IMT SCHOOL FOR ADVANCED STUDIES LUCCA

'Cognitive Computational and Social Neurosciences' Track
XXXVIII Cycle A.A. 2022/23

– Profile Proposals -

- **Social and affective neuroscience: behavioral and brain correlates of emotion, theory of mind and empathy**
- **The representation of the external world: from sensory-based percept to more abstract concepts**
- **Sensory Experience Dependence and Plasticity**
- **Local regulation of sleep and wakefulness**
- **Action representations and action taxonomy**
- **Neuroscience Impact: Brain and Business**
- **Cognition, Reasoning and Economic Decisions**
- **Understanding the Social Brain: implications for Forensic Psychiatry and the Law**

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Social and affective neuroscience: behavioral and brain correlates of emotion, theory of mind and empathy

Abstract: Social cognition represents the cornerstone of successful human interactions: any social contact requires one's ability to observe people's behavior, infer their cognitive or affective state and predict their actions. Despite decades of psychological research, the mechanisms underlying such complex mental faculties are still far to be fully understood. Recently, data-driven approaches and computational models provided novel insights in this regard: cognitive and affective social abilities are now studied through the recording of real-time subjective reports and accurate monitoring of peripheral activity (e.g., skin conductance, pupil size). Also, neuroimaging techniques are used in combination with naturalistic stimulation (e.g., movies, narratives) to assess how the brain represents the nature and content of social interactions in situations akin to real life. Research activities conducted in the Social and Affective Neuroscience (SANe) Group combine the collection of behavioral data (both *deep phenotyping* and *crowd-sourcing* approaches) with natural language processing, psychophysics, graph analysis and neuroimaging methods to build reliable descriptions of human social and affective abilities. Current projects include:

- *Ontology of affect*: the aim of this project is to determine which terms (e.g., joy, elation, dread) people use to describe their subjective experience and which properties (e.g., valence, unpredictability, social relevance) are unique to each of these terms. Suggested reading: Jackson, J.C., et al. "Emotion semantics show both cultural variation and universal structure." *Science* 366.6472 (2019): 1517-1522.
- *Kinematics of genuine facial expressions*: the aim of this project is to establish a novel data-driven method to quantify facial expressions and track their trajectory as function of the unfolding of emotional experiences. Suggested reading: Jack, R.E., et al. "Four not six: Revealing culturally common facial expressions of emotion." *JEP: General* 145.6 (2016): 708.
- *Temporal characteristics of affective forecasting*: the project aims at understanding how far in the future one can predict others' emotions and which affective dimensions inform mental models of transitions. Suggested reading: Thornton, M.A. and Tamir, D.A. "Mental models accurately predict emotion transitions." *PNAS* 114.23 (2017): 5982-5987.

Key words: social cognition, emotion, affect, theory of mind, empathy, MRI, fMRI

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· Gentili, C., et al. "ROI and phobias: The effect of ROI approach on an ALE meta-analysis of specific phobias." Human brain mapping (2019).

Reference person: Luca Cecchetti, SANe - MoMiLab

Interacting with the external world:
from sensory-based percept to sensory-independent representations

Abstract: How do we see, interpret, make sense and represent the external world? Perception and mental processing are fundamental aspects of understanding how knowledge is cognitively and neurally represented and organized. Furthermore, to what extent do low-level sensory-based information and high-level abstract features contribute to the organization of conceptual knowledge? The study of (the lack of) sensory experience provided our group with a unique tool to understand to what extent a specific modality is truly a mandatory prerequisite for the brain's morphological and functional architecture to develop and function.
This topic has always been of major interest at MoMiLab, and research activities exploit advanced tools in cognitive neuroscience to characterize the neural correlates of perception and content-specific mental representations, semantic processing and knowledge organization, and action representation. Current projects are relative to:

- Topographic mapping of multisensory processing and representation exploiting resting state or long-lasting naturalistic stimulation fMRI protocols
- Supramodal processing in sensory-deprived individuals
- Behavioral and functional effects of heteromodal remapping
- Knowledge organization and semantic processing
- Abstractness and Abstraction: from sensory-based processing to conceptual representation

Methods of investigation: behavioral, f/MRI, EEG and psychophysics

Keywords: mental representation, knowledge organization, supramodality, sensory processing

