Information rates and redundancy in the responses of striate cortical cells to natural movie stimuli

Roger Herikstad¹, Shih-Cheng Yen¹, Jonathan Baker², and Charles M. Gray²

¹National University of Singapore, ²Montana State University

When presented with simple stimuli like bars and gratings, adjacent neurons in striate cortex exhibit responses that are thought to be highly redundant. On the other hand, when presented with complex, time-varying natural scenes (i.e. movies), striate neurons exhibit high population sparseness, as well as high lifetime sparseness [1,2]. This raises the question of how much redundancy might be found in the responses of adjacent neurons to movie stimuli, and how the redundancy changes with distance between the neurons. We investigated this question by simultaneously recording the responses of groups of neurons in cat striate cortex to the repeated presentation of movies using silicon probes in a multi-tetrode configuration. The movies used in this experiment were 30 s long and were repeated 100 times.

Using the direct method [3,4], we calculated the information rates of 48 single cells, as well as 45 pairs of cells simultaneously recorded on the same tetrode (intra-group) and 53 pairs of cells recorded on tetrodes separated by at least 150 um (inter-group). For the single cells, we found a maximum mutual information rate of 20 bits/s, a minimum rate of 0.14 bits/s, with medians and quartiles at 3.6, 1.8, 6.0 bits/s respectively. The intra-group pairs had a maximum joint information rate of 15 bits/s, a minimum rate of 1.2 bit/s, and medians and quartiles at 7.1, 5.4, 9.4 bits/s. The inter-group pairs, on the other hand, had a maximum rate of 16 bits/s, a minimum rate of 1.6 bits/s, and medians and quartiles at 7.4, 5.4, 11 bits/s. The intra-group and inter-group distributions were not significantly different (two-sample Kolmogorov-Smirnov test, p=0.66).

We also used a synergy measure [5] to compare the joint mutual information rates to the sum of the individual information rates. This measure was normalized so that a value of 0 indicated independent coding, a value of -1 indicated maximal redundancy, while a value of 1 indicated maximal synergy. 27 of the intra-group pairs were synergistic (60%) while the other 18 pairs were redundant. For the inter-group pairs, 32 were synergistic (60%) while the other 21 were redundant. The median and quartiles for the intra-group pairs were 5.9x10⁻³, -2.1x10⁻², 4.5x10⁻², while those for the inter-group pairs were 5.8x10⁻³, -1.5x10⁻², 1.2x10⁻¹. A two-sample KS-test did not find any significant differences between these two distributions (p=0.53).

Our results indicate that when stimulated with natural movies, pairs of adjacent neurons encode just as much information as pairs of neurons that are separated by at least 150 um. Our results also suggest that the responses of adjacent neurons may not be as highly redundant as previously thought.

References