Increasing retinal prosthetic stimulation efficiency in degenerated retina through characterization of the electrical stimulus waveform

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Retinal degenerative diseases, such as retinitis pigmentosa or macular degeneration, impair the retina. This begins with photoreceptor stress and death, followed by perpetual remodeling and degeneration that leads to blindness. The lack of photoreceptors removes the ability of the retina to respond to light stimuli. However, surviving cells have been shown to remain responsive to electrical stimuli. Multiple different retinal prosthetic devices have been developed to take advantage of this finding, using strategically placed electrodes and stimuli to induce phosphenes indicative of the image facing the patient. Research towards improving the efficacy and safety of such devices has continued to advance, using both computational and experimental approaches.

In the authors' previous work, a multi-scale modeling approach has proven effective in modeling retina neural networks and their behavior resulting from electrical stimulation. This method has been largely connectome-based, translating neural morphology and connectivity within a connectome that has been populated using TEM images of a rabbit retina, into a computational model. This includes every observed neural connection and cell within a ganglion cell network. Using a connectome to construct the model is advantageous in that it is the only current approach that includes cellular morphology and network topology with this degree of granularity. This model has been implemented in NEURON software, and is coupled with an Admittance Method model of the surrounding tissue and electronics to simulate its response to electrical stimulation.

The model has then been digitally degenerated through the choice of biophysical parameters. This allows for spontaneous activity that has been observed in the degenerated retina to be incorporated, in addition to reduced synaptic connectivity. Using this model, the authors have found that for a given injected charge, such spontaneous activity can be mitigated or eliminated completely by modifying the shape of the stimulation waveform. This can largely influence the efficacy and safety of currently used electrodes in retinal prosthetics, by decreasing the required charge to invoke neural activation, as well as reducing spontaneous activity in diseased retina. In this work, the stimulation waveform will be further characterized, analyzing the response of the retina to various stimulation waveform shapes and magnitudes. Results will include an analysis of an asymmetric and symmetric biphasic waveform, investigating required amount of charge for both stimulating the retina and reducing spontaneous activity.