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| As Published | http://dx.doi.org/10.1109/IJCNN.2009.5179097 |
| Publisher | Institute of Electrical and Electronics Engineers |
| Version | Final published version |
| Accessed | Mon Nov 07 16:32:09 EST 2016 |
| Citable Link | http://hdl.handle.net/1721.1/58973 |
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| Detailed Terms | |
Neural Synchrony and Selective Attention

Robert Desimone

Abstract—A complex visual scene will typically contain many different objects, few of which are currently relevant to behavior. Thus, attentional mechanisms are needed to select the relevant objects from the scene and to reject the irrelevant ones. Neurophysiological studies in monkeys have identified some of the neural mechanisms of attentional selection within the ventral, “object recognition”, stream of the cortex, which begins with area V1 and continues through areas V2, V4, and IT cortex. At each stage along this stream, attended, or behaviorally relevant, stimuli are processed preferentially compared to irrelevant distracters. The source of the attentional feedback to visual cortex seems to originate in parietal and prefrontal cortex. We proposed some years ago that this attentional feedback biased competitive interactions among neurons in visual cortex, in favor of neuronal responses to the most behaviorally relevant stimulus. More recent work indicates that these competitive interactions are one aspect of a more general visual mechanism for contrast normalization, which is present in most or all visual areas. By providing the appropriate input to this normalization mechanism, feedback from parietal and prefrontal cortex appears to shift the balance of visual cortical responses towards the attended stimulus.

In recent years, we have focused on the detailed mechanisms by which the attentional feedback affects cells in visual cortex. Our work has suggested that the attentional bias is mediated, at least in part, in visual cortex through an increase in high-frequency (gamma) synchronization of neurons carrying critical information about the location or features of the behaviorally relevant stimulus (Fries, Reynolds et al. 2001; Liang, Bressler et al. 2003; Fries, Womelsdorf et al. 2008). Increases in gamma synchrony are found during both spatial attention and featural attention engaged during visual search (Bichot, Rossi et al. 2005), and the presence of synchrony in visual cortex predicts faster responses in visual tasks (Womelsdorf, Fries et al. 2006).

Recent evidence shows that inputs from the frontal eye fields (FEF) in prefrontal cortex initiates coupled gamma-frequency oscillations between FEF and area V4 in the ventral stream during attention, and these oscillations are phase, or time-shifted to allow for conduction and synaptic delays between the two areas, thereby achieving maximally effective communication (Gregoriou, Gotts et al. 2009). Attentional effects in V2 and V1, which are earlier stages in the ventral stream, occur later in V4, suggesting that attentional feedback works in a “backwards”, step by step through the ventral stream. Our unpublished human experiments using magnetoencephalography (MEG) show results that are remarkably similar to that found in animals. Specifically, with attention, neural activity in visual cortex becomes synchronized with that in the prefrontal and parietal cortex, which a phase shift that seems to allow for the necessary conduction and synaptic delays. Cross-area synchrony may be a general mechanism for regulating information flow through the brain (Buschman and Miller 2007; Saalmann, Pigarev et al. 2007; Lakatos, Karmos et al. 2008) and for regulating spike-timing dependent plasticity.

REFERENCES

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