Brain network dynamics in task and disease

The brain dynamically recruits networks of interacting brain regions in order to perform tasks. Intriguingly, these same networks can also be seen activating spontaneously in on-going 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 new, ground breaking MEG scanners - https://www.nature.com/articles/nature26147)), EEG and invasive electrophysiology). We have potential research projects building state-of-the-art machine and deep learning techniques in a number of areas:

1) Spatial inference of graph/network structures: developing methods that account for differences over subjects in the spatial location of network nodes and in network structure, using hierarchical Bayesian models.

2) Inferring brain network dynamics across a hierarchy of time-scales: capturing how networks exhibit sequential patterns of activity over time, using recent advances in HMMs (see http://www.nature.com/nrn/journal/v15/n5/full/nrn3738.html), and deep learning (e.g. LSTMs, temporal convolutional neural networks, Wavenets).

3) Biophysical modelling of brain network dynamics: combining knowledge of the anatomical (white matter) connectivity, with models that capture the dynamic behaviour of neuronal populations within the grey matter.

Computational methods and measures derived from these different research areas can then be combined with supervised learning methods to predict the dynamics in experimental tasks, in cognition and disease states.

These projects require the development and use of artificial intelligence (AI), machine learning and deep learning techniques. Students will need good mathematical/engineering and computing skills, and through the project will acquire a strong set of skills in the areas of image and signal processing, Bayesian inference, AI and machine/deep learning.

These research projects would also be part of a collaboration between the OHBA analysis group (http://www.ohba.ox.ac.uk) and the FMRIB analysis group (http://www.fmrib.ox.ac.uk), as part of the Wellcome centre for Integrative Neuroscience (WIN - https://www.win.ox.ac.uk).