Maximum-entropy analysis of multi-neuron firing patterns in primate V1 reveals stimulus-contingent patterns

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Introduction

The activity of pairs of neurons in V1 are correlated over a few tens of milliseconds. However, the implications of these correlations on the higher-order structure of cortical networks is not known.

In the retina, maximum entropy (MaxEnt) techniques have demonstrated that the structure of multi-neuron firing patterns can be accounted for by interactions between pairs of neurons (Schneidman et al. 2006 and Shlens et al. 2006).

Here, we implement a similar maximum entropy analysis of multi-neuron firing patterns from tetrode recordings in V1 of the anesthetized macaque.

Methods

6 macaques under sufentanil/propralol anesthesia and vecuronium paralysis.

Tetrode recordings of V1 - 19 different sites with 3-5 simultaneously recorded single units. 14 trios, 1 quadruplet, 2 quintuplets, 64 neurons in total.

Binary mneuron-modulated checkerboard stimulus: 0.5 Hz frame rate (14.8 ms frame length). 8-16 repeats of 60.6 s stimulus and its contrast inverse (16-32 mins of data).

Spike sorting and spike trains binned into 14.8 ms bins.

Spike sorting prevents detection of multiple spike that are within a 1.2 ms look-out window. This leads to a systematic underestimate of multi-neuron spiking events within a 14.8 ms bin.

Correction assumes that within a bin all possible assortments of k spikes into n slots are equally likely but only 1/k! are observable.

Since a range of probability distributions could have generated the observed firing counts, we use Markov-Chain Monte Carlo simulations to sample from the a posteriori distribution under different Dirichlet priors (β = 0, 0.5, 1).

Because the posterior distributions were not significantly different under the various priors, we present only the analysis from the naive estimate, β = 0.

Sampling from the a posteriori distribution generates confidence intervals for model fits.

Results

To evaluate the models we compare the likelihood of generating the data under different models. We calculate the log-likelihood ratios between models (perfect fi = 0). These can be computed from firing pattern probability distributions via the K-L distance.

To determine the fraction of deviations from independence observed in the data that can be accounted for by the models, we calculate ratios of the connected information.

Analyzing the influence of stimulus driving

To determine which pixels most strongly modulated the response of neural clusters, we calculated the K-L distance between stimulus-triggered population responses to each of the stimulus conditions (On/Off) for each pixel, at each lag.

Since each conditional pixel divides the data in half, we restrict the analysis to the four most informative pixels.