MEG/EEG/TMS

Non-invasive human neurophysiology hub at CFIN

by Yury Shtyrov

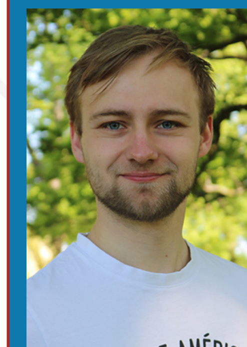
Unlike fMRI and PET – spatially precise but temporally poor methods that measure brain activity based on blood flow and metabolism – the techniques on this page tackle electrophysiological activity of neural cells directly. Both electroencephalography (EEG) and magnetoencephalography (MEG) can monitor human brain activity with sub-millisecond temporal precision. Using these techniques, mass neuronal activity of large ensembles of cells in the brain can be tracked in time and space, profiled for its frequency make-up and for synchronization of various networks across the brain. Transcranial magnetic stimulation (TMS) can, in turn, target focal cortical areas with strong magnetic pulses, using anatomically precise navigation to noninvasively disturb/enhance neuronal functionality at precisely defined times, which allows making inferences about causal involvement of specific brain structures in behaviour and cognition.

Following the move of all experimental and clinical neuroimaging facilities to the new Aarhus University Hospital location in Skejby, human neurophysiology techniques at CFIN have seen a major boost to their functionality and use. Various improvements to the data acquisition and stimulation procedures, lab setup and work space have been introduced. MEG, EEG and TMS labs were consolidated under the same management as part of the same 'hub' at our CFIN North compound. In addition to electromagnetic shielded room for MEG, a new purpose-build shielded room was built during 2020-21 to enable higher-quality EEG recordings, with an added provision for running combined TMS-EEG studies, sleep-EEG experiments, as well as hyperscanning studies with EEG recordings carried out simultaneously in two individuals (e.g., during communication, musical performance or other joint activities). The latter can be done both in the same shielded room or, if needed, in two separate cubicles, where behavioural data can also be collected. All facilities are located very close to each other and to CFIN's MRI scanners, enabling integrated multimodal studies that can seamlessly use multiple neuroimaging methods in one session (for an example, see TMS-DKI study in NeDComm Lab contribution to the annual report).

The centrepiece of this facility is our MEG laboratory, hosting one of our key brain imaging resources. CFIN's MEG Lab is the first installation of its kind in Scandinavia, and the only one in Denmark. It houses a Triux™ device (Megin Oy, Finland), which incorporates 306 MEG sensors of different types, 128 EEG channels and various other data outputs, capable of yielding the most accurate spatial-temporal image of the brain activity currently possible. It also boasts another first – a zero-boiloff liquid helium recirculation system, which ensures its economical use independent of irregularities in cryogen supplies. The MEG technique registers brain activity by contactless recordings of miniscule magnetic fields generated by electric currents, which are, in turn, produced by cortical neurons. These tiny magnetic fields are picked by the so called super-conductive quantum interference devices (SQUIDs), sophisticated miniature sensors, distributed around a person's head in a helmet-shaped device and kept at super-low temperatures near the absolute zero using liquid helium. As the magnetic fields freely permeate through human tissues and air, there is no need for a solid conductor between the head and the measuring device, which makes MEG recordings easy, convenient and time-efficient. The technique is entirely non-invasive and does not involve any currents, fields or pharmacological substances. Its operation is completely silent with participant seated in a comfortable chair in a spacious magnetically-shielded room. This makes MEG the most patiently-friendly technique for investigating neural processes without the need to be confined in a noisy narrow environment of an MR scanner or to go through other uncomfortable and intimidating procedures. Unsurprisingly, our MEG lab is heavily used by clinicians at Aarhus University Hospital, most importantly for pre-surgical mapping in epilepsy patients, and for experimental studies aimed at understanding neurological deficits in various diseases (see, for example, our MEG research on Parkinson's disease in the NeDComm Lab contribution).