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Reference people: Emiliano Ricciardi, Giacomo Handjaras, Pietro Pietrini - SEED/SEMper- MoMiLab

Sensory Experience Dependence and Plasticity

Abstract: Much of what we observe in the adult brain reflects how neural circuitries have been sculpted by experience along the life cycle. A powerful way to investigate the impact of experience on the functional and structural organization of the brain is provided by sensory deprivation models. By perturbing the availability of a sensory input, as for instance adopting (1) permanent sensory deprivation (e.g., deafness or blindness), (2) sensory re-afferentation after a period of deprivation (vision: individuals treated for congenital bilateral cataracts; audition: cochlear implanted individuals) or (3) short-lasting deprivation in the adult (e.g., blindfolding), as models of investigation, we can understand the degree of plasticity of sensory systems and of their interactions. Developmental and multisensory perspectives are adopted.

Related topics:

- Degree of plasticity and functional recovery in case of temporary sensory deprivation and restoration
- Impact of visual deprivation on auditory development
- Impact of auditory deprivation on visual development
- Neural entrainment to sensory signals in Cochlear implanted individuals (PRIN 2017, PI Bottari)
- Functional organization underpinning cross-modal responses in typical development

Methods of investigation include: EEG, Computational Neuroscience, fMRI and psychophysics

Key words: experience dependence, sensory deprivation and restoration, neural plasticity, development, sensory interplay

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Reference people: Davide Bottari, Emiliano Ricciardi, Pietro Pietrini, SEED/ SEMper - MoMiLab

Local regulation of sleep and wakefulness

Abstract: Traditionally, sleep and wakefulness have been considered as two global, mutually exclusive states. However, this view has been challenged by the discovery that sleep and wakefulness are actually locally regulated and that islands of these two states may often coexist in the brain. Importantly, the local regulation of sleep seems to be key for many of the known functions of this physiological state, including the maintenance of brain functional efficiency, the consolidation or stabilization of new memories and the modulation of mood and emotional reactivity. Local changes in brain activity during sleep may also explain the emergence of conscious experiences (dreams) and may modulate the level of sensory disconnection that is essential for restorative sleep. On the other hand, during wakefulness, the reiterated activation of specific brain areas leads to a state of 'functional fatigue', characterized by the appearance of local, sleep-like episodes. These events may have important consequences for behavior and cognition and may contribute to explain the known effects of sleep deprivation. Given these premises, alterations in the local regulation of sleep and wakefulness may represent the pathophysiological substrate of symptoms observed in many sleep disorders, but also in some psychiatric or neurological disorders.

Topics of interest related to this research field include:

- mechanisms and functions of local sleep regulation in humans;
- the role of sleep and dreams in memory consolidation and emotional regulation;
- influencing dreams through sensory stimulation protocols (dream engineering);
- local sleep during wakefulness and its implications for behavior and cognition;
- the effects of sleep deprivation/restriction on brain structure and function;
- alterations of local sleep regulation in pathological conditions.

Projects may involve one or more of the following investigation techniques: psychometric questionnaires, behavioral testing, recording of autonomic activity, high-density EEG recordings, functional/structural MRI. Additional research opportunities (e.g., for the study of patients with neurological, psychiatric or sleep disorders) and methodologies (e.g., combined EEG-fMRI, intracranial EEG recordings) may become available through established national and international collaborations.

Key words: sleep, consciousness, dreams, learning, memory, emotion.

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Reference people: Giulio Bernardi, SPACE - MoMiLab

Action representation and action taxonomy

Abstract: A key function in our brain is the coding of information related to movements. Many questions regarding how motor schemes and actions are represented in the brain, how we process sensory information relevant for planning movements or to understand others' actions, how we do represent our and others' space for action are still open and debated. In addition, the importance of exploiting our knowledge about the motor system and the action representation system to develop more efficient strategies for rehabilitation and restoration of movement in coordination developmental disorders or in patients who suffered brain damage is consistently growing. The study of this topic can be pursued through different methods, ranging from behavioral and psychophysiological studies to the usage of functional imaging to investigate the brain correlates of motor planning or perception, action observation or processing.
In the last years, the MoMiLab has conducted much work on this field, leveraging also on collaborations with researchers even from the bioengineering and bionics field, for the investigation of multiple topics related to motor control, such as:

