a second part in which those notions are applied to examples by using the software R.

Bibliography:
Wilcox, Rand R - Understanding and applying basic statistical methods using R - John Wiley & Sons (2016).
Wilcox, Rand R. - Modern statistics for the social and behavioral sciences _ a practical introduction - CRC Press (2017).
Russell Poldrack - Statistical Thinking for the 21st Century An open source textbook for statistics, with companions for R and Python - Stanford University (2020).

Final Exam:
The final exam will consist in a short applied essay in which students will elaborate and try to answer a simple research question, such as investigating the effect of some treatments in a clinical trial/(social)experiment, or using observational data (surveys or administrative data) to study the effect of some individual characteristics/behaviors on some individual outcome.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Basic Programming for Neuroscience
Monica Betta
20 Hours

Learning Outcomes:
You will learn how to plan and script by yourself the simple and complex functionalities that will be fundamental for your research activity, and to understand the code before running it

Abstract:
The course is aimed at students who have little or no experience with programming and will provide a general introduction to the Matlab software package.
Basic concepts and description of elementary functions will be illustrated.
Practical applications, in particular in the framework of neuro-signal analysis, will be carried out during hands-on sessions.

Lecture Contents:
Basic concepts of programming (defining the problem, planning the solution, coding the program, testing the program, documenting the program) and a preliminary description of Matlab environment

Teaching Method:
Frontal lessons followed by hands-on sessions

Bibliography:
I am a biomedical engineer. During my PhD in "automation, robotics and bioengineering" I intensely worked on the development of validated and automated functionalities for sleep research, in collaboration with the Institute of Clinical Physiology (CNR, Pisa) and the Lausanne University Hospital (switzerland). I am a member of the MoMiLab since 2016.

Final Exam:
Oral examination. At the end of the course you will be asked to write by yourself some parts of a code

Prerequisites:
None

Biosignals, Bionics and Neuroscience
Michele Emdin, Graziella Orrù, Enzo Pasquale Scilingo, Silvestro Micera, Antonio Bicchi
28 Hours

Course description will be available soon.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Clinical Psychopathology and Psychiatry
Pietro Pietrini
16 Hours

Learning Outcomes:
By attending this Course, students will learn the fundamental psychopathological and clinical aspects of the main psychiatric disorders, including affective disorders, psychosis and personality disorders. Students will learn the most recent acquisitions from genetic and cognitive neuroscience to the understanding of the etiopathogenesis and clinical course of mental disorders. Implications for mental insanity evaluation will also be discussed.

Abstract:
Mental disorders remain to-date still undiagnosed or misdiagnosed in many cases, with deleterious effects on the individual patient's life, including extreme acts that could be prevented by early and prompt diagnosis. Because most mental disorders appear during adolescence, their effects may be even more disruptive and dramatic. Furthermore, mental disorders may favor alcohol and drug abuse as well as promote abnormal behaviors that may pose serious risks for the patients and their family members. At the same time, mental disorders may affect, even severely, the ability of the patient to control their acts. This, in turn, may become relevant for assessing their responsibility in situations that fail to respect the law. Implications for the forensic and legal setting, including the role of personality disorders in imputability (see the Raso Sentence by the Italian Supreme Court in 2005) will be discussed.

Lecture Contents:
* The issue of the diagnostic process in Psychiatry. Differences as compared to the other medical branches
* Affective disorders. Mood depression. Psychopathological factors in mood depression. The neurobiology of depression
* Bipolar disorder. The psychopathological condition of mania. Lack of critical abilities in mania. Clinical course of bipolar disorders. Predicting switch from one polarity to the other
* Anxiety disorders. General anxiety, panic attacks. Obsessive-compulsive disorders
* Psychoses. Schizophrenia and schizophreniform disorders. Delusional thinking. Hallucinations
* Personality disorders. Definition and classification. The three clusters of personality disorders. Psychopathological and clinical aspects of the individual personality disorders.
* Mental disorders and implications for imputability: the assessment of insanity and implications for the forensic and legal settings

Teaching Method:
The course includes theoretical and methodological face-to-face lessons, with the help of slides and publications. E-learning platform are used to share learning materials (slides, data, publications, text chapters, etc.).

Bibliography:
Lesson slides; selected papers and text chapters discussed in class

Final Exam:
Knowledge will be verified throughout the course by student's engagement into discussion in class; a written examination with open questions and multiple choice questions will be administered at the end of the course

Prerequisites:
It is strongly suggested, though not mandatory, that students have taken the following courses prior to enrolling in this one: Introduction to Cognitive and Social Psychology; Neurobiology of Emotion and Behavior.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Cognitive Economics
Luca Poloni, Gustavo Cevolani
20 Hours

Learning Outcomes:
At the end of the course, the student should have a clear understanding of different methods in the field of cognitive economics. The student should be able to design an experiment to investigate simple economic decision making processes. The student should be able to recognize the weaknesses and strengths of published articles, starting from the research question, through the method used, to the reporting of the project's outcome.

Abstract:
Cognitive economics studies patterns of (strategic) behavior and decision-making starting from the analysis of the actual beliefs, preferences, and cognitive abilities of real people.
It thus relies on an interdisciplinary approach merging economics, psychology and cognitive science in general, and it emphasizes the relevance of individual differences and heterogeneity for the study of human reasoning and cognition. The goal of the course is to provide an introduction to cognitive economics and a balanced view of the main approaches in this field. These include dual-process theories of reasoning and cognition, the process tracing approach, and different models of choice, such as drift diffusion and rational inattention models. Moreover, the course aims to provide a practical understanding of different methods from psychophysics, including the analysis of reaction time, mouse-lab and eye-tracking, enabling students to design their own experiments.

Lecture Contents:
1) What is Cognitive Economics
2) Approaches in Cognitive Economics and Cognitive Science
3) Rationality, Reasoning and Decisions: Theory and Practice
4) The Role of Cognitive Abilities in Decision Making
5) Methods from psychophysics for the investigation of decision making (analysis of reaction time, mouse-lab and eye-tracking)
6) Bounded Rationality and Social Preferences
7) The Role of Emotions in Decision Making
8) Drift diffusion and rational inattention models

Teaching Method:
Lectures/Oral presentations

Bibliography:
Brocas, I., & Carrillo, J. D. (2003). The Psychology of Economic Decisions: Volume Two: Reasons and Choices.
Rachel Croson & Monica Capra & Mary I. Rigdon & Tanya Rosenblat (ed.), 0. "Handbook of Experimental Game Theory," Books, Edward Elgar Publishing.

Final Exam:
Writing of a research project proposal

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Computer Programming and Methodology
Mirco Tribastone
30 Hours

Learning Outcomes:
This course aims to provide students with basic principles and methodologies of computer programming using Python. It is aimed particularly to students without a computer science background. The main objective is to develop the necessary skills to effectively read, write, and maintain computer programs. It provides background for facilitating the understanding of advanced programming classes as well as the proficiency with domain-specific software libraries and tools.

