Attention and Expectation in Human Visual Perception

Chair: Floris de Lange, Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behavior, Nijmegen, Netherlands

Perception is not merely a passive process of accumulation of sensory evidence, but rather is strongly influenced by the ‘top-down’ influence of internal brain states, incorporating our goals, expectations, and knowledge about the world.

Research into the neural mechanisms by which top-down information shapes perception has expanded rapidly over past decades. However, many conceptual issues still remain open. One of the most pressing of these concerns the interrelationship between two important concepts: attention, relating to the relevance of a stimulus for the task at hand, and expectation, relating to the likelihood that it will occur. These two concepts are often conflated and confounded, such as when spatial attention is guided with a probabilistic cue. Nevertheless, in real life both expected and unexpected events may be task-relevant. Recently, empirical findings have emerged that characterize the complex relationship between attention and expectation. In this symposium we review these recent developments, which are rooted in computational modeling, neuroimaging (EEG/MEG and fMRI), and psychophysics.

We will provide a variety of perspectives, each based on novel conceptual frameworks and experimental approaches. Peelen will illustrate the richness of attentional mechanisms that facilitate visual perception of naturalistic scenes. Muckli will describe expectation-related contextual top-down signals in the primary visual cortex. Then, de Lange will report a neural dissociation between the top-down effects of expectation and attention, in terms of sharpening of sensory responses. Finally, Summerfield will address how relevance and probability may have different effects on brain and behavior, using novel signal detection and reverse correlation techniques.

Learning Objectives: This workshop will:
1. Review novel insights into the working mechanisms of top-down influence on perception and cognition; and
2. Explain how attention and expectation, which are traditionally conflated, are conceptually, behaviorally and neurally, distinct.

The Neural Basis of Attentional Selection from Natural Scenes
Marius Peelen, CIMEC, Rovereto, Italy

The visual system has an extraordinary capability to extract categorical information when searching complex natural scenes. For example, subjects are able to rapidly detect the presence of object categories such as animals or vehicles in novel scenes that are presented very briefly. I will discuss a series of fMRI studies that were aimed at elucidating the neural basis underlying such visual search at the level of object categories in the human brain. A major mechanism that mediates visual search in natural scenes is the pre-activation of object-selective cortex in category-specific ways through the formation of mental ‘search templates’. This mechanism operates across the entire visual field and is independent of space-based mechanisms of selective attention. The strength of the category-specificity of pre-activated cortex determines a subject’s search performance. Together, these results provide first insights into more complex attention strategies that are required when being confronted with the richness of natural vision.
Context Feeding Back to V1
Lars Muckli, Glasgow University, Psychology Department, Glasgow, UK

How does visual context trigger expectations in early visual cortex? Primary visual cortex is typically investigated in terms of the visual information presented to the eyes. Here I will present studies on non-feedforward stimulated parts of V1, that is, when no visual information was presented to the eyes. We occluded large sections of natural visual stimuli and used brain reading techniques (MVPA) to investigate information content in non-stimulated parts of V1 and V2. We show that lateral interaction and cortical feedback provide information to the non-stimulated sections of V1. To further investigate V1 information coding as a function of cortical feedback, we looked at the layer specific information in V1 during feed-forward and during feedback stimulation using high-res fMRI (0.73mm resolution). The results demonstrate expectation-related information in non-stimulated parts of V1.

Dissociable Influences of Prior Probability and Relevance on Visual Detection Sensitivity
Chris Summerfield, Oxford University, Wadham College, Oxford, UK

I will describe novel evidence that signal probability and signal relevance have dissociable influences on visual detection. I will begin by describing a study in which observers detected whether one of two independently located visual signals had occurred. Advance cues predicted the probability of occurrence of a signal, and its relevance to the task (the probability that that location would be interrogated). Using a reverse-correlation method, we show that probability and relevance have dissociable influences on detection: probability enhances detection of low-energy signals, whereas relevance is most influence in the detection of higher-energy signals. Using computational simulations, we show that this finding is consistent with the view that probability modulated visual input gain, whereas relevance determines levels of decision noise. Subsequently, I will describe comparable results from a study in which we varied the probability and relevance of a visual feature (orientation). I will conclude by discussing the significance of these findings for current models of visual attention.

Expectation Sharpens Representations in Early Sensory Cortex
Floris de Lange, Radboud University Nijmegen, Donders Institute for Brain, Cognition and Behavior, Nijmegen, Netherlands

Perception is facilitated by prior expectation. Yet, neural recordings often show reduced sensory activity for expected events. Here I will describe a series of neuroimaging (MEG and fMRI) experiments that show that fulfilled expectations about upcoming sensory events lead to a reduction of neural activity but an increase in amount of information in sensory areas, as revealed by pattern classification methods. These effects were distinct from, and independent of the attentional relevance of the sensory information, arguing for separate working mechanisms of attention and expectation. These results underline the importance of carefully distinguishing between expectation and attention in experimental design and interpretation, as these top-down factors may have a distinct neural implementation.

Session Topic(s):
Higher cognitive functions