INTRA- AND EXTRA-CELLULAR STMULATION OF RETINAL BIPOLAR CELLS

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INTRODUCTION

Retinal implants use an array of electrodes to generate visual perceptions in blind people that have lost their photoreceptor cells [1]. Some types of retinal implants aim for stimulating the bipolar cells (BC) electrically whereas in healthy conditions BCs receive inputs from photoreceptors. The aim of the Switch Board Marie Sklodowska Curie project, which I and other fourteen PhD students are involved in, is to explore general features of BCs and their roles in the neuronal network of the retina.

The coming optic light to the eye from the environment reaches the retina after passing from cornea, pupil, lens and vitreous body. The retina is considered to be a part of the brain where the vision processes start. It is so interesting for neuroscientist because interneurons in the brains are strongly connected, often more than thousands of connections for each neuron, but retina is less complicated. Retina is made of five layers, three neuronal and two synaptic layers. There are five kinds of neurons in the retina, photoreceptors, horizontal cells, bipolar cells, amacrine cells and ganglion cells. The coming light from the environment is absorbed by photoreceptors and after changing to electrical and chemical signals is transferred to the brain through ganglion cells as action potentials, after passing from horizontal, bipolar and amacrine cells [2].

RESULTS AND DISCUSSION

We used a reconstructed morphology of a retinal bipolar cell from real data and determined the exact places of compartments which contains sodium and calcium channels [3]. Figure 1 (left) shows different parts of the reconstructed cell, the big sphere represents the soma while small spheres show synaptic terminals contain calcium channels, thick lines show places of sodium channels, called initial segments, and regular lines shows compartments without ion channels. The neuron is modelled as electric circuit (Fig. 1, right) and by writing the current ohm's law for each compartment, we simulate the transmembrane voltages for every segment of the cell by solving a system of differential equations [3, 4]

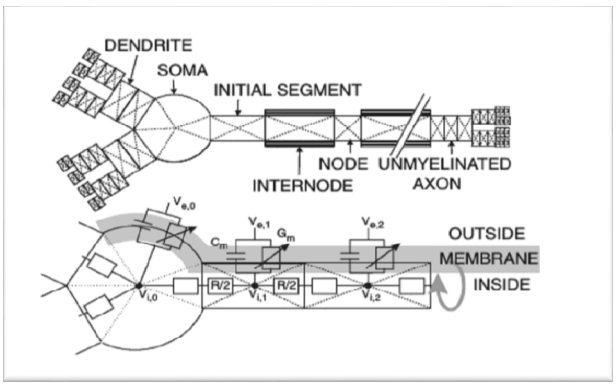

Figure 1: Left: Three dimensional reconstruction of the target cell. The upper part is the dendritic tree, followed by soma and axon with sections of high sodium channel density marked as thick lines. The axon has a branching part with synaptic endings that send signals to the ganglion cells. Right: A neuron is segmented in compartments differing in their functional role (top). Every compartment is modelled as a corresponding system of resistances and capacitance (bottom).

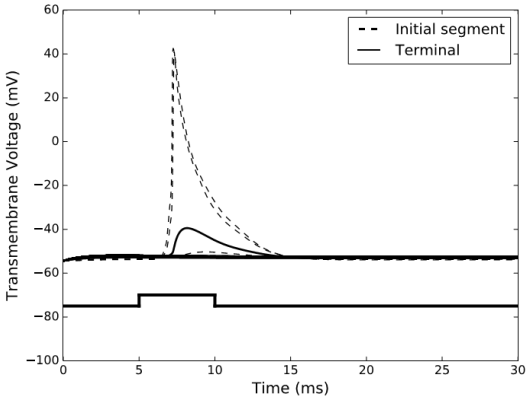

Figure 2: Transmembrane voltage versus time for selected compartments. The cell is stimulated intracellularly with a positive pulse of 0.2µA (bottom) while the electrode is in the soma. Compartments containing sodium channels extremely amplify the signal which supports depolarization of terminals which help vision perception.

We compared the needed intra- and extra- cellular amplitudes to elicit spikes in the terminals (calcium spike) as seen in [3, 6, 7, 8]. Intracellular stimulation has a large function in neurophysiology by making spikes in neurons artificially. We found that the least intracellular amplitude which is injected to the soma is around 0.2µA to make bipolar cell spike and it is around 5µA in the extracellular case where the electrode is 40µm far from the center of the soma near the dendrites.

CONCLUSION

Here we simulated the response of a specific bipolar cell which was stimulated with a microelectrode of spherical shape. For retinal implant simulations the electric field is generated via multichannel electrodes that should be modelled with finite element method. Other cell types can be simulated with the same technique in order to get more insight on strategies which should be used by the next generation of retinal implants.

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