

Response sparseness in the early visual system

Vincent Bonin, Valerio Mante, and Matteo Carandini
The Smith-Kettlewell Eye Research Institute, San Francisco

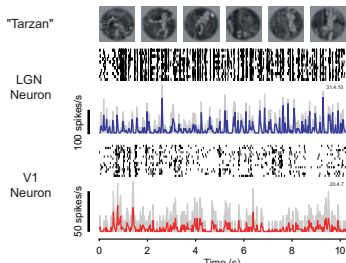
1. Introduction

Responses in primary visual cortex (V1) are very sparse [1,2]. Brief periods of high activity are interspersed by long periods of silence. This lifetime sparseness is thought to reflect the high selectivity of the neurons for stimulus attributes [2].

Neurons in lateral geniculate nucleus (LGN) are much less selective for stimulus attributes. Are their responses less sparse?

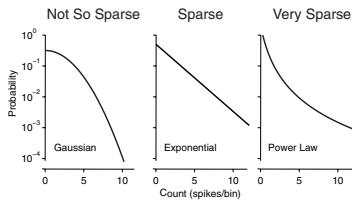
2. Methods

We measured responses in LGN and V1 of anesthetized, paralyzed cats. We stimulated neurons with > 6 movie clips: (1) natural sequences recorded by a camera mounted on a cat's head [3]; (2) artificial sequences from a Walt Disney cartoon. Stimuli lasted 10-12 s and were repeated 6-20 times.



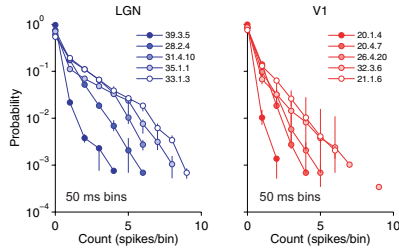
3. Distribution of Spike Counts

Sparseness can be inferred from the distribution of spike counts.



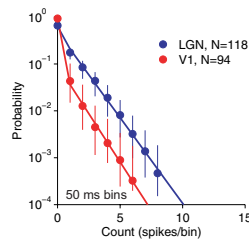
4. Example Cells

Different neurons exhibit different degrees of sparseness.



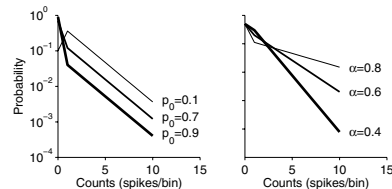
5. Population

Except for the probabilities of zero spike counts, all probabilities fall on a line (linear-log scale) corresponding to an exponential distribution.



6. Model

We described the distributions with a probability of silence p_0 and an exponential decay α .

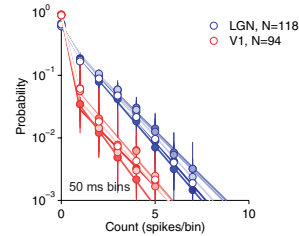


Decay α is the relative probability that an extra spike falls in a bin. Together p_0 and α determine the sparseness of the responses.

LGN and V1 neurons have similar probabilities of extra spike ($\alpha=0.43$ vs. 0.39) but different probabilities of silence ($p_0=0.64$ vs. $p_0=0.94$).

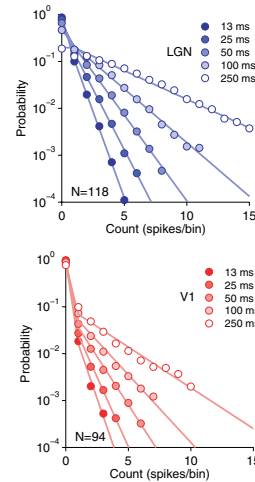
7. Invariance to Stimulus Identity

Responses to different movie clips have similar sparseness.

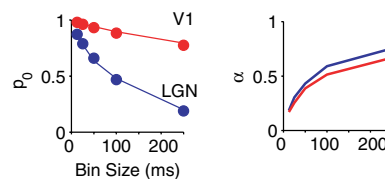


8. Effects of Bin Size

The model is an accurate description of the spike count distributions at all bin sizes.

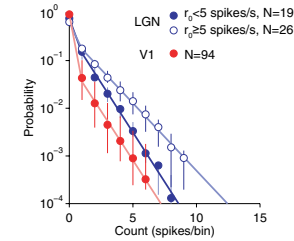


The differences in probabilities of silence p_0 between LGN and V1 neurons strongly increase with bin size. The differences in probabilities of extra spike α do not.



9. Effects of Spontaneous Activity

Can the differences in the spike counts distributions of LGN and V1 neurons be explained by differences in threshold? Neurons with lower threshold have higher spontaneous firing rate r_0 .



The spontaneous firing rate r_0 weakly affects the probability of silence p_0 . When $r_0 < 5$ spikes/s $p_0=0.77$. When $r_0 > 5$ spikes/s $p_0=0.64$.

The spontaneous firing rate r_0 strongly affects the probability of extra spike α . At high r_0 , α equals 0.52. At low r_0 , LGN and V1 responses have similar α (0.38 and 0.39).

10. Conclusions

LGN and V1 responses have exponential distributions of spike counts with similar decay α .

LGN responses are less sparse than V1 responses mostly because they have a lower probability of silence p_0 .

Spontaneous activity strongly affects α but has only weak effects on p_0 .

Our findings hold for a variety of stimuli and bin sizes.

References

- [1] Baddeley et al, 1997
- [2] Lehy, Sejnowski and Desimone, 2005
- [3] Betsch et al, 2004

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