Evidence for One Dimensional Dynamics of Attention and Decision Making in Macaque Parietal Cortex

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Where we allocate our visual spatial attention depends upon a continual competition between internally generated goals and externally generated distractions. Neurons in the macaque lateral intraparietal area (LIP) can predict the amount of time a distractor can shift the locus of spatial attention away from an internal goal imposed by a delayed saccade instruction.[1,2] Individual neurons reflect this robust attentional switching time scale (350 or 425 ms in two different monkeys) in the time at which their decaying response to a distractor stimulus crosses their own level of sustained activity to a target of a delayed saccade task. Different neurons show this common crossing time despite substantial heterogeneity in their dynamics.

We propose that this remarkable correspondence between single neuron and attentional dynamics can be explained by a network model of LIP in which high dimensional, transient firing-rate vectors rapidly become one-dimensional. This single dimension is determined by a slowly decaying mode induced by recurrent connectivity within LIP. The model predicts that this slow mode will dominate the background activity during fixation as well as during the delay period, implying that delay period activity should correlate strongly on a cell-by-cell basis with background activity, but not with the visual transient, a prediction verified by the data. We also discover direct evidence for one-dimensional dynamics in the firing rates.

Furthermore we analyze data from a completely different experimental paradigm in which LIP mediates a decision making task via a ramp to threshold process driven by motion stimuli.[3] We again find essentially one-dimensional dynamics: ramping activity at low motion coherences shows strong cell-by-cell correlation to background activity during fixation, albeit slightly weaker than in the delayed saccade task.

A functional advantage of having a single slow mode is that the temporal dynamics of this mode is relatively insensitive to stochasticity in single neuron biophysics. We propose that such a rapid reduction to low dimensional dynamics provides a common network organizational scheme whereby robust timing of behaviors, beyond attention and decision-making observed so far, can emerge naturally from the heterogeneous dynamics of single neurons.

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References

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