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Early bottom-up and *later* top-down attentional selection

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Among the most fundamental issues in cognitive neuroscience is the issue of the extent to which one is able to exert cognitive control over visual selection processes. Overt or covert selection may either be controlled by the properties of the stimulus field or by intentions, goals and beliefs of the observer. When an observer intentionally selects only those objects required for the task at hand, selection is said to occur in a top-down, voluntary, goal-directed manner. When specific properties present in the visual field determine selection independent of the observer's goals and beliefs, selection is said to occur in an involuntary, bottom-up, stimulus-driven manner. From a neurophysiological point of view, it can be assumed that bottom-up signals, mediated primarily by magnocellular visual inputs, are combined with top-down signals at several cortical (e.g., frontal, parietal) and subcortical (e.g., basal ganglia, superior colliculus, thalamus) stages. Bottom-up and top-down control of attention represent the interplay of exogenous (feedforward) and endogenous (feedback) neuronal activities within the cortex. Early visual areas such as LGN and V1 have relatively small receptive fields and respond basically to simple features. Upstream, inferotemporal (IT) and posterior parietal cortex (PPC) have much larger receptive field and can respond to more complex and abstract features.

Imagine a situation in which the visual system is confronted with two different objects in different locations in the visual field (see Figure 1). Within the system these two objects are in competition and question is which object wins this competition and drives neurons throughout the visual system forming an ensemble of neurons that represent this one single object. In line with the biased competition model of Desimone and Duncan (1995) it is conceivable that attention biases these competitive interactions such that attended stimuli receive priority over unattended stimuli. Attentional effects on resolving this competition are the result of bottom-up and top-down factors. The bottom-up signal depends on the properties of the stimulus field. Objects that are highly salient and stand out from the background may immediately receive attention priority. Indeed, it is likely that before top-down influences can have an effect, the visual system is biased towards salient stimuli that resolve the competition simply on the basis of the bottom-up input (see e.g., Theeuwes, 1992, 1994; Van Zoest. Donk & Theeuwes, 2004). This type of selection is basically exogenous and automatic and is often referred to as attentional or oculomotor capture.

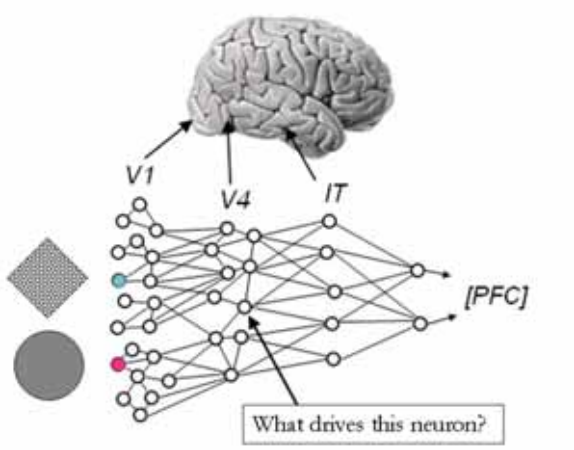

Figure 1: A schematic drawing of the visual system. In this example, two different objects in different locations are in competition. The question is which object will win the competition and drive the neuron. Bottom-up and top-down activity can resolve this competition (adapted from Serences & Yantis, 2006).

Another way to bias the competition within the visual system is through top-down feedback signals that depend on the goals, intentions and expectations of the observer. Directing voluntary attention to a location in space increases the sensory gain for features at that location and appears to alter the apparent stimulus contrast. These results imply that the directing attention to a location results in a greater neuronal sensitivity (i.e., a decreased threshold). This type of selection is endogenous and is often referred to as goal-driven control.

In this talk I will give an overview of research that I conducted over the last 15 years addressing the issue of top-down and bottom-up control. I will provide evidence from behavioral, ERP and fMRI experiments suggesting that initially, top-down knowledge cannot modulate the selection priority within the initial first sweep through the brain. Objects that are salient and stand out from the environment are automatically selected (cf. attentional capture). We show that later in time, possibly through recurrent processing massive top-down processing is possible on items that are already selected. The only way to exert top-down control over the initial selection (the first sweep through the brain) is through space. Only by focusing attention on to a limited area in space, it is

possible to prevent bottom-up automatic selection of salient objects.

References

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