- Models for coding hand and upper limb movements. In the last years, the MoMiLab has conducted studies to demonstrate that the human motor system encodes low-dimensional models based on synergies. These models are particularly important for the design of prostheses, and the study of their direct coding in the brain is important for both research and application purposes.
- Representation of different classes of movements in the human action observation systems
- Representation of space for action, effectors, affordances, objects for motor planning and its interaction with sensory modalities

Methods of investigation include: fMRI, EEG, EMG, optical joint tracking and psychophysics

Keywords: motor representation, action observation system, synergies, object processing

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Reference people: Emiliano Ricciardi and Giacomo Handjaras, SEMper - MoMiLab

Neuroscience Impact: Brain and Business

Abstract: Neuroeconomics, consumer neuroscience, organizational neurosciences are emerging interdisciplinary fields promoting a dialogue between neuroscience, psychology, behavioral science, economics and marketing.
The IMT School has started the development of a joint laboratory - Neuroscience Lab (NS LAB) - to exploit, through applied and translational research cases, the most advanced interdisciplinary approaches of cognitive, computational, and social neurosciences in the managerial sciences and strategic field of company organization, and human resources. The NS LAB has been created to foster this interdisciplinary research fields within a multidisciplinary team to:

- apply behavioral science and design thinking to optimize consumer behavior, businesses, and policy
- investigate behavioral and neural correlates of consumers' response to stimuli
- design solutions that make products and services more responsive to human behavior and drive behavior change
- investigate the neural correlates of decision making

The research projects will use brain imaging methodologies, biometrics and other technologies in assessing how specific samples (e.g., potential consumers, branch managers, transfers, etc.) respond when presented with specific products and/or related stimuli. In particular, the comprehension of how information on a specific product/item is conveyed through different sensory modalities and media channels and influence decision-making processes represents a current challenge for neuroscientific research in marketing. Original approaches in neuroimaging studies applied to social sciences, behavior, decision-making processes should, not simply, characterize the individual (social and personological) profile, behavioral and brain functional processes, but mainly look for potential predictive biomarkers of individual choices or social outcome and contribute to the design of behavioral-change interventions.
Methods of investigation include: behavioral and psychophysical, brain imaging (e.g., fMRI, eye-tracking, and EEG)

Keywords: neuroeconomics, decision making, neuromarketing, social sciences

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Reference people: NS LAB, MoMiLab, AXES

Models, Inference, and Decisions

Abstract: Recent research in cognitive and behavioral sciences is increasingly illuminating the basic mechanisms of human reasoning and cognition, as well as their limitations and systematic deviations from normative theories of rational inference and decision-making. It also raises interesting questions concerning the foundations and methods of different scientific disciplines, and the analysis of scientific reasoning in general.

This research line puts together theoretical and formal models of inference and decision-making with empirical approaches to the study of human reasoning and cognition. The aim is twofold: to better understand, and possibly improve, how people reason and make choices in different contexts, both in ordinary life and in science; and to clarify and strengthen the methodology and foundations of cognitive, behavioral, and social sciences.

Topics of interest for research proposals include:

- Formal epistemology and philosophy of science: Bayesian confirmation theory, truthlikeness theory, cognitive decision theory.
- Philosophy of cognitive, behavioral, and social sciences, including neuroscience, (behavioral) economics, medicine, forensic science, statistics, machine learning, history, textual criticism, etc.
- Philosophical issues in the foundations, epistemology, and the methodology of science: e.g., reverse inference, abduction, analogy, simplicity, replicability, explainability, etc.
- Normative and descriptive models of reasoning, rational inference and decision-making: heuristics and biases, ecological rationality, nudge theory.
- Analysis of expert judgment and reasoning, especially clinical and legal reasoning.
- Inferences and fallacies in moral and social dilemmas.
- Neural bases of different kinds of reasoning (deductive, inductive, abductive, etc.).
- Behavioral and cognitive interventions targeting heuristics and cognitive biases on social media: hampering the spread of fake news, overconfidence, hateful commenting, and other toxic behaviors while promoting thoughtful interactions and charitable interpretation.
- The role of expertise and trustworthiness in message communication and behavior change in health campaigns: what messages promote healthy choices while also empowering citizens?

