A computational study on the role of gap junctions and rod I_h conductance in the enhancement of the dynamic range of the retina

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Supporting Information

The retina conductance based model was created using the NEURON software [37] and it is composed of single compartment neuron models with passive parameters described in Table 1 of the main text. The conductances and reversal potentials for the neuron models are described in Table 1. For all conductances in the model we used the Hodgkin-Huxley formulation [46] where the activation, inactivation and non-inactivating variables (m,n,h) were numerically calculated as :

$$\frac{dx}{dt} = \alpha(1-x) - \beta x \tag{1}$$

where x represents any of the m,n,h variables, and α and β are the voltage-dependent activation and inactivation rates.

For all compartments in the neuron models that express calcium dependent channels the same calcium removal mechanism was used. The calcium influx is controlled by the voltage gated calcium and calcium dependent channels while the efflux is given by the second term in the following expression :

$$\frac{d[Ca^{+2}]_i}{dt} = \frac{-kI_{Ca}}{2Fd} - \frac{K_T[Ca^{+2}]_i}{[Ca^{+2}]_i + K_d} \tag{2}$$

where $k = 0.1$, $d = 1\mu m$, $K_T = 10^{-4} mM/ms$, $K_d = 10^{-4} mM$ and F is the Faraday constant.

Rod photoreceptor

The rod model is based on the single compartment model described in our previous work [16]. The modified model has a potassium current with fast dynamics responsible to accelerate the response to light stimulus (I_{Kx}), a potassium current with rectifier characteristics (I_{Kv}), a calcium dependent potassium current (I_{KCa}), a hyperpolarization activated current (I_h), a L-type calcium current (I_{Ca}) and a calcium dependent chloride current ($I_{Cl(Ca)}$) with parameters and dynamics taken from the references indicated in Table 2 and Table 4.

Cone photoreceptor

The cone model is a modified version of the single compartment model described by Kourennyi and others [17]. The modified model has a potassium current with rectifier characteristics (I_{Kv}), a calcium dependent potassium current (I_{KCa}), a hyperpolarization activated current (I_h), a calcium current (I_{Ca}) and a calcium dependent chloride current ($I_{Cl(Ca)}$) with parameters and dynamics taken from the references indicated in Table 2 and Table 4.

Rod and cone bipolar cell

The bipolar cells participate in both the rod and cone circuits connecting AII amacrine cells and ganglion cells [2, 3]. In this work we used the same model to simulate both the rod bipolar cell and the cone bipolar cell. The only difference between the single compartment models is that the rod bipolar cell model expresses the TEA sensitive I_A current [19]. The model is based on the single compartment model described by Usui and others [19] and has a potassium current with rectifier characteristics (I_{Kv}), a calcium dependent potassium current (I_{KCa}), a hyperpolarization activated current (I_h), a calcium current (I_{Ca}) and a TEA-sensitive potassium current (I_A) with parameters and dynamics taken from the references indicated in Table 2 and Table 6.

AII amacrine cell

The AII amacrine cell model is a modified version of the single-compartment model described by Smith and Vardi [24]. The modified model has only the Hodgkin-Huxley sodium and potassium channels [46] with parameters and dynamics taken from the references indicated in Table 2 of the main text and Table 7. The potassium current is activated when the cell is depolarized to -20mV while the sodium current is activated at -30 mV [24].

Ganglion cell

The ganglion cell model is a modified version of the single-compartment model described by Fohlmeister and Miller [25]. The modified model has a potassium current with rectifier characteristics (I_{Kv}), a calcium dependent potassium current (I_{KCa}), a calcium current (I_{Ca}), a TEA-sensitive potassium current (I_A) and the Hodgkin-Huxley sodium channels with parameters and dynamics taken from the references indicated in Table 2 and Table 8.

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