Direct measurement of "suppression" in the LGN in the context of natural stimuli and its implications for visual coding

Daniel A. Butts[1], Chong Weng[2], Jianzhong Jin[2], Chun-I Yeh[2], Nicholas A. Lesica[3], Garrett B. Stanley[3], Jose-Manuel Alonso[2], and Liam Paninski[4]

[1]Weill Medical College of Cornell University, [2]State University of New York, [3]Harvard University, [4]Columbia University

Some of the greatest advances in neural coding have occurred in the visual system, where the relationship between visual stimuli and the observed neuronal activity is relatively straightforward. However, experiments that probe this relationship in more "natural" contexts have revealed many higher order aspects of visual neuron responses, such as their precise timing down to milliseconds, adaptation to contrast, and non-linear summation of multiple stimuli. Here, we describe a new modeling framework applied to LGN neuron data recorded in the context of both artificial noise stimuli and "natural" movies. The basis of this model is the familiar "LN" (linear-non-linear) cascade model based on a linear spatiotemporal receptive field (STRF), but adds a second "suppressive" STRF with different tuning properties. Extending the maximum-likelihood estimation framework proposed by [1], we simultaneously fit both spatiotemporal receptive fields using a modest amount of recording time in the context of both artificial "noise" stimuli and natural movies.

The resulting model reveals the rich computation performed by LGN neurons and accurately describes their responses to both simple (such as spatially homogeneous) and complex "natural" stimuli. [Because we use maximum likelihood estimation, the model can be applied to highly correlated stimuli (such as natural movies) as easily as to uncorrelated "noise" stimuli, permitting a direct comparison.] In addition to providing an improved prediction of the observed LGN neuron responses (*i.e.*, significantly higher likelihood using data not included in the original fit), this "suppression model" captures much of the temporal precision observed experimentally, because the suppressive STRF is mostly overlapping but temporally delayed compared with the linear STRF. Furthermore, suppression may also be related to other "higher-order" features of LGN responses: for example, the relative strength of suppression increases with contrast, which reproduces many of the effects of "contrast gain control" [2,3]. The suppressive STRF likely derives from particular elements of retinal processing (*e.g.*, [4]), but this modeling reveals more general computational principles that arise through commonalities in neuronal processing present across sensory areas. Thus, in accounting for several disparate higher-order elements with a tractable computational model, we can understand their role in the processing of natural vision.

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References

[1] Maximum likelihood estimation of cascade point-process neural encoding models. L. Paninski, *Network* 15:243-262, 2004.
[2] The effect of contrast on the transfer properties of cat retinal ganglion cells. R. Shapley and J. Victor, *J. Physiol.* 285:275-98.
[3] The suppressive field of neurons in the lateral geniculate nucleus. V. Bonin *et al.*, *J. Neurosci.* 25:10844-10856.
[4] Bipolar cells contribute to non-linear spatial summation…, J. Demb *et al.*, J. Neurosci. 21:7447-54.