Visual Response in LGN Neurons Beyond the Monosynaptic Retino-Geniculate Transmission

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Relay neurons in Lateral Geniculate Nucleus (LGN) receive strong feed-forward excitation predominantly from a single retinal ganglion cell (RGC), from which the LGN neuron inherits the primary features of its receptive field. LGN neurons also receive synaptic connections from other sources including interneurons, thalamic reticular neurons, the visual cortex and the brainstem. To what extent these other sources influence the response properties of the LGN neurons is an important question. To address this, we fit a Generalized Linear Model (GLM) to the spike responses of cat LGN neurons elicited by spatially homogenous spots with different sizes, whose luminance was rapidly modulated in a pseudo-random fashion. Our extra-cellular recordings captured both the LGN spikes and the incoming RGC input (S potentials), allowing us to provide our LGN model with the exact times of each retinal input [1]. The instantaneous firing rate of the GLM has the general form $f(b + \vec{D}.\vec{X}(t) + \sum_j H_j\, n_{t-j} + \vec{K}.\vec{l}(t)\,)$, where $\vec{X}(t)$, n_{t-j} and $\vec{l}(t)$ represent the RGC spikes, past LGN spikes and the luminance of the visual stimulus respectively. $\vec{D}$, H and $\vec{K}$ are the linear temporal filters acting on the inputs and the parameter b defines the background firing rate. $\vec{D}$ represents the retino-geniculate (RG) transmission, whereas $\vec{K}$ potentially transmits the stimulus information beyond that transmitted to the LGN by the retina (such as cortical feedback and intrageniculate inhibition). After convolving the inputs with the filters, the spike train is produced by an inhomogeneous point process whose rate is an increasing function ($f(.)$) of the convolved inputs. The filter parameters are optimized so that the likelihood of reproducing the observed LGN spikes is maximized [2].

The results show that for all spots sizes, the $\vec{D}$ filter is large and resembles an exponentially decaying function. For small spot sizes (no larger than the receptive field center), $\vec{K}$ is nearly zero; i.e. the RG transmission is sufficient to account for the LGN responses. However, for larger spots the waveform of the K filter has a peak. This result is particularly interesting since the analyzed LGN neurons were OFF cells; i.e., this secondary filter $\vec{K}$ is of opposite sign than the primary visual receptive field of these cells. For even larger spots (4 times the receptive field center), the $\vec{K}$ filter vanishes again. Cross-validating the model reveals that the $\vec{K}$ filter accounts for up to 12% of the variance of the LGN spiking activity. We conclude that apart from the RG monosynaptic transmission, the LGN neurons receive information about the visual stimulus from other sources, the anatomical nature of which is yet to be determined [cf. 3].

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References

[1] Casti A. et al (2007) A simple model of retina-LGN transmission. *J Comput Neurosci.* 2007 Sep 1.
[2] Paninski L., Pillow J., Lewi J. (2007) Statistical models for neural encoding, decoding, and optimal stimulus design. *Prog Brain Res.* ;165:493-507.
[3] Wang X. et al (2007) Feedforward excitation and inhibition evoke dual modes of firing in the cats visual thalamus during naturalistic viewing. *Neuron* 55(3):465-78