Value representation via divisive normalization in parietal cortex

Kenway Louie, Lauren Grattan, and Paul W. Glimcher

Center for Neural Science, New York University, New York, NY

Value information is a critical component of the decision-making process. In the lateral intraparietal area (LIP), visuomotor neurons are strongly modulated by reward variables such as expected gain, prior probability, and reward income, suggesting that individual LIP neurons represent the subjective value of specific saccades [1,2]. In this framework, decision activity across the LIP population initially encodes the values of the available targets; comparison of these values results in action selection and output of choice information to downstream oculomotor structures. Notably, such a decision framework would be robust to many transformations of neural activity, permitting for example the scaling of value information.

We explore here the computational representation of multiple option values during decision-making. In an initial experiment, we explicitly examine the effect of the value of targets outside the response field (RF) on single neuron activity. Our results show that even though such stimuli elicit no activity when presented alone, when presented in a choice situation with a target in the RF they strongly modulate LIP activity. Specifically, the spiking rate of LIP neurons decreases significantly as the value of targets outside the RF increase. The activity of these same neurons increase when target value in the RF increases, as previously reported for LIP. Examined together, these results show that LIP neurons encode a relative measure of saccade value, normalized across available options.

What is the form of this normalization? Visual cortical processes such as gain control in V1 and responses to multiple stimuli in MT have been explained by a form of divisive normalization [3,4]. More general models of divisive normalization include tunable normalization weights, allowing activity to be optimized for example to minimize statistical dependencies between responses [5]. To fully characterize value normalization in this context, we have developed a multiple-option version of the previous choice experiment. In each trial of this task, the monkey fixates a central cue and views three peripheral targets. Target onsets are asynchronous to allow examination of the dynamics of normalization within a trial, and reward values are varied to characterize how target number and value interact. The existence of value-based divisive normalization in parietal cortex suggests that this may represent a general mechanism of cortical operation, and provides insight into how decision processes handle multiple options and values.

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