Visual Representations

Organizer: Dimitrios Pantazis

Room: # 104

Date and Time: Tuesday, October4 / 08:30-10:30

Neural Dynamics of Visual Representations

The human visual brain shows highly dynamic patterns of activity, as one transient visual representation is followed rapidly by another. This symposium focuses on several recent studies offering novel insights into the human visual brain. We show that a) MEG measurements can capture the neural signature of a perceptual Gestalt, demonstrating that differences in perceived global form are accompanied by corresponding differences in neural representations; b) conscious and unconscious perceptions share neural signatures that are initially identical and then subsequently diverge, as conscious access engages additional neural activity patterns whereas unconscious access leads to a slow decay of brain activation; c) MEG signals can capture information at spatial scales much more refined than previously believed, giving access to information encoded at the level of individual cortical columns; d) the rich content of MEG visual representations allows view-invariant decoding of human action as early as 200 ms after stimulus onset; and e) the direction of MEG source currents at fusiform cortex dissociate the feedforward and feedback inputs of the hierarchically organized visual brain. Taken together, these results exemplify the power of MEG in capturing visual representations and promise even more exciting results in the future.

Speakers:

- **Thomas Carlson** (Macquarie Univ., Australia)
  "Decoding the time varying representation of abstract visual patterns with MEG"

  Perceptual similarity is a cognitive judgment that represents the end-stage of a complex cascade of processing. Here we explore the temporal relationship between the human brain's time-varying representation of visual patterns and behavioral judgments of perceptual similarity. The stimuli were abstract patterns constructed from identical perceptual units (oriented Gabor patches) so that each pattern had a unique global form or perceptual 'Gestalt'. The stimuli were decodable from evoked neural activation patterns measured with magnetoencephalography (MEG), however, stimuli differed in the similarity of their neural representation as estimated by differences in decodability. Early after stimulus onset (from 50ms), a model based on retinotopic organization predicted the representational similarity of the visual stimuli. Following the peak correlation between the retinotopic model and neural data at 80ms, the neural representations quickly evolved so that retinotopy no longer provided a sufficient account of the brain's time-varying representation of the stimuli. Overall the strongest predictor of the brain's representation was a model based on human judgments of perceptual similarity. Our results show that large-scale brain activation patterns contain a neural signature for the perceptual Gestalt of composite visual features, and demonstrate a strong correspondence between perception and complex patterns of brain activity.

- **Lauri Parkkonen** (Aalto Univ., Finland)
  "Decoding conscious and unconscious visual percepts"

  Visual evoked responses measured by MEG carry information not only about the features and location of a stimulus in the visual field but also about whether the stimulus was consciously perceived or not. I will describe our recent study comparing the brain responses to perceived and unperceived stimuli. We pursued a novel approach, tracking the neuronal coding of consciously and unconsciously perceived

contents while keeping behavior identical. EEG and MEG were recorded while participants reported the spatial location and visibility of a briefly presented target. Multivariate pattern analysis showed that information about the spatial location of the stimulus is available in MEG/EEG also for unperceived targets but that starting about 270 ms post-onset, information unique to consciously-perceived stimuli emerges in superior-parietal and superior-frontal regions. Therefore, conscious access appears characterized by the entry of the perceived stimulus into a series of additional brain processes while the failure of such access results in the breaking of this chain and a subsequent slow decay of the lingering unconscious activity.

- **Dimitrios Pantazis** (MIT, USA)
"Can visual information encoded in cortical columns be decoded from magnetoencephalography data in humans?"

  It is a principal open question whether noninvasive imaging methods in humans can decode information encoded at a spatial scale as fine as the basic functional unit of cortex: cortical columns. We addressed this question in five magnetoencephalography (MEG) experiments by investigating a columnar-level encoded visual feature: contrast edge orientation. We found that MEG signals contained orientation-specific information as early as approximately 50 ms after stimulus onset even when controlling for confounds, such as overrepresentation of particular orientations, stimulus edge interactions, and global form-related signals. Theoretical modeling confirmed the plausibility of this empirical result. An essential consequence of our results is that information encoded in the human brain at the level of cortical columns should in general be accessible by multivariate analysis of electrophysiological signals.

- **Leyla Isik** (Boston Children's Hospital / MIT, USA)
"Fast, invariant representations for human action in the visual system"

  The ability to recognize the actions of others from visual input is essential to humans' daily lives. The neural computations underlying action recognition, however, are still poorly understood. We use magnetoencephalography (MEG) decoding and a computational model to study action recognition from a novel dataset of well-controlled, naturalistic videos of five actions (run, walk, jump, eat drink) performed by five actors at five viewpoints. We show that that actor- and view-invariant representations for action arise in the human brain as early as 200 ms after a video begins. We next extend a class of biologically inspired hierarchical computational models of object recognition to recognize actions from videos and explain the computations underlying our MEG findings. This model achieves 3D viewpoint-invariance by the same biologically inspired computational mechanism it uses to build invariance to position and scale. These results suggest that robustness to complex transformations, such as 3D viewpoint invariance, does not require special neural architectures, and further provide a mechanistic explanation of the computations driving fast, invariant action recognition.

- **Seppo Ahlfors** (Massachusetts General Hospital / Harvard Medical School, USA)
"Characterizing activation patterns among hierarchically organized visual areas with MEG"

  Identifying inter-area communication in terms of the hierarchical organization of functional brain areas is of considerable interest in human neuroimaging. We have examined the hypothesis that the direction of magneto- and electroencephalography (MEG, EEG) source currents depends on whether the input into a cortical area originates from an area that is below or above in the hierarchical order of cortical areas, as defined by layer-specific connectivity patterns. The direction in MEG source currents was determined in a visual object recognition experiment in which there were specific expectations of activation in the fusiform region being driven by either feedforward or feedback inputs. The source for the early non-specific visual evoked response, presumably corresponding to feedforward driven activity, was found to point outward, i.e., away from the white matter, whereas later object-recognition related source currents, expected to be driven by feedback inputs, pointed inward. Computational modeling was used to

demonstrate a dependence between the dipole direction and the spatial pattern of synaptic inputs within the dendritic tree of pyramidal cells. Associating specific features of the MEG/EEG source waveforms to feedforward and feedback inputs could provide unique information about the activation patterns within hierarchically organized cortical areas.