UNIVERSITY OF BIRMINGHAM | CHBH CENTRE FOR HUMAN BRAIN HEALTH

CENTRE FOR HUMAN BRAIN HEALTH

ANNUAL REPORT 2020

The Centre for Human Brain Health (CHBH) has world-leading expertise in attention, memory, sleep, neuronal oscillations and multi-modal research.

The Centre works with industry partners on the development of new technologies, as well as improving the understanding of how brain health contributes to wellbeing.

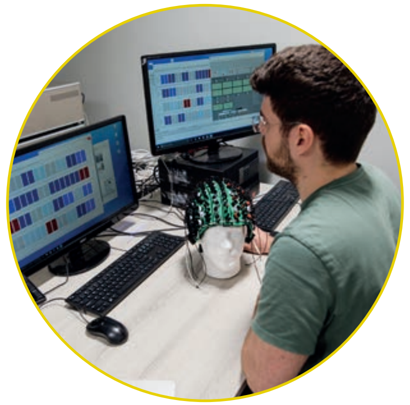
Co-Directors

Professor Ole Jensen
Professor Ole Jensen is a leading expert on neuronal oscillations in humans and animals. In 2016, he received the Royal Society Wolfson Research Merit Award and in 2018 the Joseph Chamberlain Award for Academic Advancement at the University of Birmingham. Professor Jensen's research is funded by a Wellcome Trust Senior Investigator award, the James S. McDonnell Foundation, the BBSRC and several EU Horizon 2020 Marie Curie fellowships.

Dr Andrew Bagshaw
Dr Bagshaw's main interest is in developing and applying non-invasive neuroimaging methods to questions in clinical and behavioural neuroscience. His current work in the Multimodal Integration Group (MIG) focuses on using EEG-fMRI to understand the influence of ongoing brain activity on evoked and behavioural responses, and to examine the localisation and functional significance of electrophysiological discharges in epilepsy and sleep. The group is also working on methods to combine structural and functional brain networks in order to shed light on how sleep and epilepsy affect the brain.

CENTRE FOR HUMAN BRAIN HEALTH

The Centre for Human Brain Health (CHBH) is a leading interdisciplinary brain research facility established with the mission of understanding the fundamental mechanisms of the human brain as well as understanding what makes a brain healthy, how to maintain it, and how to prevent and reverse damage.



Our vision is to cross the boundaries of traditional academic and clinical disciplines to transform our understanding of the human brain. We recognise that to achieve the goal of personalised brain health we must first identify what constitutes a healthy brain and how lifestyle, developmental and societal factors interact and contribute to this endeavour.

~£22 million
of funding generated since CHBH's inception

The CHBH is an ever-growing neuroscientific community, which currently comprises 47 principal investigators; including 14 professors, 5 readers, 12 senior lecturers and supported by groups of dedicated post-doctoral researchers and PhD students.

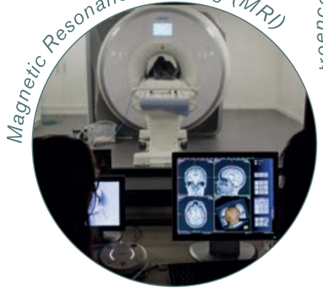
Since its inception, CHBH has generated ~£22 million of funding from a wide range of sources, including:

- Alzheimer's Research UK
- Baily Thomas Charitable Fund
- Biotechnology and Biological Sciences Research Council (BBSRC)
- BRIDGE – Birmingham-Illinois Partnership
- Early Postdoc Mobility
- European Research Council (ERC)
- Economic and Social Research Council (ESRC)
- European Commission Marie Curie Fellowships
- Facebook Enterprise
- Greater Birmingham Enterprise Partnership
- Guangzhou Municipal Hospital
- James S. McDonnell Foundation
- Leverhulme Trust
- Medical Research Council (MRC)
- NIH-NINDS
- Templeton World Charity Foundation
- The Royal Society
- The Waterloo Foundation
- The Wellcome Trust
- The Wellington Hospital – HCA Healthcare
- The Wolfson Foundation