Abstract:
The course will cover the basic principles of programming, starting from the interaction between programs and the environment (memory, input/output) in which they execute. It will discuss: fundamental programming constructs (conditional statements, l oops); how to effectively structure code using functions; recursion; object-oriented programming; basics of functional programming; memory management for programs (garbage collection). The Python programming language will be used to demonstrate these concepts and to develop simple illustrative programs that will be presented throughout the course.

Lecture Contents:
Introduction to computer architectures; programming; variables; data structures and Python sequences; memory management; conditional statements; for and while l oops; functions; basics of object-oriented programming; basics of functional programming.

Teaching Method:
Blackboard; slides; programming tutorials

Bibliography:
M. Lutz. Learning Python, O'Reilly.

Final Exam:
Group project

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Contextual Analysis and Individual Objects: Arts, Sciences, Techniques, Beliefs
Linda Bertelli
30 Hours

Learning Outcomes:
By the end of this course, Ph.D. Students will be able to:
- describe and interpret the main contents and methodologies in visual culture studies and visual studies of science;
- perform close readings of key texts in visual culture studies and media theory of the 20th Century;
- analyze critically key essays regarding the topics covered in class (presentation);
- understand and evaluate the main features of scientific photography (case studies from the end of the 19th Century).

By the end of the assessment, Ph.D. Students will be able to:
- Critically evaluate a specific topic at the juncture of the topics discussed in class and their own research projects;
  - Produce an original paper

Abstract:
The course will be divided into two, closely interrelated parts. The first part will be dedicated to a clarification of contents and methodologies of the research field visual studies of sciences, mostly conducted through a genealogical approach. Mentioning and analyzing a vast array of texts and authors, the course will offer an in-depth study of visual culture studies, Bildwissenschaft and theories of media from the 20s and 30s (L. Moholy-Nagy and W. Benjamin in particular).
In order to put the methodological framework outlined in the first part to work, the second part of the course will be dedicated to specific case studies, starting from the photographic work of the French physiologist Etienne-Jules Marey (1830-1904).
The understanding of the course material will be assessed through a (1) mid-term examination given in class through the course and (2) a final paper. The paper will be based on material from any topic discussed in class, in engagement with Students' research projects. The aim is to publish the best papers, and/or use your essay in order to prepare a joint publication together with me and/or your classmates.
A more detailed course description with additional information (required readings, grading scale, class policies, etc.) will be sent to all the Students at least 2 weeks before the beginning of the course.

Lecture Contents:
(I) Course Presentation. Introduction and Key Concepts: visual studies of science and visual cultures studies (1st part).
(II) Introduction and Key Concepts: visual cultures studies (2nd part).
Methodological conclusion and brief description of the impacts of visual studies of science.
(III) Midterm Presentation#1: Key texts on visual cultures studies.
(IV) Media theories and the cultural meanings of images: Laszlo Moholy-Nagy, Walter Benjamin and Siegfried Kracauer (1st part).
(V) Media theories and the cultural meanings of images: Laszlo Moholy-Nagy, Walter Benjamin and

Siegfried Kracauer (2nd part).
(VI) Midterm Presentation#2: Key texts on media theory.
(VII) Analysis of the first case study.
(VIII) Analysis of the second case study.
(IX) Midterm Presentation#3: Key texts on case studies.
(X) Conclusions and general discussion about the final paper.

Teaching Method:
The course combines various teaching approaches, both student-centered and teacher-centered methods, such as:

(1) Inquiry-based learning.
(2) Direct Instruction.
(3) Eventual off-site lectures

Bibliography:

- Albera, F., and M. Tortajada (eds.), Cinema Beyond Film: Media Epistemology in the Modern Era. Amsterdam: Amsterdam University Press, 2010.
- Benjamin, W. One-way street and other writings. London: Penguin, 2009.
- Benjamin, W., The Work of Art in the Age of Its Technological Reproducibility and Other Writings on Media, Harvard University Press, 2008, pp. 158-165.
- Braun, M., Picturing Time. The Work of Etienne-Jules Marey (1830-1904). Chicago: University of Chicago Press, 1992.
- Bredekamp, H., "A Neglected Tradition? Art History as Bildwissenschaft", Critical Inquiry, 29, 3, 2003: 418-428
  - Charney, L., and V. R. Schwartz. Cinema and the Invention of Modern Life. Berkeley, Calif: University of California Press, 1995.
- Crary, J., Techniques of the Observer. On Vision and Modernity in the Nineteenth Century. Cambridge [Massachusetts]: MIT Press, 1990.
- Daston, L., and P. Galison, Objectivity, Zone Books, 2007, pp. 115-190.
- Didi-Huberman, G., Images in spite of all: four photographs from Auschwitz. Chicago: University of Chicago Press, 2008.
- Gordon, R.B., Why the French Love Jerry Lewis: From Cabaret to Early Cinema. Stanford, Calif: Stanford University Press, 2001.
- Edwards, E., Anthropology and photography 1860-1920. New Haven: Yale University Press, 1992.
- Elkins, J., "Art History and Images that are not art", The Art Bulletin, 77, 4, 1995: 553-571.
- Ginzburg, C., " Minutiae, Close-up, Microanalysis", Critical Inquiry, 34, 1: 174-189.
- Hansen, M., Cinema and Experience. Siegfried Kracauer, Walter Benjamin, and Theodor W. Adorno. Berkeley, Calif: University of California Press, 2011.
- Jones, Caroline A., and Peter Galison. Picturing Science, Producing Art. New York: Routledge, 1998.
- Mitchell, W.J.T., Picture Theory. Essays on Verbal and Visual Representation, Chicago/London: The University of Chicago Press, pp. 1-34 (Introduction and Chapter I).
- Mitchell, W.J.T., What do pictures want? The lives and loves of images, Chicago/London: The University of Chicago Press, pp. 28-56.

- Moholy-Nagy, L., Painting Photography Film. Cambridge, Mass: MIT Press, 1987.
- Pauwels, L., Visual cultures of science: Rethinking representational practices in knowledge building and science communication. Hanover, New Hampshire: Dartmouth College Press, 2006.
- Rabinbach, A., The Human Motor: Energy, Fatigue, and the Origins of Modernity. New York: BasicBooks, 1990.
- Valihao, P., Mapping the Moving Image: Gesture, Thought and Cinema Circa 1900. Amsterdam: Amsterdam Univ. Press, 2009.
- Véray, L., Les images d'archives face à l'histoire: de la conservation à la création. Futuroscope: Scéren, 2011.

Final Exam:
In order to delve deeper into critical issues at the juncture of the topics discussed in class and students' research projects, each student will be responsible for submitting one essay assignment on a topic of her/his choice which must be established in agreement with me. Each student can decide on the topic of the final paper at any point during the course. Essays should be 8-10 pages in length.
Deadline for the submission will be scheduled during the course.

