# On the agnosticism of spikes: attention, intention, and salience in the monkey lateral intraparietal area


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Attention is the process whereby the brain filters out sensory information unimportant for behavior. Clinical studies show that the parietal lobe is important for the attentional processes. Neurons in the lateral intraparietal area (LIP) filter out visual stimuli that are behaviorally unimportant, for example stable objects in the environment, although they do respond to those same stimuli when they appear abruptly in the environment.

Although LIP filters out behaviorally irrelevant visual stimuli, it does not filter out salient objects that are not the targets of a planned saccade. When a monkey plans a memory-guided saccade away from the receptive field of a neuron, the abrupt onset of a distractor in the receptive field evokes an enhanced response relative to the case when the monkey plans a saccade to the receptive field and the distractor subsequently appears in the receptive field. In these cases the distractor had no effect on the performance of the saccade.

Attention, as measured by an improvement in contrast sensitivity at the attentionally advantaged site, lies at the goal of a memory-guided saccade during the delay period, but it can be briefly captured by the abrupt onset of a distractor. The activity of neurons in LIP correlates with the monkey's attention both when it lies at the saccade goal and when it lies at the distractor site, and the time at which attention returns from the distractor to the saccade goal is predicted by the activity of neurons in LIP.

Most studies of eye movements in awake, behaving monkeys demand that the animal make specific eye movements. We have developed a new paradigm in which the monkey performs a visual search for an upright or inverted T among 7, 11, or 15 cross distractors, and reports the orientation of the distractor with a hand movement. The search array is radially symmetric around a fixation point, but once the array appears the monkey is free to move its eyes. The monkey's performance in this task resembles that of humans in similar tasks (Treisman and Gelade, 1980): manual reaction time shows a set size effect for difficult searches (the crosses resemble the T's) but not for easy searches (the T pops out). Saccades are made almost exclusively to objects in the array, and not to intermediate positions, but fewer than half of the initial saccades are made to the T. We recorded from neurons in the lateral intraparietal area (LIP) while the monkey performed the search. LIP neurons distinguish the saccade goal at an average of 86 ms after the appearance of the array. The time at which neurons distinguish saccade direction correlates with the monkey's saccadic reaction time, suggesting that most of the jitter in reaction time for free eye movements comes from the discrimination process reflected in LIP. However, they also distinguish the T from a distractor on an average of 111 ms after the appearance of the array even when the monkey makes a saccade away from the target, suggesting that LIP has access to cognitive information about the target independent of the saccade choice.

We suggest that LIP provides a salience map which can be used by multiple systems. The salience map is constructed from independent signals (visual, cognitive, saccadic) which are summed in a linear fashion. When a saccade is appropriate, the oculomotor system can use the peak of the salience map to drive a saccade. The visual system uses the same spikes to determine the locus of attention. The source of the spikes, whether from a saccade plan or the visual system reporting the abrupt onset of a visual stimulus, is irrelevant to the use to which the recipient area puts the signal.