Oscillatory circuits underlying the retinal detection of temporal periodic pattern

Juan Gao, Greg Schwartz, Michael Berry II and Philip Holmes

Department of Mechanical and Aerospace Engineering, Department of Molecular Biology, Program in Applied and Computational Mathematics. Princeton University, Princeton, NJ 08544, U.S.A.

It is observed that retinae subjected to periodic patterns of light flashes in the range of 6-20 Hz can respond to an omitted flash by ganglion cell spikes after a precisely fixed amount of time [1]. We explore the mechanism underlying the omitted stimulus response (OSR) with emphasis on the function of ON bipolar cells. We model ON bipolar cell terminals with LRC circuits in which an inductor represents the voltage-dependent conductances. Two models are developed and tested: a single adaptive oscillator model and a resonator bank model. In the former there is only one LRC oscillator whose inductance is determined by calcium concentration which effectively leads to the dependency of oscillator’s resonant frequency on stimulus frequency. In the latter multiple oscillators are involved which individually dominate the response at each stimulus frequency. The matching of terminal oscillation frequency with flash stimuli frequency implies a fixed latency from OSR to omitted flash as observed in experiments (See Fig. 1). For the resonator bank model the effects of gap junction coupling and synchronization are examined. We also compare model predictions and empirical observations in term of OSR size and latency when flash number and duration vary. We find that the adaptive oscillator model is more robust and can better encompass the frequency range in which OSR is observed, suggesting that calcium dynamics and the nonlinear conductance-voltage relation play important roles.

Figure 1: Predicted delays from OSR to omitted flash using single adaptive oscillator model (black triangles) and resonator bank model (red circles). Dashed line shows average latency observed [1].

Acknowledgments
This work is supported by PHS grants MH58480 and MH62196 (Cognitive and Neural Mechanisms of Conflict and Control, Silvio M. Conte Center). J. G. is supported by The Britt and Eli Harari Fellowship.

References