Areas of specialism

The Centre is home to state-of-the-art brain imaging facilities, which are used to uncover the mechanisms supporting cognition in both the healthy and the dysfunctional brain. These include:

- **Magnetic resonance imaging (MRI)** laboratory, providing a range of options for stimulus delivery and physiological and behavioural recordings
- **Magnetoencephalography (MEG)** laboratory, which allows for continuous recordings of ongoing brain activity with a millisecond time resolution and advanced analysis tools to identify where in the brain the measured electrophysiological activity is generated
- **Electroencephalography (EEG)** laboratory, a high-performance EEG laboratory for accurate timing and application of auditory and visual stimulation (concurrently or separately)
- **Sleep laboratories**, equipped with 64-channel EEG amplifiers and peripheral equipment for experimental testing and stimulus delivery
- **Functional Near Infrared (fNIRS)** laboratory, housing the Imagent (v2) system that allows non-invasive functional imaging of the brain
- **Optically Pumped Magnetometer (OPM)** laboratory, where we are developing new sensors to be used for magnetoencephalography (MEG) using quantum technology
- **Non-Invasive Brain Stimulation** laboratory, housing all the equipment required for both transcranial magnetic (TMS) and electrical (TES) non-invasive brain-stimulation experiments
- **Exercise Laboratory**, working across various modalities, studies examining acute and longer term effects of exercise on brain health



Industrial partners
Our partners include HSBC, Facebook, P1vital, Oculus, Obi-Robotics and Neuroelectrics (Barcelona).

We have strong links with many hospitals, including: Queen Elizabeth Hospital Birmingham, The Barberry National Centre for Mental Health, Birmingham Women's and Children's, Moseley Hall Hospital, Royal Leamington Spa Rehabilitation Hospital, Wellington Hospital HCA Healthcare UK and Heartlands Hospital.

> **Our collaborations with local hospitals mean we're well placed to use our techniques and expertise to help develop fundamental insights into brain disorders, and a deeper understanding of what it means to have a healthy brain.**
>
> *Dr Andrew Bagshaw*

Quantum Hub Connection

The Optically Pumped Magnetometers (OPM) facility is based on a collaboration between the School of Psychology and the School of Physics and Astronomy. Furthermore, we are working with the UK Quantum Technology Hub for Sensors and Timing to maximise the potential economic benefit from our developments and aid the translation of the technology to UK industry. The Quantum Hub for Sensors and Timing provides an ideal pathway for applications, given the 70 industrial partners interested in developing and commercialising innovative quantum technologies.

RESEARCH HIGHLIGHTS

Researchers at the CHBH have published a large number of papers in renowned international journals, these research highlights are just a few.

Dr Ian Charest

Senior Lecturer in Psychology

Our brains are constantly bombarded with sensory information coming from the environment. In order to make sense of the world the brain needs to prioritise certain information, leaving us unaware of most things in our surroundings. But how could the brain favour access to some information in our consciousness at the cost of other information remaining unconscious?

To better understand what kind of visual information in images of natural scenes reaches consciousness, we used a combination of well-established experimental psychology paradigms and state-of-the-art computer vision algorithms.

Our results show that different semantic categories of objects seem to have different propensities to reach conscious awareness. We also showed that high-level visual features explain these differences between categories best.

Revealing the mechanisms supporting conscious access in brain and behaviour advances our understanding of the healthy brain, and has potential implications for our understanding of disorders of consciousness.

Lindh D., Sligte I.G., Assecondi S., Shapiro K.L., Charest I (2019). Conscious perception of natural images is constrained by category-related visual features. *Nature Communications*, 11;10(1):4106.

Dr Elise Facer-Childs

Translational Fellow, Biosciences

Would students and employees be more productive if schools and workplaces allowed more flexibility in their hours?

We were able to show that the brain function of very late risers 'night owls' and early risers 'morning larks' differs during the working day. Tests (functional MRI, subjective sleepiness and cognitive performance) performed between 8.00am and 8.00pm on both groups, found that night owls had relatively less connectivity in brain regions linked to maintaining consciousness; they had poorer attention, slower reactions and increased sleepiness. This suggests that night owls would be disadvantaged by the 'constraints' of the typical working day. Night owls are constantly having to fight against their preferences and their innate rhythms.