Keywords: rationality, reasoning, decision-making; philosophy of science, logic, epistemology, critical thinking, scientific method

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Reference people: Gustavo Cevolani and Folco Panizza, MInD– MoMiLab

Other involved research units: AXES (Ennio Bilancini, Giorgio Gnecco), LYNX (Amos Bertolacci, Silvia Di Vincenzo)

Understanding the Social Brain: implications for Forensic Psychiatry and the Law

Abstract: Understanding human behavior has been a matter of speculation since the ancient Greek philosophers. The recent discoveries acquired by behavioral genetics, brain imaging and cognitive neuroscience have provided a novel and exciting ground for the investigation of the neurobiological correlates of social behavior and its deviance, with implications that fall well beyond neuroscience and reach out to ethics, philosophy, psychiatry and even to the law.
Over the last twenty-five years, scientists at *MoMILab* have focused on the investigation of the genetics, biological, cognitive and brain correlates of human behavior by studying the distinct components of social and antisocial acting.
How does the brain modulate aggressive and impulsive behavior? Do genes affect our moral choices? Why do we forgive others? How do *nature* and *nurture* relate in shaping the individual personality and in favoring pro-social vs anti-social behavior? To what extent are criminals *Bad* or *Mad*? How do laypeople and experts reason about morality and assess right and wrong behavior? These are among the main questions that we pursue by combining state-of-the-art molecular biology techniques with experimental psychology, theoretical philosophy and brain structural and functional brain imaging methodologies.
The ultimate aim of this research is to achieve a neurobiologically based definition of **imputability**, that is, to provide an objective measurement of the ability to intend and to will, which are the fundamental pillars required by the Law (Penal Codes) for one to be considered responsible for their own actions. Within the forensic psychiatric settings, often expert evaluations are still highly subjective and speculative and thus they fail to provide the Court with conclusive reports that can be evaluated on objective data. Moreover, forensic experts and other professionals involved in the trial (including judges, jurors, and attorneys) can fall prey to cognitive biases, so developing sound heuristics and debiasing strategies is crucial to improve legal reasoning and decision making. We intend to integrate methods from neuroscience and cognitive science with theoretical models from normative theories of rationality to contribute to radically change forensic evaluations.

Candidates accepted to the Ph.D. program will have an opportunity to work in a multidisciplinary environment including neuroscientists, psychiatrists, philosophers, molecular biologists, psychologists, economists and law experts. Candidates also will have the opportunity to conduct first-hand examinations of criminal defendants, collaborate in the writing of expert reports and participate in expert discussions in Court (excellent knowledge of Italian language is required except for the international cases). Depending on the individual background and interest, candidates will work on behavioral molecular genetics research projects or in experimental cognitive/brain imaging studies or on imputability conceptual projects. Candidates will have the opportunity of spending time in collaborating labs, including the Clinical Biochemistry and Molecular Biology Lab at the University of Pisa (Prof. Silvia Pellegrini), the Psychology Department at the University of Padua (Proff. Giuseppe Sartori and Cristina Scarpazza) the Dept. of Psychology at the University of New Mexico, USA (Prof. Kent Kiehl).

Key words: forensic neuroscience, human behavior, (anti)sociality, imputability, law

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Reference persons: Pietro Pietrini and Gustavo Cevolani - MoMiLab

Computational modeling of the fine-grained functional architecture of the brain: Individual differences across the lifespan

Abstract: Information processing is represented in population responses that can be studied as distributed, fine-grained patterns of activity that can be measured with fMRI. Changes in the representational geometry of these population responses along processing pathways provide a window for studying how information is transformed by processing. Fine-grained patterns of activity and connectivity, however, are idiosyncratic. We have developed a computational model, hyperalignment, that affords study of individual differences in the information that is embedded in these idiosyncratic topographies. In this project we will use fMRI with naturalistic stimulation to study how fine-grained functional brain architecture changes with aging and, in particular, how these changes are related to cognitive function and cognitive inefficiency associated with minimal cognitive impairment, which can be a precursor for dementia. Sensitive detection of biomarkers for early cognitive decline could have important implications for early intervention in progressive neurodegenerative disease. Research activity will include fMRI with naturalistic stimuli and computational cognitive neuroscience, as well as analyses of large public data sets.

Key words: fMRI, multivariate pattern analysis, hyperalignment, aging, mild cognitive impairment

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