Prerequisites:
None

Critical Thinking
Gustavo Cevolani
20 Hours

Learning Outcomes:
The course aims at improving the students' skills in understanding, presenting and evaluating problem statements and arguments. After following the course, students will be able to rigorously distinguish between "strong" and "weak" arguments; they can formulate and analyze theses and hypotheses and evaluate the impact that evidence and information has on them; and they can better draw logical and effective conclusions from both hypotheses or evidence.

Abstract:
Constructing and evaluating arguments is fundamental in all branches of science, as well as in everyday life. The course provides the basic tools to recognize and analyze correct forms of inference and reasoning, detect the unsound or fallacious ones, and assess the strength of various kinds of argument. The toolbox includes elementary deductive logic, naïve set theory, patterns of inductive and abductive inference, and elements of statistical and probabilistic reasoning. By engaging in real-world exercises of correct and incorrect reasoning, students will familiarize with basic epistemological notions (truth vs. certainty, knowledge vs. belief, theory vs. evidence, etc.), with the analysis of relevant informal concepts (like truth, falsity, lies, misinformation, disinformation, post-truth, fake news, rumors, etc.) and with common reasoning pitfalls, heuristics and biases as investigated in cognitive psychology and behavioral economics.

Lecture Contents:
Lecture 1. Presentation, discussion and choice of specific topics. Arguments and statements.
Lecture 2. Evaluating statements: Truth, certainty, informativeness, truthlikeness, etc. Relativism and post-truth.
Lecture 3. Evaluating arguments: Deductive reasoning and valid arguments. Fallacies and invalid arguments.
Lecture 4. Evaluating arguments: Non-deductive and uncertain reasoning. Inductive and abductive reasoning.
Lecture 5. Evaluating arguments: Probabilistic reasoning and confirmation. Correlations.
Lecture 6. Reasoning and decision-making: Dual-process theories. Heuristics and biases.
Lecture 7. Reasoning and decision-making: Ecological rationality and fast-and-frugal heuristics.
Lecture 8. Recap, verification and general discussion.

Teaching Method:
Mixture of lectures and discussion seminar.

Bibliography:
We won't have a textbook or a proper reading list. Relevant readings will be shared on the IMT Google Drive. The following are useful general texts on the main topics of the course (all of them are owned by the IMT Library).

- Ronald N. Giere, John Bickle, and Robert Mauldin (2005). Understanding Scientific Reasoning. Wadsworth Inc Fulfillment.
- Gerd Gigerenzer (2008). Rationality for Mortals: How People Cope with Uncertainty. Oxford and New York: Oxford University Press
- Hacking, Ian (2001). An Introduction to Probability and Inductive Logic. New York: Cambridge University Press.
- Darrell Huff (1993). How to lie with statistics. New York: Norton
- Daniel Kahneman (2011). Thinking, Fast and Slow. 1st edition. New York: Farrar, Straus and Giroux
- Richard E. Nisbett (2015). Mindware: Tools for Smart Thinking. New York: Farrar, Straus and Giroux
- Merrilee H. Salmon (2013). Introduction to Logic and Critical Thinking. 6th ed.
- Wesley C. Salmon (1963). Logic. Englewood Cliffs, N.J., Prentice-Hall
- Cass R Sunstein (2009). On Rumors: How Falsehoods Spread, Why We Believe Them, What Can Be Done. New York: Farrar, Straus and Giroux

Final Exam:
Active contribution from the participants is a prerequisite for passing the course.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Decision-Making in Economics & Management
Massimo Riccaboni
10 Hours

Learning Outcomes:
The main goals of the course are: (1) to take marketing theories and methodologies out into the world, applying them to interesting questions of individual behavior and societal outcomes; (2) to develop a basic understanding of human psychology and social dynamics as they apply to marketing contexts; (3) to become familiar with the major theory and research methods for analyzing consumer behavior; (4) to develop market analytics insight into consumer actions.

Abstract:
This class is structured into two parts: 1) general knowledge relating to basic conceptual notions of marketing and consumer behavior; and 2) heritage marketing. Most of time will be devoted to close reading of textbook and research papers, including discussion of the relative merits of particular methodologies. Students will participate actively in class discussion, engage with cutting-edge research, evaluate empirical data, and write an analytical paper. The course aims at enabling students to develop and enhance their own skills and research interests.

Lecture Contents:
1. Course overview, consumer behavior; Chapters 1-4, Principles of Marketing
2. Marketing to create value, theory and practice; Chapters 5-9, Principles of Marketing
3. The Marketing Plan; Chapters 14-16, Principles of Marketing
4. Heritage marketing
5. Behavioral economics insights, guidelines for final paper

Teaching Method:
Lecturing

Bibliography:
The main textbook for this course is entitled "Principles of Marketing" and is freely available online https://open.lib.umn.edu/principlesmarketing/.

See also: Kotler (2019), Principles of Marketing, Peason (17th Edition), available at the library and Misiura (2006), Heritage Marketing, Elsevier.

Additional readings will be provided by the instructor based on students' research interests (see Google Drive)

Final Exam:
50% Participation. Attendance is required and will be recorded. The teaching format is interactive, i.e. active discussion is expected between students and instructor and will be part of the student evaluation. Abstract concepts will be understood through real life examples and observations.

50% Final Paper. You will select a topic related to marketing and consumer decision making and write a paper.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Forensic and Legal Psychology
Pietro Pietrini
16 Hours

Learning Outcomes:
By attending the course, students will learn the fundamentals of psychology and psychiatry as well as the most innovative applications of cognitive and experimental neuroscience to the forensic field. Students will have a first-hand presentation of ground-breaking cases, including the expert report in the 2009 Trieste Court of Appeal case, the 2011 Como's Court case and others, in which neuroscientific data have been used to corroborate the expert report conclusions. Students will learn the critical aspects and the pitfalls of psychiatric forensic examinations and of expert cross-examination.

Abstract:
Contrary to all the other branches of medicine, diagnostic process in psychiatry still suffers from the (almost) complete absence of objective laboratory tests. which results in a poor diagnostic concordance. Even worse is the case in forensic psychiatry, where matters are more complex as compared to the clinical setting. Faced with the classical forensic question, whether or not the defendant is capable to understand and to will, consultants appointed by the different parts (i.e., the judge, the prosecutor, the defendant, the victim) most of the times reach opposite conclusions - based on their role - which are highly speculative and lack of any objective support . Over the last decade, progressive effort has been put to minimize subjective speculations in forensic psychiatric assessment. Applications of neuroscience methodologies, including structural and functional brain imaging and molecular genetics, have proven to increase objectivity.