There is a critical need to better understand how adapting to school and work times, to which people are not suited, may be affecting health and productivity. Increasing flexible work and study options could go a long way towards maximising productivity and minimising health risks.

Facer-Childs E.R., Campos B.M., Middleton B., Skene D.J., Bagshaw A.P (2019). Circadian phenotype impacts the brain's resting-state functional connectivity, attentional performance, and sleepiness. *Sleep*, 1;42(5).

RESEARCH HIGHLIGHTS
(CONTINUED)

Electroencephalography (EEG)

Magnetic Resonance Imaging (MRI)

Dr Davinia Fernández-Espejo
Senior Lecturer in Psychology

Due to improvements in intensive care many patients survive the most severe brain injuries, and progress to chronic states of disordered consciousness, known as the vegetative and the minimally conscious state. Recent research has shown that some of these patients retain a much higher level of cognitive function than could be expected by their clinical diagnoses – but they remain unable to demonstrate this with external responses, trapped in their unresponsive bodies.

The study that I led, based at the CHBH, pinpointed what happens in the brain to cause this unresponsive behaviour. Specifically, we demonstrated that damage to the white matter fibres that connect regions of the brain involved in the control of voluntary movement, can lead to reduced responses in vegetative and minimally conscious patients – suggesting that standard clinical diagnosis underestimate the level of retained cognitive function in these patients, and providing for the first time a potential target for treatment.

Stafford, C.A., Owen, A.M., Fernández-Espejo, D. (2019). The neural basis of external responsiveness in prolonged disorders of consciousness. *Neuroimage: clinical,* 22, 101791.

Benjamin Griffiths
Doctoral Researcher in Psychology

What's our brain up to when we're watching the latest block-buster movie, or listening to our favourite music on the daily commute? We recorded participants' brain activity with fMRI and EEG while they watched short film clips or listened to brief melodies. Using machine learning to detect and decode the fMRI data, we found that neural activity in the EEG appeared to 'desynchronise' when participants' processed more details about the film clips or melodies. This suggests that desynchronisation of neural activity marks the processing of sensory information within the brain. Knowing this, desynchronisation could potentially be used to indicate whether someone is engaging with a task or not; providing useful feedback on how effective their learning and retention may be.

Conceivably, by incorporating our findings with recent advances in brain stimulation, we may also be able to artificially induce desynchronisation in individuals with memory difficulties. This has the potential to help them remember old, or create, new memories.

Griffiths B.J., Mayhew S.D., Mullinger K.J., Jorge J., Charest I., Wimber M., Hanslmayr S. (2019). Al-pha/beta power decreases track the fidelity of stimulus-specific information. *eLife,* 29;8.

Dr Ned Jenkinson
Senior Lecturer in Sport, Exercise and Rehabilitation Sciences

There is an increasing recognition of the significant non-motor symptoms that burden people with Parkinson's disease. There is a pressing need to better understand and investigate the mechanisms underpinning these non-motor deficits.

With this study, we provide the first strong evidence that the abnormal brain activity that has previously been implicated in the motor symptoms of Parkinson's disease, is also associated with non-motor symptoms. We found that people with Parkinson's showed impaired memory strength compared to age-matched controls, and the degree of impairment directly related to an inability to modulate beta-range brain activity during memory formation.

These findings provide important empirical evidence that should be considered in the development of intelligent next-generation therapies.

MacDonald H.J., Brittian J.S., Spitzer B., Hanslmayr S., Jenkinson N. (2019). Memory deficits in Parkinson's disease are associated with reduced beta power modulation. *Brain Communications*, Vol 1(1).

Dr Maria Wimber
Senior Lecturer in Psychology

Memory is one of the big mysteries in neuroscience, and very little is known about how the human brain reconstructs memories of past events.

We managed to track this mnemonic reconstruction process 'online', with millisecond precision, while our participants remembered images they had previously learned. We found that the brain tends to reconstruct visual memories in a systematic order, starting with the core meaning or 'gist' (eg, that it was an animal), and then working backwards to more specific visual details (eg, the animal's colour).

