Electrical Stimulation Waveform Design Towards Increasing the Effectiveness of Retina Prosthetic Devices

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Retina prosthetic devices that use electrical stimulation have been designed in attempt to restore some vision in patients with degenerative diseases, such as retinitis pigmentosa (RP) or age-related macular degeneration (AMD). These devices function by using electrodes to stimulate local regions of retina tissue, approximating spatiotemporal patterns for representing the image facing the patient, intending to induce a pixelized percept. This has proven effective and has led to the design of multiple different prosthetic devices, providing an invaluable increase in functional vision to blind subjects. However, the resolution of the induced visual percept is greatly limited. To address this, research has been conducted in attempt to improve the efficiency and effectiveness of the stimulus waveform, considering electrode geometry, placement, etc., along with the retinal tissue response to the electrical stimulation.

A limitation of previous work towards the design of effective electrical stimuli is the exclusion of features of degenerated retina, with computational and experimental studies of electrical stimulation considering healthy retina (or beginning stages of degeneration) and/or excluding neural activity, considering the membrane voltage to be at a constant resting potential during electrical stimulation. Properties of degeneration are clinically relevant and important to include in computational approaches for improving rehabilitative techniques. We address this in this work, proposing a simulation framework for understanding the response of degenerating retina to currently used electrical stimuli and for designing new electrode geometries and stimuli waveforms. This framework is based on a multiscale multiphysics platform, using the Admittance Method for computing the electric field within a model of tissue, and NEURON for simulating the resulting response in a neural network, following the authors' previous work (Loizos et al., Phys Med Biol, 2016).

Results to be presented include simulations of spontaneous activity in a model of degenerated retina circuitry, along with the retinal response to currently used electrical stimulation waveforms. In addition, we present recommendations for stimulation parameters that may provide increased control over retina electrical stimulation, comparing the response with currently used stimuli.