Lecture Contents:
* The concept of Free Will in the forensic context. The psychological determinants of behavior. How we make decisions
* Structural and functional brain correlates in decision making processes. How we control (aggressive) behavior. Behavioral abnormalities associated with brain lesions or neurodegenerative disorders. Fronto-temporal dementia.
* Psychopathy and behavior. Psychopathy from a psychiatric perspective. Is there a moral blindness?
* Psychopathy and anti-social behavior. Psychopathy as a predictor of criminal behavior. Inside the brain of psychopathics: structural brain differences between psychopathic individuals and healthy controls.
* The functional neuroanatomy of aggressive behavior in humans. Relevance to the understanding of anti-social behavior
* Genetic bases of personality and behavior. Principles of genetics
* Gene and environment in the modulation of social and anti-social behavior.
* Structural and functional brain imaging examinations in the forensic domain: what can these methods tell us about imputability?
* Behavioral genetic examinations in the forensic domain
* Applications of behavioral genetics and brain imaging examinations in the individual assessment in the forensic domain: the 2009 Trieste Court of Appeal case (the first case in Europe); the 2011 Como Court case

* Acquired paedophilia as a results of brain tumor. Literature review and discussion of a recent Italian case.
* Working research hypothesis: is there a Functional Frontal Fragility Syndrome?

Teaching Method:
The course includes theoretical and methodological face-to-face lessons, with the help of slides and case-report publications. E-learning platform are used to share learning materials (slides, data, publications, etc.). Hands-on lessons will be promoted.

Bibliography:
Lesson slides; selected papers of studies and case reports discussed in class

Final Exam:
Knowledge will be verified throughout the course by student's engagement into discussion in class; a written examination with open questions and multiple choice questions will be administered at the end of the course

Prerequisites:
Basic knowledge of brain imaging methodologies; strongly suggested, though not mandatory, that students have followed the following courses prior to enrolling in this one: Introduction to Cognitive and Social Psychology ; Neurobiology of Emotion and Behavior: Clinical Psychopathology and Psychiatry

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Foundations of Probability and Statistical Inference
Irene Crimaldi
30 Hours

Learning Outcomes:
By the end of this course, students will:
- have the ability to employ the fundamental tools of Probability Theory in order to solve different kinds of problems,
- have the fundamental concepts of Statistical Inference in order to perform various kinds of statistical analysis,
- appreciate the importance of mathematical formalization in solving probabilistic problems and in performing statistical analysis,
- be able to independently read mathematical and statistical literature of various types and be life-long learners who are able to independently expand their probabilistic and statistical expertise when needed.

Abstract:
This course covers the fundamental concepts of probability and statistical inference. Some proofs are sketched or omitted in order to have more time for examples, applications and exercises.

Lecture Contents:
This course deals with the following topics:
- probability space, random variable, expectation, variance, cumulative distribution function, discrete and absolutely continuous distributions,
- random vector, joint and marginal distributions, joint cumulative distribution function, covariance,
- conditional probability, independent events, independent random variables, conditional probability density function, order statistics,
- multivariate Gaussian distribution, copula functions,
- probability-generating function, Fourier transform/characteristic function,
- types of convergence and some related important results,
- Mathematical Statistics (point estimation, interval estimation, hypothesis testing, linear regression, introduction to Bayesian statistics).

Teaching Method:
Frontal teaching

Bibliography:
- Slides and other material provided by the lecturer
- R. Durrett, Elementary Probability for Applications, Cambridge Univ. press (2009)
- S. M. Ross, Introduction to Probability Models, Academic press (2003)
- M. Mitzenmacher, E. Upfal, Probability and Computing, Cambridge Univ. press (2005)
- O. Kallenberg, Foundations of Modern Probability, Springer (1997)
- S. M. Ross, Introductory Statistics, Elsevier (2010)

- K. V. Mardia, J. T. Kent, J. M. Bibby, Multivariate analysis. Academic press (1979)
- R. B. Nelsen, An Introduction to Copulas, Springer Series in Statistics (2006)
- P. K. Trivedi, D. M. Zimmer, Copula modeling: an introduction for practitioners (2005)

Final Exam:
Written test

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Funding and Management of Research and Intellectual Property
Marco Paggi
10 Hours

Learning Outcomes:
How to write a research/mobility project proposal; fundamentals on the management of intellectual property rights.

Abstract:
The long seminar aims at providing an overview of funding opportunities for PhD
students' mobility, post-docs, and researchers (Erasmus+ scheme; scholarships by the Alexander von Humboldt Foundation; initiatives by the Deutscher Akademischer Austausch Dienst; scholarships offered by the Royal Society in UK; bilateral Italy-France exchange programmes; Fulbright scholarships; Marie Curie actions; grants for researchers provided by the European Research Council). For each funding scheme, specific hints on how to write a proposal are given. In the second part of the long seminar, fundamentals on the management of intellectual property rights (copyright transfer agreements, open access, patents, etc.) are provided.

Lecture Contents:
- Overview of funding schemes to support research mobility;
- Fundamentals of Intellectual Property Rights (patents, copyrights, etc.)

Teaching Method:
Powerpoint slides

Bibliography:
Handouts are provided to the participants.

Final Exam:
This long seminar has no final exam.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Game Theory
Ennio Bilancini
20 Hours

Learning Outcomes:
The goal is to equip students with an in-depth understanding of the main concepts and tools of game theory in order to enable them to successfully pursue research related to strategic behavior.

Abstract:
The course begins by providing a detailed discussion of the state of the art approach to the modeling of strategic situations as games. Then, basic solution concepts and their main refinements will be reviewed. Finally, prominent applications concerning incomplete and asymmetric information will be presented.

Lecture Contents:
Game concepts covered:
Dominance and iterative dominance, rationalizability, Nash equilibrium, subgame perfect Nash equilibrium, trembling hand perfect Nash equilibrium, weak perfect Bayes-Nash equilibrium, sequential equilibrium, perfect Bayes-Nash equilibrium, out-of-equilibrium beliefs refinements.
The discussion of all theoretical concepts will be accompanied by representative applications from economics and the social and behavioral sciences.

Teaching Method:
Frontal lectures

Bibliography:
Mas-Colell A, Whinston MD, Green JR. Microeconomic theory. New York: Oxford university press

Final Exam:
1/3 assignments, 1/3 final written exam, 1/3 essay

Prerequisites:
The course is self-contained, but being familiar with basic concepts from calculus, l inear algebra, and probability theory is quite helpful.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Introduction to Cognitive and Social Neurosciences
Pietro Pietrini, Emiliano Ricciardi
24 Hours

Learning Outcomes:
At the end of the course, naïve-to-neuroscience students are expected to have a general background knowledge of general topics of cognitive and social neurosciences, and to get introduced to the basic principles of brain functional techniques and their applicability for assessing neural bases of mental functions.