The study suggests that our memories are not simple snapshots of the past, but rather reconstructions that are heavily biased towards our own interpretations of the world. These results have the potential to help us understand a range of real-life phenomena, including false memories, and over-generalised fear memories in post-traumatic stress disorder.

Linde-Domingo J., Treder M.S., Kerrén C., Wimber M (2019). Evidence that neural information flow is reversed between object perception and object reconstruction from memory. *Nature Communications*, 14;10(1):179.

RESEARCH HIGHLIGHTS
(CONTINUED)

Dr Bernhard Staresina
Birmingham Fellow, Psychology

When looking at a picture of a sunny day at the beach, we can almost smell the scent of sunscreen. Our brain often completes memories and automatically brings back to mind the original experience. A collaborative study between the University of Birmingham and the University of Bonn made an exciting discovery about the underlying mechanisms of this auto-complete function.

Computational models suggested that upon receiving a partial memory cue ('beach'), neurons in the hippocampus coordinate reinstatement of associated memories ('sunscreen') in cortical target sites. The similarity between recall and learning was so strong that a computer algorithm was able to tell which of the two associated items the participant had remembered.

Like a librarian, hippocampal neurons might provide pointers telling the rest of the brain where particular memories are stored.

Staresina, B. P., Reber, T. P., Niediek, J., Boström, J., Elger, C. E., & Mormann, F. (2019). Recollection in the human hippocampal-entorhinal cell circuitry. *Nature communications*, 10(1), 1-11.

Professor Rachel Upthegrove
Professor of Psychiatry and Youth Mental Health
Consultant Psychiatrist Early Intervention in Psychosis
Institute for Mental Health

Social and occupational impairments contribute to the burden of psychosis and depression. We were able to demonstrate, for the first time, that machine learning prediction models trained on clinical, neuroimaging and combined data can accurately determine social outcomes at one year in young people with emerging depression and clinical high-risk states. These models outperformed clinicians best-guess estimates showing the added benefit of Artificial Intelligence (AI) in healthcare.

The development of accurate prediction models for future social and occupational disability in individuals in clinical high-risk states of psychosis or with recent-onset depression could guide more effective personalised, precision medicine for mental health disorders that cause suffering to millions of young people.

Koutsouleris, N., Kambeitz-Ilankovic, L., Ruhrmann, S., Rosen, M., Ruef, A., Dwyer, D. B., ... Upthegrove, R. & Schmidt, A. (2018). Prediction models of functional outcomes for individuals in the clinical high-risk state for psychosis or with recent-onset depression: a multimodal, multisite machine learning analysis. *JAMA psychiatry*, 75(11), 1156-1172.

For more outstanding CHBH papers, search *Centre for Human Brain Health* at **https://research.birmingham.ac.uk**

> **The development of accurate prediction models… could guide more effective personalised, precision medicine for mental health disorders that cause suffering to millions of young people.**
>
> *Professor Rachel Upthegrove*

FUTURE RESEARCH

DEVELOPING OPTICALLY PUMPED MAGNETOMETERS FOR RECORDING HUMAN BRAIN ACTIVITY.

> **The outcome of our project will not only help to understand brain connectivity but could also advance stimulation treatment schemes in patients with specific neurological disorders, such as dementia.**

By Dr Anna Kowalczyk, Research Co-Investigator

Magnetoencephalography (MEG) is a non-invasive technique for imaging brain activity. Current flow produced by nerve cells generates small changes in the magnetic field outside the head. Highly sensitive magnetic field sensors are used to detect these small variations and three-dimensional images depicting moment-to-moment changes in brain current are then reconstructed using computational models.

Teaming up with cognitive neuroscientist, Professor Ole Jensen and atomic physicist, Dr Giovanni Barontini, we are setting up new laboratory facilities dedicated to the development of novel magnetic field sensors based on Quantum Technology. I am excited to be uniting these two disconnected communities; working towards breaking down the barriers that conventional MEG imposes. By collaborating with experts from psychology and affiliated institutes, together, we can investigate human brain mechanisms to better understand cognition and disease, achieving accelerated innovation in healthcare technologies.

