The effects of correlated neural activity on single-neuron spiking variability in the primate retina

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Visual neurons fire stochastically in response to stimuli: repeated presentations of a single visual stimulus result in spike patterns that differ markedly from trial to trial. In retinal ganglion cells, this variability places critical limits on the fidelity with which neurons can convey visual information to the brain. However, single-neuron measurements of response variability neglect the fact that neurons in a local population exhibit statistical dependencies in their responses, which can influence the effective variability (and hence coding fidelity) of the full population. Does the variability observed in individual neurons primarily reflect their intrinsic stochastic properties or the stochastic behavior of the local network? Here we show that a model of spiking activity in a population of macaque retinal ganglion cells can be used to account for a substantial fraction of a single neuron's variability in terms of variability present in the population response.

The model, an instance of generalized linear model, describes each neuron's response as a point process whose conditional intensity (i.e., spike-rate) is given by the exponentiated net output from a bank of linear filters applied to the stimulus, the neuron's recent spiking history, and the recent spiking history of other neurons in the population. This model provides an accurate description of $p(\mathbf{r}|\mathbf{x})$, the joint probability distribution over spike responses $\mathbf{r}$ given a stimulus $\mathbf{x}$, which encompasses both the the stimulus-dependence and the detailed space-time correlation structure of the population response.

We present a novel approach to understanding the relative contribution of intrinsic and network stochasticity to the response variability of a single cell, by using the model to probe the influence of neighboring cells in the population. Specifically, we draw samples from $p(\mathbf{r}_i|\mathbf{r}_{j\neq i}, \mathbf{x})$, the distribution over the i'th neuron's response given both the stimulus and the responses of other neurons in the population. Averaging these responses gives a population-conditioned PSTH, which can be considered a single-trial rate prediction of the cell's activity based on both the stimulus and the population activity during that trial. We show that this model-based calculation predicts single-trial activity more accurately then the neuron's actual PSTH (which gives the lowest possible variance for any stimulus-based prediction). Thus, a traditional raster plot reflects only a lower-bound on the precision and reliability of single neurons, and a significant fraction of the variability observed in such rasters can be attributed to spiking activity in the local population.

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