Cell Selectivity in Response to Retinal Prosthetic Stimulation

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Implantable retinal prosthesis has been developed to restore some vision to patients who have been blinded by degenerative diseases. This is done by stimulating retinal ganglion and bipolar cells with an implanted electrode array in a pattern that corresponds with the image in front of the eye. While this has been shown to produce partial vision restoration, the understanding of how the retina cells react to this systematic electrical stimulation is relatively unknown. In this work, studies of the effect different stimuli have on the retinal cells are conducted using a multi-scale modeling approach. By modeling which cells respond to which stimuli, the stimulus can be modified appropriately to produce the desired result.

First, a computational model of the tissue is constructed that includes the multiple layers of the retina. The boundaries between these layers are rippled based on the cell body size in each respective layer in order to create a more anatomically correct model. The electrode array and implant electronics are then incorporated into the model, placed on top of the optic nerve layer. A time-stepping, multi-resolution variant of the Admittance Method (AM) is used to solve for potentials due to one of the electrodes firing on this model. This is done for sinusoidal inputs of varying frequency.

Second, a computational neural network model is constructed in NEURON software. It contains multiple biologically and physiologically accurate ganglion and bipolar cells and their synaptic connections, based on nanoscale connectome data. The resulting potentials from the AM simulations are applied to these networks as extracellular voltage sources, and the resulting internal activity of the cells is recorded. This will allow for the study of whether the ganglion cells and/or bipolar cells respond to the stimulation based on the frequency response of their channel mechanisms. These results would be useful in tailoring the implant stimuli to selectively activate only the desired cells.

The results to be presented include the methods used for the simulations, plots of the models at the tissue level and the neuronal network level, and the resulting response at the network of neurons due to a different stimuli applied to an electrode at the retina surface.