In the OPM Lab we are developing new quantum sensors, Optically Pumped Magnetometers (OPMs), allowing us to investigate connectivity within the human brain. OPMs are currently among the most sensitive devices for measuring weak magnetic fields. They are capable of recording biomagnetic signals and have numerous applications in bioscience, as well as in geophysics, non-destructive testing, detection and fundamental physics.

Optically Pumped Magnetometers (OPM)

Magnetoencephalography (MEG)

OPMs record the absorption and dispersion of light passing through a glass cell filled with atoms. The properties of light change with the changes of magnetic field surrounding them (eg, magnetic fields generated by brain activity). The lab's first OPM sensor prototype will be ready to start testing on human subjects in 2020. Application of our novel sensors for MEG presents huge advantages and holds a strong promise; OPMs can be placed closer to the head enhancing signal quality.

Our team of physicists are working on developing so-called hybrid sensors that will allow new possibilities of combining MEG with other neuroscience methods. Sensors can be tailored to be compatible with different modalities. For example, our quantum magnetometers are capable of recovering within a few ms after a disturbance, opening up opportunities for measurements of the brain's reaction to a controlled magnetic or electric stimulus.

Our aim is to develop a prototype of an integrated stimulus-measurement system based on closed-loop bio-stimulation. The outcome of our project will not only help to understand brain connectivity but could also advance stimulation treatment schemes in patients with specific neurological disorders, such as dementia.

We are establishing collaborations with clinicians at Queen Elizabeth Hospital Birmingham, to tailor our sensors for applications that include neuromonitoring of Traumatic Brain Injury (TBI) or post-surgical neuroinflammation to predict patients at risk of developing postoperative cognitive dysfunction. In the future, our aim is to combine OPMs with functional Near-Infrared Spectroscopy (fNIRS) in collaboration with Professor Hamid Dehghani (CHBH). Adding fNIRS modality to OPM will allow us to gain information about patho-physiological changes due to functional activity or a concussion. Such hybrid OPM/fNIRS sensors have massive research and clinical potential, especially to study mild TBI.

My future vision for the research carried out in the OPM lab would be the development of advanced theranostic brain monitoring-stimulation devices for various brain disorder conditions. Individualised OPM devices would provide the basis for adaptive human interfaces operating as a specific brain interface with intelligent sensor-stimulation feedback, capable of restoring and/or supporting cognitive functions, detecting TBI, predicting postoperative cognitive dysfunction or treating dementia at an early stage.

Anna Kowalczyk testing the prototype for the first in-house OPM sensor developed at the CHBH

Engagement Highlights

PODCAST
@WCNEURO

The CHBH's very own PhD researcher, Wilf Nelson, set-up the *Water Cooler Neuroscience* podcast in 2018 as a means to '*...share stories that bust common myths from psychology and neuroscience...*'. Since its launch, Wilf has recorded two seasons of content encompassing interviews with over 15 world-renowned experts, hosted at events for the non-specialist and has won a number of funding awards from: the CHBH, Biochemical Society, Entrepreneurship and Innovation and UoB Public Engagement.

Image: mythosmedia.com

PINT OF SCIENCE FESTIVAL 2019
21–22 MAY 2019

Two of our Principal Investigators (PIs) were featured in the 2019 Pint of Science Festival, which advocates academic research for the non-specialist, connecting scientific researchers with the local community, in pub/café settings. Dr Sarah Aldred spoke at the Victoria pub about how diet and exercise can effect Alzheimer's risk factors, and Dr Katrien Segaert informed audiences at Cherry Reds Bar on how exercise improves the ageing brain's ability to recall words in 'tip-of-the-tongue' moments. **#pint19**

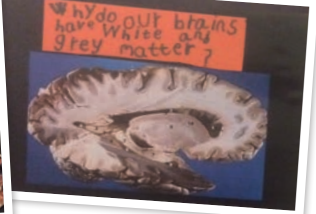
Image: pintofscience.co.uk

Launch of the Institute for Mental Health *(IMH) and* Centre for Human Brain Health *(CHBH)*

24–25 September 2019

This two-day event celebrated the opening of the IMH and CHBH and their key role in representing the University of Birmingham's world-leading interdisciplinary position at the forefront of local, national and international research into mental health and neuroscience. The launch hosted academic and clinical stakeholders through a range of keynote lectures delivered by world-leading experts, presentations and workshops delivered by early-career researchers and insight from the IMH's Youth Advisory Group.

