Introduction

In the retina, it has been shown that cells act as independent encoders, where the spike trains are generally independent across cells (Nirenberg et al., 2001). We wanted to see what kind of dependencies, if any, might exist in the firing rates of cells in primary visual cortex.

Barlow’s original efficient coding hypothesis suggests that cells in cortex should respond independently. But a more recent view is that as one moves from retina to the much larger visual cortex, “redundancy must increase, because information cannot be created,” (Barlow, 2001), and that the purpose of expansion is to represent the input in a more convenient way for later use. Perhaps this redundancy might reveal itself in firing rate dependencies (correlations, or perhaps other types) in neuronal populations in cortex.

Methods

We used silicon polytrodes with closely spaced electrode sites (50-75 um) to simultaneously record from dozens of cells over multiple cortical layers in area 17 in anesthetized cat (Blanche et al., 2005). Electrode sites were closely spaced so as to isolate many adjacent cells within the recordable volume of roughly 2000 x 200 x 130 um.

We stimulated with white noise (wn), pink noise (pn, 1/f amplitude spectrum), and contrast normalized natural scene (ns) movies on a 200Hz monitor. Stimulation area was about 3X the classical receptive field area. Receptive fields (RFs) were mapped using spike triggered averaging of an msequence noise or sparse bars stimulus, for simple and complex cells respectively.

We calculated instantaneous firing rates instead of PSTH rates because we wanted to track rate dependency over time, not over trials. Due to spontaneous variations in brain state and depth of anesthesia, the two are not necessarily the same.

Responses to ns saturate at low contrast, to pn at medium contrast, and to wn at high contrast. As responses saturate, variance in firing rates decreases. Without variance, covariance is not possible. To roughly normalize for variance in firing rates, we used low contrast ns, medium contrast pn, and high contrast wn movies for the above comparison.

The factorial firing rate probability distribution function (FPDF) was calculated by first finding the rate distribution for each cell separately, and then taking the outer product of the two distributions. Doing so assumes that the rates are independent.

The joint firing rate probability distribution function (JPDF) for each cell pair was constructed by stepping through every time point in the rates of both cells and building up a 2D histogram of joint rate probabilities. Rates were binned on a log scale.

In addition to the JPDF, the FPDF indicates the level of dependency in the rates of the pair. To effectively compare distribution shapes, the distributions were smoothed and 66% probability contours were plotted. The shapes of these contours for joint and factorial distributions were then compared by measuring their percentage of overlap.

Results

Of 325 cell pairs, we found that some showed dependency, and others did not. The presence/absence of cross correlogram (xc) peaks did not seem to predict dependency. RFs A percent overlap threshold of 75% was chosen to classify cell pairs as either dependent or independent. This classification criterion matched qualitative impressions of whether the JPDF and FPDF looked significantly different.

References

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