Neurotechnology Workshop
Advanced Research Centre
University of Glasgow
25 March 2024
09:00-17:30

Morning Session

08:30	*Meet & greet over coffee*	
09:00	Prof Simon Hanslmayr	Welcome and Introduction

Session 1: New Technologies (Chair: Dr. Michele Svanera)

09:15	**Dr Elsa Fouragnan**	***Keynote:*** **Inducing short to medium neuroplastic effects with Transcranial Ultrasound Stimulation**
10:00	Prof Daniele Faccio	Optical sensing of brain activity and neurodegeneration
10:20	Prof Hadi Heidari	Scalable Magnetic Sensors for Super-Resolution Muscle Measurements
10:40	*Coffee break*	

Session 2: Non-invasive electrical stimulation (Chair Prof. Gregor Thut)

11:00	**Dr Nir Grossman**	***Keynote:*** **Non-invasive Temporal Interference Deep Brain Stimulation**
11:45	Dr Gang Li	Reduced Motion Sickness Using Brain Stimulation
12:05	Dr Gemma Learmouth	Is it all a sham? The importance of double-blinded control conditions in electrical neurostimulation

12:25	***Lunch & Poster session in Atrium***

Special session (Chair: Prof. Simon Hanslmayr)

13:45	**Dr Jacques Carolan**	***Keynote:*** **Precisely interfacing with the human brain at scale: unlocking the next frontier in neurotechnologies**

Session 3: Open Session (Chair Dr. Gabriela Cruz)

14:30	Dr Emma Gordon	Cognitive Enhancement, Neurotechnology and Authenticity
14:50	Dr Aleksandra Vuckovic	EEG technology for neuropathic pain management
15:10	*Coffee break*	

Session 4: Clinical Applications (Chair Prof. Monika Harvey)

15:30	**Prof Keith Mathieson**	***Keynote*****: Photovoltaic Restoration of Sight in Macular Degeneration**
16:15	Dr Cassandra Sampaio-Baptista	Using fMRI Neurofeedback to modulate brain function and structure in chronic stroke survivors
16:35	Prof. Jesse Dawson	Vagus nerve stimulation for post stroke recovery
16:55	Prof Simon Hanslmayr	Closing remarks

Speakers, titles and abstracts

Keynote Speakers

Session 1: New Technologies

Speaker: Dr Elsa Fouragnan

Title: Inducing short to medium neuroplastic effects with Transcranial Ultrasound Stimulation

Abstract: Sound waves can be used to modify brain activity safely and transiently with unprecedented precision even deep in the brain - unlike traditional brain stimulation methods. In a series of studies in humans and non-human primates, I will show that Transcranial Ultrasound Stimulation (TUS) can have medium- to long-lasting effects. Multiple read-outs allow us to conclude that TUS can perturb neuronal tissues up to 2h after intervention, including changes in local and distributed brain network configurations, behavioural changes, task-related neuronal changes and chemical changes in the sonicated focal volume. Combined with multiple neuroimaging techniques (resting state functional Magnetic Resonance Imaging [rsfMRI], Spectroscopy [MRS] and task-related fMRI changes), this talk will present preliminary evidence that TUS may have state-dependent effects.

Biography: Dr Fouragnan's research focuses on the neurobiology of decision-making and learning, both in healthy adults and in patients with psychiatric disorders. After working as a biomedical engineer, developing brain-related clinical devises, she pursued an academic career in computational neuroscience at the universities of Glasgow and Oxford. Her previous research focused on the use of multimodal neuroimaging, including simultaneous EEG and fMRI methods, which allowed uncovering latent brain states that remain unobserved with conventional methods. Additionally, she worked on the proof of principle - in an animal model - that transcranial ultrasound neuromodulation can safely and transiently change neural activity in precise parts of the brain. She is now working towards bringing this technology forward and apply it to mental health challenges.

Session 2: Non-invasive electrical stimulation

Speaker: Dr Nir Grossman

Title: Non-invasive Temporal Interference Deep Brain Stimulation

Abstract: Deep brain stimulation (DBS) via implanted electrodes has been used worldwide to treat patients with severe movement and affective disorders. However, the risk associated with inserting electrodes into the brain makes exploring different brain targets difficult and limits the therapeutic impact. We developed a technology to modulate neural activity in deep brain structures without surgery. The technology is based on temporal interference (TI) of multiple kHz electric fields, which are too high to recruit effective neural firing but for which their difference frequency is sufficiently low to drive neural activity (Grossman, *Science* 2018). I will describe the principles of TI brain stimulation and the series of tests we conducted to validate it in rodents (Grossman et al., *Cell* 2017) and humans (Violante et al., *Nature Neuroscience*, in press). Finally, I will show how novel mathematics can help uncover the TI brain stimulation's mechanism of action and expand its capabilities.

Biography: Nir Grossman leads the Interventional Systems Neuroscience group at Imperial College London (ICL) and UK Dementia Research Institute (UK-DRI*)*. He has physics and electromagnetic engineering education, a PhD in Neuroscience (ICL,) and postdoc training at MIT with Ed Boyden and Harvard with Alvaro Pascual-Leone. His research is dedicated to pioneering new neuromodulation capabilities and translating them into disease-modifying interventions for people with dementia. He is the inventor of the temporal interference (TI) brain stimulation technology, for which he was awarded the Neuromodulation Prize by the *Science* Journal and the American Association for the Advancement of Science (AAAS).

Special Session

Speaker: Dr Jacques Carolan

Title: Precisely interfacing with the human brain at scale: unlocking the next frontier in neurotechnologies

Abstract: Neurological and neuropsychiatric disorders are the cause of an overwhelming societal and economic burden. We need to build highly targeted, minimally invasive technologies that enable us to interface, at scale, with the human brain. In this talk, we'll give first an overview of the Advanced Research and Invention Agency (ARIA) and then present our opportunity space developing next-generation neurotechnologies.