Following the difficult times of the COVID-19 pandemic, when recordings continued in spite of various restrictions, we continue to see an influx of new users and new research projects. This includes large-scale projects on music perception, sleep, schizophrenia and bipolar disorder, epilepsy, vision, language, consciousness disorders, Parkinson's disease, etc, etc. We continue to develop tools and algorithms for MEG and EEG data analysis, contributing to the international development of open-source scientific software. Furthermore, CFIN scientists are actively involved in developing next-generation MEG systems based on optically-pumped magnetometers (OPMs), which do not use superconductivity and thus do not need liquid helium and thermal insulation (see inset). OPM MEG is a rapidly developing technology that will allow for much more flexible recordings, including wearable MEG, foetal, spinal and retinal recordings, higher spatial resolution, etc., and we are proud to be part of these new developments (see OPM research in the NEMOlab contribution to the annual report).

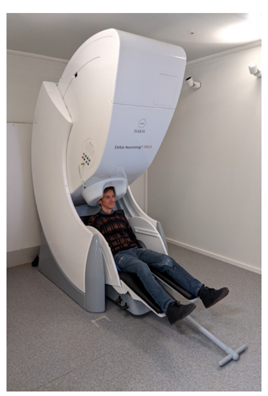
NEW FACE at CFIN

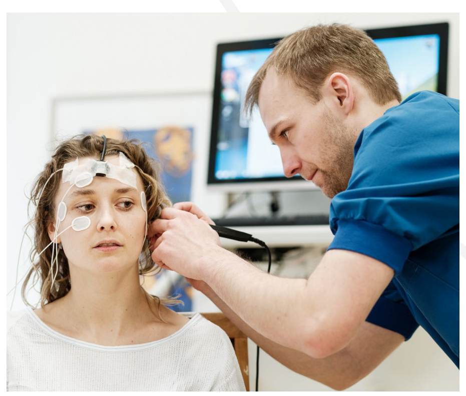


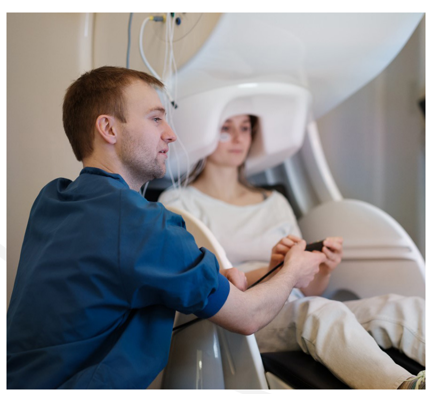
Oskar Hougaard Jefsen joined CFIN in 2021 as a PhD student supervised by Professor Yury Shtyrov and co-supervised by Assistant Professor Martin Dietz (CFIN), Professor Ole Mors (AUH – Psychiatry), and Karl Friston (University College London). Oskar graduated as a medical doctor from Aarhus University 2021 and has been engaged in both preclinical and epidemiological research in the field of psychiatry. Oskar is employed at the Psychosis Research Unit at the psychiatric department at Aarhus University Hospital.

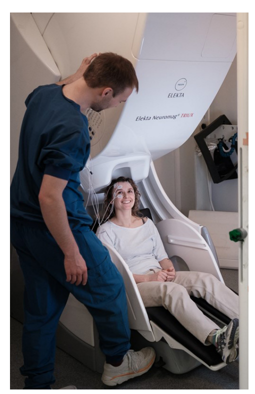
As a PhD student, Oskar applies magnetoencephalography and dynamic causal modeling (DCM) to study neural alterations in children at familial high risk of schizophrenia and bipolar disorder, as part of the large nationwide study 'The Danish High Risk and Resilience Study – VIA'. The aim of Oskar's PhD project is to identify prodromal biomarkers of psychosis that may both have predictive value and reveal pathophysiological mechanism of psychosis-development.

Besides looking at brains, Oskar is a music teacher, choir leader, and a lead singer in a party-band.









MEG, EEG and TMS at CFIN North, Skejby
Photos: James Lubell and Jesper Voldgaard