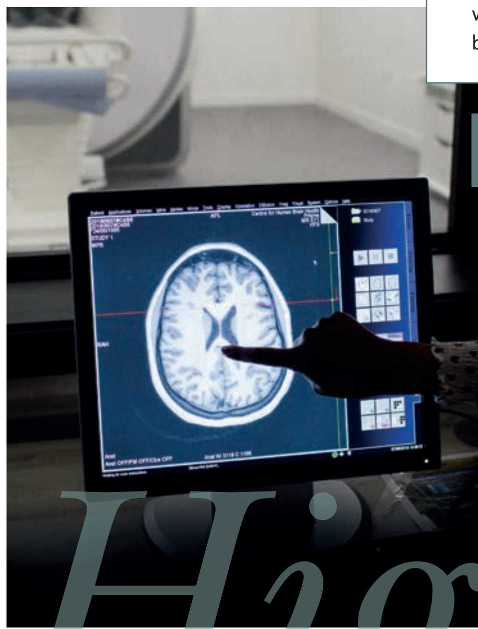
#LaunchIMHCHBH



Brain Awareness Week 2019

9–17 March 2019

The CHBH, and its predecessor Birmingham University Imaging Centre (BUIC), has a history of celebrating the annual *Brain Awareness Week.* From academic talks targeted at the University community to practical demonstrations for the non-specialist. 2019 was no exception, and featured lots of events, including the *Birmingham Brain Café*, in which leading brain researchers presented a series of talks and hosted Q&A sessions. The week itself was rounded off with a family-orientated day out at the museum: *Meet the Brain Experts* at Birmingham's ThinkTank Science Museum, where visitors of all ages and walks of life were encouraged to interact with all things brain-related. **#BrainAwarenessWeek**



WHAT MAKES A MURDERER

CHANNEL 4 DOCUMENTARY
NOVEMBER 2019

The CHBH's Siemens MAGNETOM Prisma 3T MRI scanner and Chief Radiographer Nina Salman were featured by documentary makers from Channel 4 during the biological and psychological investigations on three convicted murderers.

THE TRUTH ABOUT TAKEAWAYS
BBC DOCUMENTARY
MARCH 2020

Dr Maartje Spetter, Senior Research Fellow and alumna of the CHBH's Eating Behaviour Research Group, assisted BBC's Nikki Fox in her investigation of the UK population's neurological relationship with the Great British Takeaway!

WOMEN IN STEM: INSPIRING THE NEXT GENERATION

Many of our PIs, lecturers, postdoctoral and doctoral researchers are regularly involved in educational outreach, near and far. Doctoral Researcher Alice Winsor, Senior Lecturer Dr Davinia Fernández-Espejo and Lecturer Dr Renate Reniers are just a few of the researchers inspiring the next generation of women in STEM. Their recent educational presence has included visits and talks at various schools in the Midlands and further afield, including: Shenley Academy, St Michael's Primary School, Kings Norton Girls School, St Edmund Campion, Bournville Village Primary School and Colegio Público Poeta Juan Ochoa.

IMPACT ON **EDUCATION**

The CHBH has already had a far-reaching impact on the training of local and international undergraduates, postgraduates and postdoctoral researchers, across an array of disciplines. Students and researchers alike join a vibrant and active Centre; encouraging them to actively participate in seminars, lab meetings and wellbeing activities. Students can also be involved in a work experience scheme, introducing them to various imaging modalities, shadowing personnel and assisting with research support work.