Abstract:
This course will provide a general overview of different topics in Cognitive and Social Neurosciences and their multidisciplinary and translational applications. The course is intended for those students that – outside the CCSN track – are interested in understanding how the comprehension of the neurobiological basis of perception, cognitive skills, behavior, motor responses and decision-making processes could be meaningful even for their research field. In the first part of the course, we will introduce to the modern methodologies to assess brain responses in the human living brain and familiarize with basic concepts in cognitive and social neuroscience. In the second part, we will review seminal findings that had a major impact on our knowledge of cognitive processes and social interactions, as well as more recent studies that took advantage of neuroimaging, electrophysiology and brain stimulation methods to shed new light on visual art and perception, decision-making and behaviors, economics and business, neuroengineering and robotics.

Lecture Contents:
- Introduction to cognitive neuroscience, interaction of neuroscience with other disciplines, historical perspective of neuroscience; introduction to neuroimaging: advantages and limitations; outline of brain physiology
- Outline of brain anatomy and functional organization, introduction to brain metabolism and implications for cognitive neuroscience and neuroimaging
- Introduction to brain imaging techniques and outline of main research and clinical applications
- Introduction to the neural correlates of selected topics of cognitive and social neurosciences, such as motor control, memory and attention, action understanding, emotion and social interaction, decision-making processes, applied with a multidisciplinary approach in behavioral sciences, economics, or aesthetic perception.- Introduction on wow to design a behavioral or neuroimaging study and an experimental protocol in cognitive and social neurosciences.

Teaching Method:
The course includes theoretical and methodological face-to-face lessons with the help of slides. E-learning platform are used to share learning materials (slides, data, etc.).

Bibliography:
Slides of the course and selected articles will be shared with the students.
Suggested readings:
Cognitive Neuroscience: The Biology of the Mind - Michael S. Gazzaniga, Richard B. Ivry, George R. Mangun

Principles of neural science - Eric R. Kandel, James H. Schwartz, Thomas M. Jessell, Steven A. Siegelbaum, A.J. Hudspeth

Final Exam:
Brief presentation of selected scientific articles

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Introduction to Network Theory
Guido Caldarelli
10 Hours

Learning Outcomes:
Basic Knowledge of Graph Theory and main results in the application of the methodology to various cases of study

Abstract:
we shall provide a broad overview of the concepts and the methods constituting
modern network theory.

Lecture Contents:
LECTURE 01 Introduction
LECTURE 02 Graph Theory Introduction
LECTURE 03 Properties of Complex Networks I
LECTURE 04 Communities
LECTURE 05 Different kind of Graphs
LECTURE 06 Ranking
LECTURE 07 Static Models of Graphs
LECTURE 08 Dynamical Models of Graphs
LECTURE 09 Fitness Models
LECTURE 10 Financial Networks
AVAILABLE AT http://guidocaldarelli.com/index.php/lectures

Teaching Method:
Power point Lectures (DOWNLOAD AT http://guidocaldarelli.com/index.php/lectures)

Bibliography:
Scale-Free Networks G. Caldarelli
Networks, Crowds and Markets by David Easley and Jon Kleinberg

Final Exam:
essay/discussion with teacher

Prerequisites:
None

Introduction to Neurolinguistics
Alessandra Rampinini
12 Hours

Learning Outcomes:
Acquiring basic concepts in General Linguistics that can be applied to Neuroscience and the study of language in the brain. Navigating the basic topics in the cognitive neurosciences of language, being able to evaluate and assess methodologies as well as results and theoretical issues related to the discipline.

Abstract:
Linguistics is a social science with a very special feature: it sits at the mind/brain interface. The brain governs our very own biochemistry, giving rise to the biological structures controlling our muscles, ears and breath in verbal languages, or our hands and eyes in the case of sign languages. The mind gives rise to the interpretation of language, as well as memory for meanings and uses, and our own intentions when using language to interact with our peers, knowing that they can understand us. In this course, we will go through these aspects in bird's eye view, studying how single languages came to be in the history of humankind, and how language as a general cognitive ability is controlled by different parts of the brain in a complex system of feedback and feedforward mechanisms.

Lecture Contents:
Introduction to language; functional and structural neuroanatomy of language-dedicated regions; language, handedness and hemispheric specialization; cognitive control in bilingualism; sign language introduction; introduction to language evolution and genetic aspects. Please note: this course is intended for students coming from different backgrounds and tries to be interesting to linguists as well as non-linguists: therefore, and due to time and logistics, some topics need to be overlooked or treated very quickly. The teacher is by all means available for further discussion or enquiries related to other topics if these lie within her own expertise.

Teaching Method:
frontal lesson with media and required interaction, guided discussions.

Bibliography:
Bibliographic suggestions will be given by the teacher in class.

Final Exam:
The final exam will be a closed-answer sheet and will be reserved to those having this class in their study plan. All auditors are welcomed to try it for personal assessment and without a a formal evaluation.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Introduction to Psychophysics
Davide Bottari
12 Hours

Learning Outcomes:
At the end of the course, students are expected to have specific knowledge of the basis of the psychophysical approach and how to analyse behavioural data sets.

Abstract:
The course will review how to implement a behavioural experimental designs, how to calculate thresholds, what are the Bayesian framework and the Optimal integration. The course will detail practical examples with hands-on sessions based on real and simulated data. Practical examples will be performed by learning Matlab based toolboxes.

Lecture Contents:
- Introduction to Introduce basic concepts and terminology.
- Experimental designs
- Available psychophysical procedures. Palamedes
- Psychometric PF functions. Fitting a psychometric function (single subj level)
- Adaptive methods, e.g. Pest, Quest
- Bayesian framework; Optimal cue integration
- MLE; toolbox from Hills et al. Optimal cue integration toolbox

Teaching Method:
The course includes theoretical and hands-on sessions. E-learning platform are used to share learning materials (slides, data, etc.).

Bibliography:
Slides of the course

Final Exam:
Knowledge is verified through hands-on sessions

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Machine Learning
Giorgio Gnecco
20 Hours

Learning Outcomes:
At the end of the course, the student will have a basic knowledge of a quite large set of commonly used machine learning techniques.

Abstract:
The course provides an introduction to basic concepts in machine learning. Topics include: learning theory (bias/variance tradeoff, Vapnik-Chervonenkis dimension and Rademacher complexity, cross-validation); supervised learning (linear regression, logistic regression, support vector machines); unsupervised learning (clustering, principal and independent component analysis); semisupervised learning (Laplacian support vector machines); online learning (perceptron algorithm); hidden Markov models.

Lecture Contents:
Lecture 1: Introduction to supervised learning and regression.
Lecture 2: Classification problems.
Lecture 3: Online learning: the perceptron learning algorithm and the LQG online learning framework.
Lecture 4: Unsupervised learning.
Lecture 5: Introduction to statistical learning theory.
Lecture 6: Structural risk minimization and support vector machines.
Lecture7: A joint application of econometrics and machine learning: trade-off between sample size and precision of supervision.
Lecture 8: A comparison of approximation error bounds for neural networks and linear approximators.
Lecture 9: Application of neural networks to optimal control problems.
Lecture 10: Connection between supervised learning and reinforcement learning.

