Restoring lost communication between in vitro neuronal assemblies

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***Abstract* — Neural stimulators and implantable systems represent one of the most promising technologies to reduce neurological impairments. Here we present a promising prosthesis prototype capable to restore the communication between damaged *in vitro* neuronal circuitries.**

I. Introduction

Enhancing recovery of cognitive and motor functions after localized brain injuries is widely recognized as a priority in healthcare. Millions of people worldwide are affected, and this number is likely to increase in coming years [1]. Moreover, the frequent lack of complete recovery makes a desirable goal the development of novel technologies and therapeutic strategies aiming at improving quality of life of affected patients when standard pharmacological treatments and/or physical rehabilitation therapies are not enough [2].

A new hope was provided by engineering studies in the field of neural interfaces [3]. Here we realized an in vitro proof-of-concept for next generation brain-prostheses aimed at restoring lost communications among neuronal populations by providing an artificial link between two previously connected assemblies.

II. Methods

The biological element used in this study is constituted by dissociated cortical rat neurons plated over a 60-channel Micro-Electrode Array (MEA) device. We used engineered neuronal networks constituted by two isolated modules linked through long-range axonal connections. These networks were able to exhibit synchronized activity events involving both modules named Network Bursts (NB). During experiments we performed a focused laser ablation to cut the connections between modules to mimic a traumatic brain injury. A neuromorphic board based on Field Programmable Gate Array was specifically designed to perform real-time event detection (e.g. NB detection) and trigger electrical stimulation to one or more electrodes in a closed-loop fashion (i.e. 'bridging' modality).

III. Results

A low-frequency regular stimulation (0.2 Hz) was delivered to an electrode belonging to one of the two modules and the response propagated to both modules. After a focal lesion, the two modules resulted both anatomically and functionally disconnected. We then performed two kinds of 'reconnection' strategies: unidirectional (i) and bidirectional (ii) bridging.

In case of protocol (i), a low frequency regular stimulation (0.2 Hz) was delivered to the first module and a bridging from the first to the second module was performed. The post-stimulus time histogram upon regular stimulation confirmed that the directed communication from the stimulated module to the other one was restored. The aim of protocol (ii) was to offer an artificial communication channel between the disconnected modules without imposing any preferred direction. The cross correlation between the activity of the two modules confirmed the partial restoration of the communication between the disconnected modules.

IV. Conclusions

Our neuromorphic board is able to put in uni- and bidirectional communication two previously connected and then disconnected neuronal networks. The developed communication protocol can be seen as an interesting starting point towards the development of a stand-alone neuroprosthetic device able to restore communication between disconnected brain regions.

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