Physics for Medicine Paris
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PhD position: Multimodal brain decoding

Physics for Medicine, Paris

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Context

Brain-machine interfaces (BMIs) are transforming the possibilities for patients with severe neurological disorders, enabling direct communication with the brain to restore lost functions such as movement, speech, and sensory perception and closed-loop modulations. This thesis is part of a project centered on exploring and developing the next-generation hybrid read-only Brain Machine Interface (BMI) framework in a preclinical setting, with a focus on high performance and progressively reduced invasiveness.

Accurate brain decoding generally requires brain activity recordings via the insertion of electrodes deep into the brain, which make it highly invasive and unsustainable across time. In this context, high-resolution functional ultrasound imaging (fUSI) is emerging as a promising candidate for brain activity measurement, as it provides real-time information about neural activation in a large volume including deep brain regions, and has already demonstrated its applicability to decoding behaviour from cerebrovascular patterns. However, fUSI currently involves invasive procedures to overcome the obstacle of the human skull, and therefore appears complementary to other recording approaches such as ECoG and EEG, which offer lower invasiveness but inferior decoding accuracy.

The aim of this PhD project is to build a first multimodal preclinical BMI combining fUSI and ECoG, following the specific objectives below:

Objectives

O1: Design and validate a minimally invasive fUSI set-up using biocompatible sonolucent materials to replace a section of skull bone as a chronic acoustic access pathway

- characterize candidate sonolucent materials and probe geometries for acoustic transmission, attenuation, phase aberration, reverberation, and frequency-dependent effects

- design a specific implant geometry based on an MRI-guided plan
- fabricate implant prototypes (3D printing + machining by an external supplier)
- validate fUSI imaging quality through the implant material versus water-only reference
- perform first in vivo test for fUSI signal quality and validate chronic imaging.

O2: Build a hybrid fUSI/ECoG system

- assess electromagnetic and acoustic compatibility between fUSI acquisition and ECoG recording
- test electrode placement configurations and integration with sonolucent materials using phantoms
- validate the combine imaging in a preclinical setting

O3: Train and validate a machine learning model decoding cognitive behaviour from the combination of fUSi and ECoG signals.

- Build a multimodal dataset from hybrid recordings
- Implement several candidate DL architectures
- Test on available data and select the optimal configuration

We are looking for a candidate with a strong background in acoustics, and an interest in both experimental work and deep learning.
Please send your CV and cover letter to thomas.deffieux@inserm.fr, and beatrice.walker@inserm.fr