Teaching Method:
The teacher will project slides on the screen.

Bibliography:
The following books are related to the course. They can be useful as a supplementary material.
D. P. Bertsekas and J. N. Tsitsiklis: "Neuro-Dynamic Programming," Athena Scientific, 1996
C. J. C. Burges, "A Tutorial on Support Vector Machines for Pattern Recognition," Data Mining and Knowledge Discovery, vol. 2, pp. 121-167, 1998
S. Mendelson, "A Few Notes on Statistical Learning Theory," in S. Mendelson, A. J. Smola (Eds.): Advanced Lectures on Machine Learning, Lectures Notes in Artificial Intelligence, vol. 2600, pp. 1-40, Springer, 2003
S. Shalev-Shwartz and S. Ben-David, "Understanding Machine Learning: From Theory to Algorithms," Cambridge University Press, New York, USA, 2014

J. Shawe-Taylor and N. Cristianini, “Kernel Methods for Pattern Analysis,” Cambridge University Press, New York, USA, 2004
R. S. Sutton and A. G. Barto, “Reinforcement Learning: An Introduction,” MIT Press, Cambridge, USA, 1998
C. Szepesvári: “Algorithms for Reinforcement Learning,” Morgan & Claypool, 2010
S. Theodoridis and K. Koutroumbas, “Pattern Recognition,” Academic Press, San Diego, USA, 2009
V. N. Vapnik, “Statistical Learning Theory,” Wiley-Interscience, New York, USA, 1998

The following are slides/lectures notes from related courses.
D. P. Bertsekas: slides for the course “Approximate Dynamic Programming,” CEA, Cadarache, 2012, available online at http://www.athenasc.com/ADP_Short_Course_Complete.pdf
T. Jebara, Lecture notes for the course “Machine Learning 4771,” Columbia University, 2015, http://www.cs.columbia.edu/~jebara/4771/handouts.html
A. Ng: lecture notes for the course “Machine Learning,” Stanford, 2017, available online at http://cs229.stanford.edu/notes

Final Exam:
The student will prepare slides for a short seminar (20-30 minutes) on a topic related to machine learning. The topic of the seminar will be either proposed by the teacher or chosen by the student. The date of the seminar will be agreed between the student and the teacher. The seminar will take place either in the teacher's office or in the classroom (in case several students will decide to have their seminars in the same day).

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Management of Complex Systems: Approaches to Problem Solving
Andrea Zocchi, Simone Gerola
40 Hours

Learning Outcomes:
Structured approach to problem solving with related tools for each step

Abstract:
Problem solving of complex situations and systems requires a structured approach. This course, which is based on the training adopted by some top management consulting Firms, provides a methodology which is applicable to a broad variety of industries and issues.

Lecture Contents:
1) 7 steps problem solving approach and related tools; 2) Grocery retail case; 3) Relaunch of museum case; 4) Company X relaunch case in group exercise

Teaching Method:
Theory applied to specific business cases. In class group exercises and discussions

Bibliography:
Lecture notes and exercises handed out during each lesson

Final Exam:
Written test and oral exam

Prerequisites:
Participation to all lessons and in class exercises

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Matrix Algebra
Giorgio Gnecco
10 Hours

Learning Outcomes:
The course is aimed to review basic concepts of matrix algebra at an intermediate/advanced level.

Abstract:
The course is aimed to review the following basic concepts of linear algebra:
- systems of linear equations: solution by Gaussian elimination, PA=LU factorization, Gauss-Jordan method;
- vector spaces and subspaces, the four fundamental subspaces, and the fundamental theorem of linear algebra;
- determinants and eigenvalues, symmetric matrices, spectral theorem, quadratic forms;
- Cayley-Hamilton theorem, functions of matrices, and application of linear algebra to dynamical linear systems;
- iterative methods for systems of linear equations;
- ordinary least squares problem, normal equations, A=QR factorization, condition number, Tikhonov regularization;
- singular-value decomposition, Moore-Penrose pseudoinverse;

The course also shows how to apply the methods above using MATLAB. Finally, an economic application of matrix algebra (the Leontief input-output model) is also detailed.

Lecture Contents:
- Systems of linear equations;
- Properties of systems of linear equations;
- Determinant and eigenvalues;
- Applications of eigenvalues;
- QR factorization, ordinary least squares problem, and variations;
- An economic application of linear algebra: the Leontief input-output model.

Teaching Method:
The teacher will project slides on the screen (a copy of the slides and of the MATLAB code will be provided to the students). He will also solve some exercises on the blackboard.

Bibliography:
Gilbert Strang, Introduction to linear algebra. Wellesley, Cambridge Press, Fourth Edition, 2009
Gilbert Strang, Linear algebra and its applications. Thomson, Brooks/Cole, Fourth Edition, 2006
MATLAB teaching codes based on Prof. Strang's books:
http://web.mit.edu/18.06/www/Course-Info/Tcodes.html

Students having already a good background in matrix algebra are encouraged to read the following more advanced topics from the second book by Prof. Strang:

- application of linear algebra to graphs (Section 2.5),
- application of Gram-Schmidt orthogonalization process to function spaces (Section 3.4),
- Fast Fourier transform (Section 3.5),
- complex matrices (Section 5.5),
- minimum principles (Section 6.4),
- finite element method (Section 6.5),
- linear programming, the simplex method, and duality (Sections 8-1-8.4),
- Jordan's canonical decomposition (Appendix B).

Final Exam:
Final written examination (optional, 2 hours)

Prerequisites:
None

Neuroeconomics
Luca Polonio
20 Hours

Learning Outcomes:
At the end of the course, the student should have a clear understanding of the strengths and limitations of the different techniques used in Neuroeconomics. The student should be able to integrate approaches coming from different disciplines such as computational neuroscience, psychology of judgment and decision, microeconomics, and anthropology. Moreover, the student should have a general understanding of how human and animal preferences are represented in the mammalian nervous systems. A general understanding of the main reinforcement learning, value learning, and value representation models. The ability to recognize the weaknesses and strengths of published articles, starting from the research question, through the method used, to the reporting of the project's outcome.

Abstract:
The course will provide an overview of the field and an exhaustive description of the most important discoveries in the major research areas of Neuroeconomics such as decision making under risk, loss aversion, inter-temporal choice and social decision making. We will discuss the need for Neuroeconomics and the limitations of the traditional fields of Economics, Psychology and Neuroscience. The course will provide an overview of how human and animal preferences are represented in the mammalian nervous systems and particular emphasis will be given to the neural mechanisms for choice. The course will include an introduction to the most influential reinforcement learning, value learning and value representation models and will describe in detail the brain circuits involved in social decision making.

