SEMINAR CYCLE

of the PhD in Neuroscience of Turin

5th Appointment

Prof. Vincenzo Romei

University of Bologna

Oscillatory correlates of perceptual priors as a function of cognitive strategies across the life span

Host: Prof. Francesca Garbarini
Prof. Carlotta Fossataro

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Organized by the Doctoral School - PhD in Neuroscience

PROF. VINCENZO ROMEI

Vincenzo Romei studied Psychology at “Sapienza” University of Rome where he also obtained his Ph.D. in 2005. He then worked in Boston (Harvard Medical School), Geneva (Department of Neurology), Glasgow (Centre for Cognitive Neuroimaging), London (WTCN and ICN at UCL) and Essex (Centre for Brain Science) where he was appointed Full Professor of Cognitive Neuroscience, before joining the Department of Psychology at the University of Bologna in 2018. He is currently Head of the Consciousness Group at the Centre for studies and Research in Cognitive Neuroscience and Director of the Master Course (Laurea Magistrale) in Cognitive Neuroscience and Neuropsychological Rehabilitation.

Prof. Romei’s research has focused on two main streams. On the one hand, on the development of state-of-the-art, cutting-edge methodologies in the field of cognitive neuroscience, with particular attention to novel neurostimulation protocols, from a multi-method perspective, by combining online Transcranial Magnetic Stimulation (TMS) and Electroencephalography (EEG). He has pioneered the concept of oscillatory entrainment through the use of rhythmic TMS, with the first ever publication on this topic back in 2010, followed by a set of studies combining both TMS and EEG with the aim of boosting oscillatory activity and thus study their causal role in shaping behavior. The protocol has since then been increasingly adopted by other groups as an established approach in the field for the causal assessment of oscillatory functions. One other methodological achievement has been the exploitation of the concept of Hebbian Plasticity through the development of a novel neurostimulation protocol named Cortico-cortical Paired Associative Stimulation (ccPAS), which has seen a handful of publications in the past years and now being adopted by many independent groups for the study of cortico-cortical brain connectivity and its malleability.

Apart from the methodological focus, Prof. Romei’s research activity has focused on the epistemological definition and empirical study of consciousness, with particular attention to interindividual differences across the lifespan, investigating healthy, subclinical, neurological and psychiatric populations.
Specifically, he investigates brain oscillations as a mean to interpret and decode the functional mechanisms through which the brain embodies its many functions including basic sensory (and multisensory) input processing, perceptual computations, decision-making, attention process, working memory, action control, etc. Fundamental advances have been in the understanding of the dissociation between and integration of subjective and objective components of sensory processing, leading to the description of perceptual phenomena as an active inference process of decision-making, in line with a predictive-coding account seeing the brain as a Bayesian statistical engine and a predictive machine. Crucially, his research has offered a unique perspective in extracting for the first time oscillatory indices associated to sensory evidence processing ability and prior model exploitation. This has culminated in the identification of cognitive styles lying along the autism-schizophrenia continuum axis, based on the differential balance between model-driven and sensory-driven choice in reaching a decision.

Prof. Romei’s has published over 100 articles with regular presence in prestigious outlets such as Neuron, Nature Communications, Current Biology, Trends in Neurosciences, Schizophrenia Bulletin, Journal of Neuroscience, etc.

ABSTRACT

Predictive coding has emerged as a fundamental framework for understanding perceptual decision-making by positing that the brain continuously integrates sensory evidence with internal priors to form percepts. Within this framework, two core components are critical: the incoming sensory information and the prior expectations. A growing body of research using behavioral experiments, computational modeling, Electroencephalography (EEG) and Transcranial Magnetic Stimulation (TMS) has provided converging evidence that humans strongly rely on aprioristic models to guide perceptual decisions. For instance, we and others have shown that individuals strategically adjust their decision strategies based on prior probabilities, leading to systematic biases in perception that, while not necessarily enhancing sensitivity, optimize performance under uncertainty. At the neural level, EEG investigations have identified distinct oscillatory signatures that underpin the integration of sensory evidence and priors.

Here I will show that when probabilistic priors are presented, posterior alpha oscillations are implicated in sensory preparation, with enhanced modulation of alpha amplitude associated with increased readiness to include prior information in the perceptual process of expected stimuli. Moreover, we found that inhibiting parietal cortex with TMS does not affect perceptual sensitivity (d prime) nor bias (criterion) per se but selectively reduces the ability to integrate prior information into actual stimulus processing, thus impacting metacognitive functions. At the neural level this is reflected in a reduced alpha amplitude modulation which cannot longer differentiate prior probability content.

At the same time, fronto-parietal theta activity appears to serve an executive and monitoring role, orchestrating the top-down control of prior integration, acting as a brake of its overly integration. Additionally, in more deterministic contexts, motor beta-band desynchronization has been observed, indicating that the motor system pre-activates responses in line with prior-driven predictions even before the full sensory evidence is available.

Recent work has also highlighted marked interindividual differences in the reliance on priors versus sensory evidence. Our own studies have revealed that these differences give rise to distinct cognitive styles—often characterized as “believers” versus “empiricists.” Believers are those who tend to overweight prior information relative to incoming sensory signals, whereas empiricists rely more heavily on the direct sampling of sensory evidence. These cognitive styles are not arbitrary; rather, they are influenced by dispositional factors, such as personality traits along the autism-schizophrenia continuum.

Moreover, our recent work has begun to address the ontogenetic dimensions of predictive coding by exploring how these integrative processes are modulated by age. Preliminary results suggest that aging is associated with a shift in the balance between priors and sensory evidence: older adults appear to exhibit diminished flexibility in modulating sensory cortical activity in a prior driven fashion, as shown by reduced alpha modulation, alongside enhanced motor beta desynchronization and attenuated fronto-parietal theta connectivity. These neural alterations may underpin to the greater reliance on prior expectations in the aging brain, leading to perceptual decisions that are less sensitive to current sensory inputs.

In summary, I will provide converging evidence bridging behavioural, computational, EEG and TMS studies shedding light on the neural and cognitive mechanisms underlying the integration of priors and sensory evidence in perceptual decision-making. These findings could have broad implications, not only for understanding individual differences in perceptual strategies but also for developing targeted interventions aimed at mitigating age-related perceptual and cognitive decline.