Host laboratory:
CRNL
Inserm, 18 Avenue du Doyen Jean Lepine, 69500 Bron
(Site of the "Hopitaux Est")

Host team :
Neurobiology of Executive Functions
https://sbri.fr/teams/neurobiology-of-executive-functions/
(Note that the team is moving institutes in 2027, but will remain in the same physical location)

Internship supervisor :
Charlie Wilson, CRCN, Charles.wilson@inserm.fr

Project title :
Computational mechanisms of learning to learn and motivation.

Project summary :

We know a lot about the brain's processes of basic learning, and there is a rich array of modeling approaches that capture learning, perhaps most influentially reinforcement learning models. But a separate process, learning to learn or learning set, allows our learning to become more efficient and flexible through repeated learning experience. This is what happens when we engage in **cognitive training** – be it in education or in general life – so that our learning and decision-making become well adapted.

The neural and computational bases of learning to learn are becoming an important topic in both computational/AI fields and neuroscience (e.g. Wang et al 2018), yet there remains much to be understood. In our team we study this using learning protocols and neurophysiological recordings in macaque monkeys, mainly recording in the prefrontal cortex that we have been shown to be critical to this function (Wilson & Gaffan 2008). We are interested in what happens – computationally and neurally – to render learning more efficient, and how other factors, in particular individual motivation – impact this process.

The proposed internship project will have two principal goals.
The first goal is to build a model of how monkeys learn in a specific task, and how that learning improves over time. An important aim will be to incorporate into that model factors that could explain (1) the improvement in learning *over time* of the animals, and (2) the impact of *motivation* within and between sessions on that learning. The model performance can eventually be compared to actual learning data from monkeys. Importantly, there are already modelling solutions for such tasks that can aid this process, but they have been applied to already acquired performance on these tasks – the key element here would be to describe the **acquisition** of that learning through a model.

The second goal would be to take parameters from this model and seek neural correlates of them in an existing large dataset of neurophysiological recordings of macaques acquiring the tasks, using computationally inspired data analysis techniques.

Please send your proposal to matteo.divolo@univ-lyon1.fr for publication on the Master of Neuroscience website.
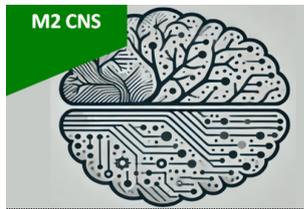
The way in which this project is developed can be tailored, through discussion, to the specific interests of the intern. Several factors of interest could be modelled. For example:

- Motivation modifies both PFC neural activity and progression in cognitive training dynamics (Botvinick & Braver 2015). We are interested in the computational basis of this, and colleagues have begun to try and model this sort of effect (Grohn et al 2024).
- Uncertainty of feedback and outcomes is an important factor in the way tasks are acquired (Faraut et al 2016).

This is therefore a **fundamental research project**, but the understanding it will bring should have important **clinical implications -** for example cognitive training forms a critical part of remediation strategies in learning impairments as well as recovery from brain injury, and changes in PFC dynamics are implicated in a range of pathologies including ADHD and OCD, as well as in aging.

M2 interns will be able to interact with experimentalists during the internship, and if they wish they can experience elements of a monkey neurophysiology project in addition to their computational work. We work hard to give a good internship experience that covers the whole process of our research, and potential candidates are encouraged to contact previous interns to discuss. The data and the analysis approaches are highly promising. There is certainly the potential for a motivated student to obtain a publication from the work in the internship.

Relevant publications from the team:

Wilson C.R.E., Gaffan D. (2008) Prefrontal-inferotemporal interaction is not always necessary for reversal learning. Journal of Neuroscience 28(21):5529-38. https://doi.org/10.1523/JNEUROSCI.0952-08.2008

Browning PG, Easton A, Gaffan D. (2007) Frontal-temporal disconnection abolishes object discrimination learning set in macaque monkeys. Cereb Cortex. Apr;17(4):859-64. https://doi.org/10.1093/cercor/bhk039

Faraut, M. C. M., Procyk, E., & Wilson, C. R. E. (2016). Learning to learn about uncertain feedback. *Learning & Memory (Cold Spring Harbor, NY)*, 23(2), 90–98. http://doi.org/10.1101/lm.039768.115

Other references:

Botvinick, M., & Braver, T. (2015). Motivation and Cognitive Control: From Behavior to Neural Mechanism. *Annual Review of Psychology*, 66(1), 83–113. http://doi.org/10.1146/annurev-psych-010814-015044

Wang JX, Kurth-Nelson Z, Kumaran D, Tirumala D, Soyer H, Leibo JZ, Hassabis D, Botvinick M. Prefrontal cortex as a meta-reinforcement learning system. Nat Neurosci. 2018 Jun;21(6):860-868. doi: 10.1038/s41593-018-0147-8. Epub 2018 May 14. PMID: 29760527.

Grohn J, Khalighinejad N, Jahn CI, Bongioanni A, Schüffelgen U, Sallet J, Rushworth MFS, Kolling N. General mechanisms of task engagement in the primate frontal cortex. Nat Commun. 2024 Jun 5;15(1):4802. doi: 10.1038/s41467-024-49128-w. PMID: 38839745; PMCID: PMC11153620.

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