Lecture Contents:
Introduction and scope of Neuroeconomics; The tools of Neuroeconomics; How human and animal preferences are represented in the mammalian nervous systems; Risk, time preferences, social preferences, and emotion; fundamentals of reinforcement learning, value learning, and value representation; The Neural mechanisms for choice; Social decision-making in humans and animals.

Teaching Method:
Lectures/oral presentations

Bibliography:
Glimcher, P. W., & Fehr, E. (Eds.). (2013). Neuroeconomics: Decision making and the brain. Academic Press.

Final Exam:
Written exam containing open questions and critical analysis essay on an article

Prerequisites:
While a general understanding of brain systems is welcome, no prerequisite is strictly necessary.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Numerical Methods for the Solution of Partial Differential Equations
Marco Paggi
20 Hours

Learning Outcomes:
Ability to solve numerically a problem related to a physical system and predict its response. The physical system can be embedded within an optimization problem, for instance, or it can be part of a complex system (biological, mechanical, thermo-mechanical, chemical, or even financial) you are interested in predicting its behaviour and evolution over time.

Abstract:
The course introduces numerical methods for the approximate solution of initial and boundary value problems governed by linear and nonlinear partial differential equations (PDEs) used to describe physical systems. The fundamentals of the finite difference method and of the finite element method are introduced step-by-step in reference to exemplary model problems taken from heat conduction, linear elasticity, and pricing of stock options in finance. Notions on numerical differentiation, numerical integration, interpolation, and time integration schemes are provided. Special attention is given to the implementation of the numerical schemes in finite element analysis programmes for fast intensive computations.

Lecture Contents:
- Numerical differentiation schemes
- Numerical interpolation schemes
- Numerical integration schemes
- Time integration algorithms
- Newton-Raphson incremental-iterative schemes for nonlinear problems
- Finite difference method
- Finite element method

Teaching Method:
Blackboard. Handouts are also provided.

Bibliography:
- A. Quarteroni, Numerical Models for Differential Problems, Second Ed. Springer, 2013.
- K.-J. Bathe, Finite Element Procedures, Pearson College Div, 2005.
- N. Hilber, O. Reichmann, C. Schwab, C. Winter, Computational Methods for Quantitative Finance, Springer, 2013.

Final Exam:
An application of the taught methodologies to one case study of relevance for the PhD student's research is recommended. Alternatively, a topic to investigate can be suggested by the lecturer.

Prerequisites:
The course is self-contained. Fundamentals of algebra are required.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Philosophical and Ethical Themes in Neuroscience
Mirko Daniel Garasic
10 Hours

Learning Outcomes:
Speculating over the ethical and political acceptability of certain innovations in the light of classical philosophical questions will provide the groundworks for any further neuroethical investigation envisaged.

Abstract:
Since its formal establishment as a self-standing field, neuroethics has been divided into two subdefinitions: the neuroscience of ethics and the ethics of neuroscience. While the neuroscience of ethics aims at explaining the way our brain works in relation to moral judgement, the ethics of neuroscience is a further expansion of bioethics: a discipline that wants to assess the moral dilemmas specifically raised by recent biotechnological advancements. This introductory course will focus on neuroethics in this latter sense, underlining the impact that discoveries concerning our brain can, do or will have on our society. Speculating over the ethical and political acceptability of certain innovations in the light of classical philosophical questions (i.e. What is justice? What constitutes a good life?) and other key terms necessary to understand the current debate (i.e. authenticity and personal identity, autonomy, responsibility and competence) will provide the groundworks for any further neuroethical investigation envisaged.

Lecture Contents:
Neuroethical Issues

Teaching Method:
Lectures and seminars

Bibliography:
Subject to change.

- Changeux, J. (2013). Neuroscience & Philosophy : An Exchange. The New York Review of Books.
- Farah, M. J. (2005). Neuroethics: the practical and the philosophical. Trends in Cognitive Sciences, 9(1), 34–40.
- McGinn, C. (2013). What Can Your Neurons Tell You?. The New York Review of Books.
- Open your mind. (2002). The Economist.
- Earp, B. D., Sandberg, A., & Savulescu, J. (2015). The Medicalization of Love. Cambridge Quarterly of Healthcare Ethics, 24(3), 323–336.
- Earp, B. D., Wudarczyk, O. a, Sandberg, A., & Savulescu, J. (2013). If I could just stop loving you: anti-love biotechnology and the ethics of a chemical breakup. The American Journal of Bioethics : AJOB, 13(11), 3–17.
- Gupta, K. (2012). Protecting Sexual Diversity: Rethinking the Use of Neurotechnological Interventions to Alter Sexuality. AJOB Neuroscience, 3(3), 24–28.
- Hauskeller, M. (2015). Clipping the Angel's Wings. Cambridge Quarterly of Healthcare Ethics, 24(3),

361–365.
- Earp, B. D., Sandberg, A., & Savulescu, J. (2014). Brave New Love: The Threat of High-Tech “Conversion” Therapy and the Bio-Oppression of Sexual Minorities. AJOB Neuroscience, 5(1), 4–12.
- Garasic, M. D. (2013). Anti-love biotechnology: was it not better to have loved and lost than never to have loved at all? The American Journal of Bioethics : AJOB, 13(11), 22–3.
- Savulescu, J., & Sandberg, A. (2008). Neuroenhancement of Love and Marriage: The Chemicals Between Us. Neuroethics, 1(1), 31–44.
- Schirmann, F. (2013). Badness, madness and the brain – the late 19th century controversy on immoral persons and their malfunctioning brains. History of the Human Sciences, 26(2), 33–50.
- Vincent, N. A. (2010). On the Relevance of Neuroscience to Criminal Responsibility. Criminal Law and Philosophy, 4(1), 77–98.
- Feresin, E. (2009). Lighter sentence for murderer with “bad genes.” Nature.
- Garasic, M. D. (2013). The Singleton case: Enforcing medical treatment to put a person to death. Medicine, Health Care and Philosophy, 16(4), 795–806.
- Erler, A. (2011). Does Memory Modification Threaten Our Authenticity? Neuroethics, 4(3), 235–249.
- Mehlman, M. J. (2004). Cognition-Enhancing Drugs. Milbank Quarterly, 82(3), 483–506.
- Ricciardi, E., Rota, G., Sani, L., Gentili, C., Gaglianese, A., Guazzelli, M., & Pietrini, P. (2013). How the brain heals emotional wounds: the functional neuroanatomy of forgiveness. Frontiers in Human Neuroscience, 7, 839.
- Tennison, M. N., & Moreno, J. D. (2012). Neuroscience, Ethics, and National Security: The State of the Art. PLoS Biology, 10(3), e1001289.
- Lavazza, A., & Garasic, M. D. (2017). How Non-invasive Brain Stimulation Might Invade Our Sphere of Justice. Journal of Cognitive Enhancement, 1–8.
- Memories could be erased to cure soldiers of PTSD, say scientists. (2017). The Telegraph.

