Investigating Single and Multi-Channel Electrical Stimulation of the Optic Nerve for Neuroprosthetic Applications

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***Abstract*— Here we demonstrate the ability to selectively activate different portions of the optic nerve with a novel nerve interface, the OpticSELINE, and show the possibility to improve the spatial selectivity of the electrical stimulation using current focusing according to computational model predictions.**

I. Introduction

Retinal dystrophies such as retinitis pigmentosa and age-related macular degeneration are amongst the leading causes of blindness in the western world and currently have no cure. In these diseases retinal ganglion cells remain mostly intact and functional, and can elicit visual percepts when electrically stimulated, making them potential targets for vision restoration through electrical stimulation.

With the ability to completely bypass the retinal network while still taking advantage of the high-level information processing occurring in the visual cortex, electrical stimulation of the optic nerve is an attractive approach for neuroprosthetic vision restoration.

II. Results

We used a novel flexible 12-channels intraneural electrode design, the OpticSELINE, to electrically stimulate the rabbit optic nerve *in vivo* [1]. After optimizing the stimulation parameters, we establish the possibility of modulating the magnitude of the cortical response resulting from the electrical stimulation by changing the amplitude of the stimulating current pulse. Furthermore, we showed that increasing the number of stimulating pulses at a high frequency (1 kHz) lowered the current threshold at which the first cortical response was observed, and also resulted in an increase in the magnitude of the cortical response.

We designed realistic model of the optic nerve of the rabbit using the already well-established hybrid computational approach, coupling COMSOL Multiphysics and Neuron software, which allows to predict which portion of the optic nerve is activated by a given combination of current pulses [2]. According to its results, when the amplitude of the stimulating current pulse is increased over a certain threshold (10 μA), the activated portions of the optic nerve resulting from the stimulation through neighboring channels of the OpticSELINE start to overlap, suggesting a loss of spatial selectivity of the stimulation. However, the size of the activated portion of the optic nerve is close to unchanged (maximal increase of 4%) when the number of pulses is increased, making it a potentially advantageous way of modulating the magnitude of the cortical response over the current amplitude modulation.

We also investigate current focusing by modeling the effect of stimulating with an anodic pulse in addition to the cathodic one, and showed it decreased the overlap between the activated portions of the optic nerve when stimulating through neighboring electrode compare to single channel stimulation, making it possible to maintain spatial selectivity for higher current amplitudes.

Finally, using a blind-source separation analysis, we divided our original signal into independent components [3] [4], amongst which the meaningful ones were identified. These components were then showed to be associated with one or a small-subset of neighboring stimulating channels, suggesting that the OpticSELINE can selectively stimulate different portions of the optic nerve cross-section.

III. Conclusion

We established two different methods to modulate the magnitude of the cortical response resulting from the electrical stimulation, which coupled with the results of the blind-source separation analysis make electrical stimulation of the optic nerve a relevant and promising approach for vision restoration in blind patients. Additionally, we showed the possibility to use a current focusing to have a more targeted stimulation, and intend to investigate other field-shaping strategies to further improve the selectivity and resolution of the OpticSELINE.

References

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