University of Birmingham undergraduate students interact with the CHBH through multiple avenues:

- As participants in research projects across the modalities.
- As volunteer lab assistants to the researchers on various projects.
- Through utilisation of the CHBH's labs as part of final-year projects. In the last year, 30 undergraduates have completed their dissertations in conjunction with a CHBH staff member, benefiting from the CHBH's Educational Funding Scheme, access to imaging modalities as well as usage of the Parallel Brain Imaging Computer Clusters (PBIC).


Research Discussion


Sleep Electroencephalography (EEG)

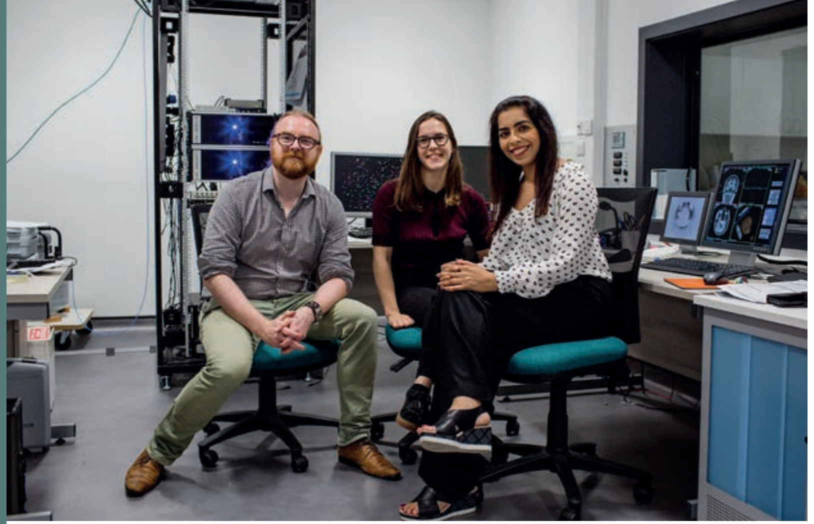
The Centre is also regularly used by students studying MSc programmes in other disciplines, such as Computational Neuroscience and Cognitive Robotics.

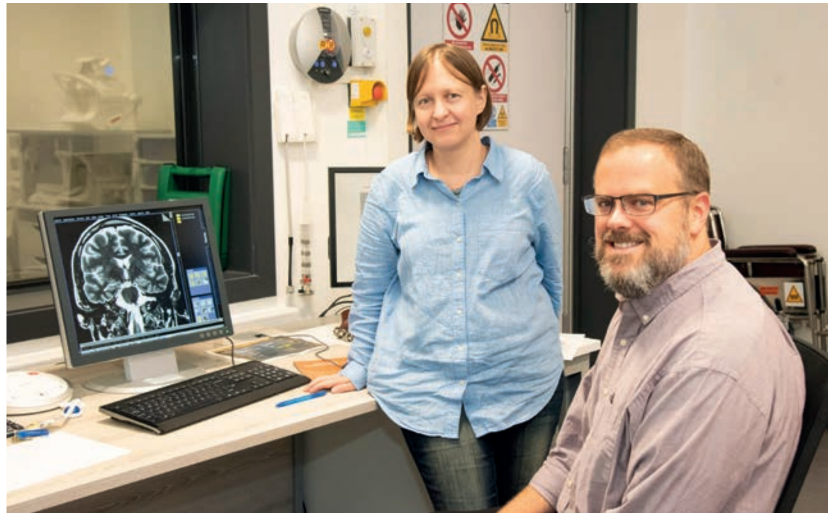
The Brain Imaging and Cognitive Neuroscience MSc is the flagship programme affiliated with the CHBH and is delivered by in-house staff and postgraduate students. These students also benefit from the CHBH Educational Funding Scheme.

The Centre sits within the School of Psychology, the School has an excellent track record in attracting Masters students and providing high-quality training. Sixty to seventy students graduate annually, half progressing to PhD level, whilst the remainder frequently obtain prestigious employment with the likes of Google, Research and Development roles and also employment with not-for-profit organisations such as the Stroke Association.


Functional Near-Infrared Spectroscopy (fNIRS)


Dr Pia Rotshtein
CHBH Educational Lead
Lecturer in Psychology





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