Control theory for neural synchrony: modeling based on optogenetics data, anda closed-loop alteration of pathological brain oscillations

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Name of Fellow

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Institution
Funder

ANR

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Country

France

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Control theory for neural synchrony: modeling based on optogenetics data, anda closed-loop alteration of pathological brain oscillations

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3.5

The project/programme is most relevant to:

Parkinson's disease & PD-related disorders

Keywords
Research Abstract
Neuronal synchronization plays a central role in brain functioning. For instance, it is linked to

memory, cognition and movement path generation. Abnormal synchronization in certain cerebral zones can also lead to pathological states such as Parkinson disease, essential tremor, epilepsy, or akinesia symptom. Deep brain stimulation (DBS) is a symptomatic treatment of several synchronization-related neurological diseases. It consists in an electrical stimulation of deep brain structures through a permanently implanted electrode.
Although DBS is a successful treatment for Parkinson disease, it still suffers from considerable limitations. In most existing DBS techniques, the stimulation is a square signal whose parameters are derived primarily by trial-and-error on each patient. It operates in open loop: no cerebral information or models of the dynamics involved are exploited. This leads to over-stimulation of the targeted brain structures and, by electrical diffusion in the tissue, to the stimulation of other zones. This has strong impact in terms of side effects and energy consumption, and precludes DBS optimization. In addition the mechanisms underlying neuronal synchronization, and its subsequent dysfunctions, are still poorly understood. An analytical study of the phenomena involved could therefore pave the way to a deeper understanding of brain functioning within basal ganglia and to the development of more adequate DBS strategies.
SYNCHNEURO gathers an interdisciplinary team of researchers to address four ambitious challenges: 1) the development of an experimentally identified firing-rate model of non-human primates basal ganglia under photostimulation; 2) the formal analysis of pathological oscillations onset based on this model; 3) the development of innovative closed-loop DBS strategies, yielding to more efficient and more parsimonious stimulation; 4) the in vivo validation of the developed DBS signals.
Two breakthroughs have recently made these ambitious objectives reachable. SYNCHNEURO’s partners have contributed to both of them. The first one is of an experimental nature and concerns the control of basal ganglia neurons in non-human primates by optogenetics techniques: SYNCHNEURO will be the first project worldwide to exploit such data, both on healthy and parkinsonian monkeys. The second one is of a theoretical nature and concerns the analysis of interconnected nonlinear systems: : recent advances in the stability and synchronization of nonlinear systems (possibly with delays) provide an integrative way of analyzing the basal ganglia interaction.

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