‘Cognitive Computational and Social Neurosciences’ Track
XXXVII Cycle A.A. 2021/22
– Profile Proposals -

PROFILE PROPOSAL 1

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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Reference person: Luca Cecchetti, SANe - MoMiLab

PROFILE PROPOSAL 2

The representation of the external world: from sensory-based percept to more abstract concepts

Abstract: The study of the sensory-deprived brain provides a unique tool to understand to what extent a specific sensory modality is truly a mandatory prerequisite for the brain morphological and functional architecture to develop and function. The demonstration that congenitally blind individuals during non-visual object recognition show topographically-organized category-related patterns of neural response in the ventral "visual" pathway indicated that visual experience is not necessary for the brain to develop a certain functional organization. On the same line, it was also shown that the brain appears to be able to process specific types of information independently from the modality that carries the input. Research from multiple labs has then confirmed an overall preservation of the large-scale functional and structural organization of congenitally blind individual brains across several domains.

This research field has always been of major interest at the MoMiLab and thus, multiple topics have been and are currently explored, such as:

- Conceptual representation and its sensory (in)dependence (e.g., Handjaras et al., 2016)
- Supramodal brain organization in sensory-deprived individuals
- Structural changes in the sensory-deprived brain
- Emotion processing and social interactions in blind individuals

Methods of investigation include: fMRI, EEG and psychophysics

Key words: supramodality, experience dependence, sensory deprivation

References

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

PROFILE PROPOSAL 3

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

References

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

PROFILE PROPOSAL 4

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 experience-dependent brain plasticity (memory/learning) and in emotional regulation;
- 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

PROFILE PROPOSAL 5

Action representations in the brain

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

Key words: motor representation, action observation system, synergies, object processing

References

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Reference people: Emiliano Ricciardi and Giacomo Handjaras - MoMiLab

PROFILE PROPOSAL 6

An interdisciplinary approach to study economic behavior

Abstract: Neuroeconomics, neuromarketing, 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 engage the use of 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 represent a current challenge for neuroscientific research in the field of 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)

Key words: neuroeconomics, decision making, neuromarketing, social sciences

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Reference people: Emiliano Ricciardi, Luca Polonio and Pietro Pietrini, MoMiLab
Other involved research units: Nicola Lattanzi and Ennio Bilancini, AXES

PROFILE PROPOSAL 7

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.).

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

References

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Reference people: Gustavo Cevolani and Luca Polonio, MInD/REED– MoMiLab

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

PROFILE PROPOSAL 8

A neuroscientific take on visual aesthetic experience

Abstract: In the past decades, visual neuroscience has greatly advanced our knowledge of the human visual system. From the retina, visual signaling steps through a relay station in the lateral geniculate nuclei, and then reach the cerebral cortex targeting the primary visual area (area V1). V1 provides an optimal encoding of natural image statistics based on local contrast, orientation and spatial frequencies, while later cortical modules process higher-level features, such as texture and shape and determine figure-ground organization. The basic features of visual processing are well preserved and commonly represented in our species and in other mammals as well.
Nonetheless, given the high inter-individual and cross-cultural variability of aesthetic responses to the same visual contents, an unanswered question in cognitive neuroscience remains whether our perception of the world is stable across time and cultural changes. In this light, the popularity of neuroimaging has grown in the last years and has spread well beyond the neuroscientific field, getting in touch with apparently distant fields. From those high-value inter-disciplinary collaborations with experts in aesthetics, architecture and visual arts, the field has started gaining a greater comprehension of what happens in our brain aside from the mere recognition of the content of a visual scene.
By combining an art historian and a neuroscientific perspective, the following project will investigate the visual aesthetic response. In particular, it will focus on the relevance of cultural and social context in shaping the relationship between different visual representations and their evoked aesthetic response. This issue will represent a key advancement in the study of the visual system, which is often assumed to be unaffected by those factors.
Methods of investigation include: recording of autonomic responses, EEG, fMRI and visual psychophysics.

Key words: aesthetic response, beauty, vision, reward, emotion

References

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Reference people: Emiliano Ricciardi and Pietro Pietrini - MoMiLab
Other involved research units: Emanuele Pellegrini, Maria Luisa Catoni, Linda Bertelli, Riccardo Olivito - LYNX

PROFILE PROPOSAL 9

Cognition, Reasoning and Economic Decisions

Abstract: One of the main causes of unequal social outcomes has been identified in the heterogeneity in individuals' ability to process and integrate the large flow of information that characterizes modern society. This information has to be filtered, organized and structured in comprehensive mental models. Learning how to select and organize information, anticipate future events, and predict future actions of other agents is crucial to make optimal decisions and achieve personal goals. Therefore, an approach which integrates choice data (behavioral economics) with the analysis of the decision process (cognitive economics) can be seen as a new and promising multidisciplinary approach to 1) understand why individuals often make choices that are not in line with their preferences, 2) define programs that can help them to translate their intentions (preferences) into behavior (that is, to exercise personal agency) and 3) help policy-makers to focus on the most effective variables to decide which intervention to select.
Cognitive economics is a branch of behavioral economics that brings into play a novel type of data to understand the dynamics of individual economic choices. This new field uses methods from psychophysics – including the analysis of reaction time, mouse-tracking, and eye-tracking – to develop computational process models that can efficiently predict choices and errors in different individual decision-making contexts. The objective of this project is to add to the classical behavioral-economics approach both physiological and psychological measures to understand the mechanisms by which economic decisions are made, help individuals to improve their decision-making skills, and drive policy-makers to identify opportunities for policy improvements. The benchmark model is general and formal, following the classical economic approach. The psychological approach is used to reduce attentional, cognitive, and motivational biases by enhancing the reasoning skills of the decision-makers and their ability to think logically. Thus, the cognitive economics approach is useful to understand the wide range of heterogeneity in human decision making and help institutions to define their programs and develop their interventions.

Topics of interest for research proposals include:

- Plasticity of strategic sophistication in interactive decision making.
- Role of intelligence in individual and social learning.
- How attentional mechanisms, logical thinking, and reasoning skills affects how individuals encode and represent relational information about contingencies.
- Identification of sources of heterogeneity in interactive and non-interactive decision making.

Key words: Cognition, decision-making, process-data, eye-tracking, computational models, reward

References:

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Reference person: Luca Polonio, REED - MoMiLab

PROFILE PROPOSAL 10

Forensic Neuroscience and Psychiatry

Abstract: The interest in understanding the origins of criminal behavior goes far back in time, to the controversial theories of Franz Josef Gall and Cesare Lombroso. Since then, some improvements and discoveries were achieved, and nowadays the body of research in forensic psychiatry has grown substantially, specially thanks to the contributions of neuroscience. In fact, despite the radical view that both Gall and Lombroso had, they got the right intuition, confirmed by recent research: the predisposition to offend (or to act in a certain way) can be associated with genetic, hormonal and neurobiological factors.
For this reason, neuroscience has become the tool to investigate the source of such offending behavior, trying to understand its motives and causes. The broader scope of Forensic Neuroscience is then to investigate the brain functioning of offenders or, more generally, the neural basis and the mechanisms that lead to break norms (social or moral) and to behave differently from the majority of people.
Therefore, our research line in Forensic Neuroscience and Psychiatry aims to shed new light on the biological and genetic underpinnings of human behavior. To reach our goal, we combine behavioral, genetic, physiological and imaging tools, investigating the roots of aggression, pro-sociality and personality disorders.

Key words: forensic neuroscience, human behavior, (anti)sociality, criminal, genetics

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Reference person: Pietro Pietrini - MoMiLab