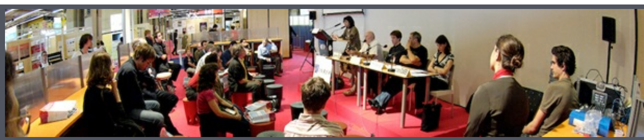
INVENTEURS DU MONDE NUMÉRIQUE

INTERNATIONAL RELATIONS



INTERNSHIP SUBJECT

2870 - Uncovering Higher-Order Brain Dynamics Across Consciousness Sta

The brain is a paradigmaic example of a complex system: it comprises billions of interconnected neurons whose dynamic interactions give rise to emergent phenomena such as perception, cognition, and consciousness. These global functions cannot be directly inferred from the activity of individual neurons alone. Functional magnetic resonance imaging (fMRI) offers a powerful lens through which to explore this complexity, by capturing large-scale patterns of brain activity and connectivity.

Traditionally, analyses of fMRI data have focused on pairwise functional connectivity—statistical correlations between signals from different brain regions. This approach has enabled the application of linear algebra and network theory to characterize brain organization, leading to significant insights, particularly with the emergence of large, high-resolution neuroimaging datasets.

However, a growing body of evidence indicates that brain function also relies on *higher-order interactions*—coordinated activity among three or more regions that cannot be fully explained by any set of pairwise relationships. These higher-order dependencies are thought to play a key role in integrative processes such as multisensory integration, complex cognition, and the modulation of states of consciousness.

By modeling triplets, quadruplets, and more general high-order patterns of co-activation, researchers can better capture the nonlinear and synergistic properties of brain dynamics. Such models not only offer a more faithful representation of neural coordination, but also uncover features and mechanisms that remain invisible when analysis is restricted to pairwise interactions.

In this project, we seek to characterize higher-order functional interactions across different states of consciousness—including wakefulness, general anesthesia, and psychedelic-induced states—using fMRI data.

We will do so by using the recently developed software THOI: an efficient and accessible library for computing higher-order interactions enhanced by batch processing. THOI leverages the well-established *Gaussian copula* method for joint entropy estimation, combined with state-of-the-art batch and parallel processing techniques to optimize performance across CPU, GPU, and TPU environments. This enables scalable and high-throughput analysis of high-dimensional neuroimaging data, making it ideally suited for large fMRI datasets spanning multiple states of consciousness.

Required Skills

The ideal candidate for this project should possess strong quantitative and computational skills, with a background in computer science or a related field. Proficiency in Python is essential, particularly with libraries commonly used in scientific computing such as NumPy, SciPy, and Pandas. While prior experience with functional connectivity analysis and complex systems is not required, it will be considered an advantage. Familiarity with information-theoretic approaches—especially joint entropy estimation and Gaussian copulas—will be highly valued.

Due to the computationally intensive nature of this project, experience with parallel computing, GPU/TPU environments, or batch processing pipelines is desirable. The candidate should be comfortable learning and working with specialized tools such as THOI, demonstrate strong problem-solving skills, and be able to work both independently and as part of a collaborative research team.

General Information

- **Research Theme :** Computational Neuroscience and Medicine
- **Locality :** Sophia Antipolis
- **Level :** Master
- **Period :** 5th January 2026 -> 4th March 2026 (2 months)

  These are approximative dates. Please contact the training supervisor to know the precise period.

- **Deadline to apply :** 1st July 2025 (midnight)

Contacts

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- **Team Manager :** Theodore Papadopoulo / Theodore.Papadopoulo@inria.fr

More information

- **Inria Team :** CRONOS
- **Inria Center :** Centre Inria d'Université Côte d'Azur