Final Exam:
No

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Philosophy and Neuroscience in Moral Reasoning
Gustavo Cevolani
12 Hours

Learning Outcomes:
On completing the course, the students will be able to appreciate the main issues surrounding the cognitive and neural foundations of morality, and to rigorously analyze and discuss them. They can also assess the relevance of empirical findings for current debates on ethics, cognition and for sensitive social issues more generally.

Abstract:
The analysis of moral reasoning and surrounding topics – how to assess "good" and "bad" actions, how to choose between them, how to justify these choices – is a classical problem of moral philosophy (ethics). More recently, moral psychologists started tackling those problems using a descriptive, empirically based approach. Still more recently, "neuroethicists" began investigating the neural correlates of moral judgment and the implications of neuroscientific results for moral philosophy. The course is an introduction to the essential issues arising at the interface between neuroscience, moral psychology, and moral philosophy. We shall explore problems concerning the biological and neural bases of moral thinking, the role of emotions in moral reasoning, the significance of empirical results for normative theories of morality, and some methodological issues arising within neuroethics.

Lecture Contents:
The topic of each lesson will be decided at the beginning of the course on the basis of student's feedback; the following is a tentative list subject to change.

Lecture 1. Presentation, discussion and choice of specific topics. Philosophical theories of moral reasoning. Consequentialism, deontology, and virtue ethics
Lecture 2. Dual-process theories of reasoning and cognition. Empirical approaches to morality.
Lecture 3. Moral dilemmas. Moral psychology and the neuroscience of ethics.
Lecture 4. Evolutionary approaches. Hume's problem. Reductionism and the debunking of morality.
Lecture 5. Objectivity, reason, and facts in moral reasoning. Machine ethics.
Lecture 6. Recap, verification and general discussion.

Teaching Method:
Mixture of lectures and discussion seminar.

Bibliography:
We won't have a textbook; the reading list will be shared later. The following are suggestions for background readings:

- David Edmonds (2013). Would You Kill the Fat Man?. Princeton University Press
- Antonio R. Damasio (2004). Descartes' Error: Emotion, Reason and the Human Brain. New York: Quill

- Jonathan Haidt (2013). The Righteous Mind: Why Good People Are Divided by Politics and Religion. Vintage
- Joshua Greene (2013). Moral Tribes: Emotion, Reason, and the Gap Between Us and Them. Penguin

Final Exam:
Active contribution from the participants is a prerequisite for passing the course.
Each student will select a paper or topic related to the fields of neuroethics, moral psychology, moral philosophy, or the philosophy of neuroscience and give a 20–30 minutes presentation during one of the classes. The talk should present, clearly and concisely, a topic/problem/thesis, relevant arguments/results supporting or undermining it, and a final assessment. Students can choose among the suggested readings or propose a topic of their choice.

Prerequisites:
None

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Philosophy of Science
Gustavo Cevolani
20 Hours

Learning Outcomes:
On completing the course, the students will be better able to understand and evaluate current debates about the reliability, the rationality and the limits of science. They can assess the scope and limits of scientific knowledge and appreciate the differences and relations between science and other scientific endeavors. They understand why and to which extent science is rational and often successful, and what is its role in guiding decision-making in modern societies.

Abstract:
The course provides an introduction to the basic concepts and problems in the philosophical analysis of scientific reasoning and inquiry. We will focus on some central patterns of reasoning and argumentation in science and critically discuss their features and limitations. Topics covered include the nature of theory and evidence, the logic of theory testing, and the debate about the aims of science and the trustworthiness of scientific results. We shall discuss classical examples and case studies from the history and practice of science to illustrate the relevant problems and theoretical positions. Students will freely engage in brainstorming on these topics and are welcome to propose examples, problems, and methods from their own disciplines.

Lecture Contents:
The topic of each lesson will be decided at the beginning of the course on the basis of student's feedback; the following is a tentative list subject to change.

Lecture 1. Presentation of the course. Discussion and choice of specific topics. What is science?
Lecture 2. How many sciences? The method(s) of science. Exact and inexact sciences.
Lecture 3. Theories, models, data. Experiments and observations.
Lecture 4. Inferences in science. Falsification, confirmation, disconfirmation.
Lecture 5. Science, pseudoscience, junk science. Trust and objectivity in science. The role of experts.
Lecture 6. History of science and scientific progress. The aim(s) of science.
Lecture 7. Science, truth, and reality.
Lecture 8. Recap, verification and general discussion.

Teaching Method:
Mixture of lectures and discussion seminar.

Bibliography:
We won't have a textbook or a proper reading list. Relevant readings will be shared on Google Drive. The following are suggestions for background readings and possible topics of discussion.

- Curd, Martin and J. A. Cover, eds. (1998). Philosophy of science: the central issues. New York: W.W. Norton.

SCHOOL FOR ADVANCED STUDIES LUCCA

- Godfrey-Smith, Peter (2003). Theory and Reality: An Introduction to the Philosophy of Science. University of Chicago Press.
- Okasha, Samir (2016). Philosophy of Science: A Very Short Introduction. Oxford
- University Press.
- Oldroyd, D. R. (1986). The Arch of Knowledge: An Introductory Study of the History of the Philosophy and Methodology of Science. Methuen.
- Hempel, C. G. (1966). Philosophy of Natural Science. Prentice Hall.
- Popper, Karl (1963). Conjectures and Refutations: The Growth of Scientific Knowledge. Routledge.
- Salmon, Wesley C. (2017). The Foundations of Scientific Inference. Pittsburgh, Pa: University of Pittsburgh Press.
- Sprenger, Jan and S. Hartmann (2019). Bayesian Philosophy of Science. OUP Oxford.

Final Exam:
Active contribution from the participants is a prerequisite for passing the course.

Prerequisites:
None

Research Seminars
Pietro Pietrini, Emiliano Ricciardi
30 Hours

Learning Outcomes:
PhD students will learn how to present their research projects, to support the rationale of their studies and to discuss with advisors, senior fellows and mates about the theoretical hypotheses and methodological approaches that will be exploited and employed in their research projects

Abstract:
These interactive lessons are made up of short lectures by senior or junior fellows of the Research Unit MOMILAB and PhD students of the CCSN track to present ideas and experimental setups of their research projects, or discuss preliminary or final findings of their research activities. The students are chaperoned through a detailed discussion and revision of all theoretical and methodological aspects of the research projects.

Lecture Contents:
Senior or junior MOMILAB fellows' and CCSN PhD students' research activities

Teaching Method:
Interactive seminars

Bibliography:
None

Final Exam:
None

Prerequisites:
None

Scientific Writing, Dissemination and Evaluation
TBD
8 Hours

Course description will be available soon.