Extraclassical Responses in V1 Modeled via Modulated Cortical Conductances

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Two competing phenomological models of extraclassical spatial summation in V1 are the Difference-of-Gaussians (DoG) and the Ratio-of-Gaussians (RoG) which argue for subtractive or divisive normalization, respectively, as the basis for a variety of extraclassical response properties, such as surround suppression and contrast-dependent receptive field growth. Problematic with these models, however, is that they are somewhat removed from the neurophysiology and thus do not lend themselves to inferring underlying mechanisms. Simulations of an anatomically and physiologically detailed large-scale spiking neuron model, which we have previous developed [1], indicate that the interaction between excitatory and inhibitory cortical conductances may be at the root of the these extraclassical phenomena and that both subtractive and divisive effects of cortical inhibition are involved. Moreover, Anderson et al showed, using intracellular recordings from cat, that cortical conductances are oscillatory [2], with stronger modulation in the inhibitory conductance. Based on these two observations, we developed a Modulated Cortical Conductance (MCC) model which explicitly captures the observed modulations in the cortical conductances and also accounts for length tuning in the membrane potential. We fit our model to experimental intracellular data (Figure 1A), and compare these fits to those for the RoG and DoG models. We show that our model produces fits as good as, if not better than, these two phenomenological models (Figure 1B), while also providing a more explicit mechanistic explanation for extraclassical spatial summation in V1 neurons.

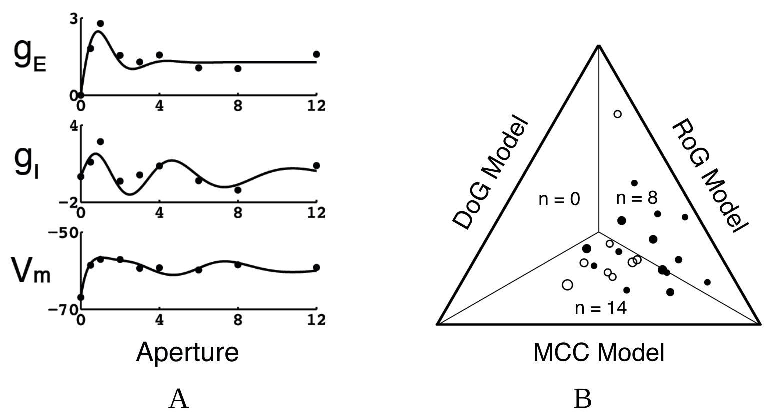

Figure 1: (A) Example fit of MCC model to experimental data. Points represent data, curves are the fit. Fits for (upper) excitatory conductance, (middle) inhibitory conductance and (lower) resultant membrane potential, generated from the fitted excitatory and inhibitory conductances, using the equation $V_m = (g_E V_E + g_I V_I + g_L V_L)/(g_E + g_I + g_L)$, with reversal potentials $V_E = -0$ mV, $V_I = -80$ mV, $V_L = -66.8$ mV. (B) Resultant χ^2_N for the three models (MCC, DoG, RoG), for data taken from 22 neurons. The DoG and RoG models are fit to the membrane potential while MCC is fit on the conductances and the membrane potential is computed from these fits. In all cases the χ^2_N is relative to the membrane potential. Axes are normalized so that the total χ^2_N for all three models is equal to 1. The distance of a point from each bounding axis represents the normalized χ^2_N for the fit to that model. A point in the center of the triangle represents a neuron that is fitted equally well by the three models, while a point lying in a subregion represents a better fit for one of the three models (total number of neurons best fit by each model is given by n). The size of a point scales with the total χ^2_N error of all three models. Responses for high contrast gratings are indicated by filled points, and those for low contrast gratings are unfilled.

Acknowledgments

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References

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