

Brain network dynamics in task and disease

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The brain dynamically recruits networks of interacting brain regions to perform tasks. Intriguingly, these same networks can also be seen activating spontaneously in ongoing brain activity. Advancing our understanding of these brain networks and their relationship with cognition is currently a major area of study in fundamental and clinical neuroscience research.

We are developing computational methods that advance our ability to infer brain networks and their dynamics by intelligently using information from different brain imaging modalities (fMRI, MEG (including the use of our new, ground-breaking OPMMEG scanners, EEG and invasive electrophysiology). We have potential research projects building state-of-the-art machine and deep learning techniques in several areas, including:

- 1) **Fast brain network dynamics:** These are *interpretable* generative models that describe large-scale cortical activity as time-varying brain networks. We use HMM's in combination with advances from deep learning, to understand both the healthy and disease brain. E.g. see <https://elifesciences.org/articles/91949>.
- 2) **Deep generative, foundational models of brain activity:** Analogous to large language models, these powerful models of how brain activity varies over time, space and individuals can be fine-tuned to perform downstream tasks: including brain decoding of cognition, behavioural traits and disease. We make use of both Transformer and Mamba Decoder architectures. E.g. see <https://doi.org/10.1162/IMAG.a.1301>.
- 3) **Cognitive cycles of internal and external cognition:** We are developing a modelling framework to describe ongoing brain activity using a "cognitive cycle". This is a recurrent architecture where internal (thinking) and external (attention) networks rapidly alternate. We are using computational models (deep reinforcement learning and the models from 1 and 2 above) in combination with behavioural and brain imaging data. E.g. see <https://www.nature.com/articles/s41593-025-02052-8>.

These research projects would primarily be carried out at OHBA (<http://www.ohba.ox.ac.uk>), which is part of the Oxford centre for Integrative Neuroscience (OXCIN - <https://www.oxcin.ox.ac.uk>).