Color Selectivity using Electrical Stimulation of Retinal Ganglion Cells: Computational Study

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Retinitis pigmentosa and age-related macular degeneration are retinal degenerative diseases, which start with the degeneration of photoreceptors. In early stages of degeneration, while photoreceptors are largely damaged, inter retinal neurons and ganglion cells remain mostly intact. Retinal prostheses have been developed with the aim of restoring sight by electrically stimulating the surviving cells. These devices have made a remarkable impact on the life of patients totally blinded by retinal degenerative diseases. Attempts have been made towards increasing the effectiveness and safety of such devices using computational and experimental methods.

While current approaches in restoring partial vision have proven effective, the ability to characterize color percept remains to be investigated. Recent experiments with a retinal prosthetic device have revealed that electrical stimulation can result in some variation of color perception. These findings suggest the possibility of encoding color in retinal prostheses. The addition of color vision would represent a significant improvement in the efficacy of current devices.

A multi-scale computational model developed by the authors has proven powerful in constructing the bulk retina tissue, neural circuitry network, the implant components, and analyzing the cells behavior in response to electrical stimulation. This approach is based on applying both the morphology and biophysical properties of neurons to the computational model. The model consists of an arrangement of different retinal ganglion cell types and the level of dendritification of each cell type in the inner plexiform layer of the retina. This model has been implemented using Admittance Method linked with NEURON software.

In this work, we use the developed computational method to increase our understanding of color encoding in the electrically stimulated degenerated retina. The physiological changes of retinal ganglion cells in response to electrical stimulation for color differentiation will be further analyzed. Since bistratified ganglion cells are known to respond to blue/yellow light and monostratified ganglion cells are responsive to red/green light, this study compares these two cell types and their response to electrical stimulation in an attempt to characterize color perception as a function of key stimulation parameters.