Biography: Dr. Jacques Carolan is a founding Programme Director at the Advanced Research and Invention Agency (ARIA) and Honorary Associate Professor at University College London (UCL). He is an applied physicist by training, having spent 10 years developing photonic technologies to accelerate quantum and classical computing, initially at MIT and then at the Niels Bohr Institute. He then pivoted into systems neuroscience, where he developed optical technologies for high-speed, large-scale interrogation neural circuits in vivo at UCL. At ARIA he leads a programme developing next-generation neural interfaces to help understand and repair the human brain. He completed his PhD at the University of Bristol in 2015. He has been awarded a BBSRC Discovery Fellowship, a Marie-Sklodowska Curie Global Fellowship and attended the 66th Lindau Nobel Laureates Meeting.

Session 4: Clinical Applications

Speaker: Keith Mathieson

Title: Photovoltaic Restoration of Sight in Macular Degeneration

Abstract: Degenerative retinal diseases, such as age-related macular degeneration, are amongst the leading causes of untreatable blindness in the world. They cause the loss of the 'image capturing' photoreceptor layer, while neurons in the 'image-processing' inner retinal layers are relatively well preserved. Electronic retinal prostheses seek to restore sight by electrically stimulating the surviving neurons.

Here, I will present the results from a collaboration with Stanford University on the development of a photovoltaic subretinal prosthesis. The implant consists of silicon photodiodes in a pixelated format that receive power and data directly through pulsed near-infrared illumination and electrically stimulate neurons. This wireless approach simplifies implantation of the device and increases the achievable resolution. Results from *in vitro* and *in vivo* studies, in animal models of retinal degeneration, have shown that retinal stimulation is produced with millisecond pulse durations and threshold peak irradiances of 0.2–5 mW/mm^2. Neural responses were elicited with pixel dimensions as small as 20-micron diameter, demonstrating the possibility of a fully integrated photovoltaic retinal prosthesis with high pixel density. Network-mediated retinal stimulation is highly localized, measured through visual acuity experiments in blind rats. Furthermore, the device preserves many features of natural vision, including flicker fusion, adaptation to static images and transient responses to changes in luminance.

The system is now licensed to Pixium Vision who have conducted clinical trials. Patients with advanced AMD have a restored visual acuity of around 20/460, which approaches the limit of pixel dimensions in the implanted device (100 microns). This demonstrates a link between device resolution and restored visual acuity in the patient, important for the development of future higher resolution systems.

Biography: Keith Mathieson received his B.Sc. and Ph.D. degrees in physics from the University of Glasgow in 1997 and 2001 respectively. In 2005 he was the recipient of a Royal Society of Edinburgh Personal Research Fellowship to develop retinal implant technology. In 2009 he was awarded an SU2P Fellowship to work at Stanford University, in the group of Professor Daniel Palanker, on the development of an optoelectronic retinal prosthesis. He returned to the UK in 2011 to take up an academic position at the Institute of Photonics, Department of Physics at the University of Strathclyde. He holds a Royal Academy of Engineering Professorial Chair in Emerging Technologies and served as Director of the Institute of Photonics from 2013-2022. His research interests are in neural interface technologies, with a focus on optogenetic devices for the study of neural circuits in the brain and optoelectronic retinal implants for restoration of sight to patients with degenerative retinal diseases.

Internal speakers

Session 1: New Technologies

Speaker: Prof. Daniele Faccio
Title: Optical sensing of brain activity and neurodegeneration

Abstract: Steady state visual evoked potentials (SSVEPs) are widely used for a range of brain-computer interactions and allow the user to perform simple control actions on the surrounding environment. Here we investigate the potential use of SSVEPs for computational imaging, i.e. for a range of tasks that include direct reconstruction of images from encoded data (mimicking so-called ghost imaging) to the training of a BCI-based physical neural network that is able to classify data. Information is encoded in frequency modulations that are transmitted simultaneously with up to hundreds of frequencies in place of the 2-3 frequency components used in most SSVEP BCIs. We also investigate the role of attention that can disrupt or enhance the performance of the computational capability of the BCI.

Speaker: Prof Hadi Heidari
Title: Scalable Magnetic Sensors for Super-Resolution Muscle Measurements

Abstract: Traditionally, surface or intramuscular electromyography (EMG) signals have been the dominant biomarker for muscle activity measurements. A significant challenge with the EMG signal is the difficulty of achieving high spatial resolution with an acceptable signal-to-noise ratio. New detection and control strategies are required to overcome these limitations. To address this problem, the Microelectronics lab (meLAB) at UofG has pioneered a new muscle-machine interface using spintronic sensors in medical diagnosis and human-machine interfacing. Through our spinout company, Neuranics, we aim to standardise the non-invasive magnetomyography (MMG) at room temperature to make a transformative impact on (i) the lives of people by developing a novel diagnostic tool that can target muscle activity and movement, and (ii) disruptive human-machine interfacing in the field of extended reality and metaverse.

Session 2: Non-invasive electrical stimulation

Speaker: Dr Gang Li
Title: Reduced Motion Sickness Using Brain Stimulation

Abstract: Recent research has indicated an increasing relationship between motion sickness and left parietal EEG phase-locking. To assess the causal relationship between motion sickness and EEG phase-locking, we developed a non-invasive transcranial alternating current stimulation (tACS) protocol and applied it to left parietal regions to disrupt phase-locking and reduce VRMS. As hypothesized, our tACS protocol indeed mitigated motion sickness in comparison to a sham tACS protocol and a control tACS protocol. Specifically, participants reported reduced nausea and stomach awareness on the fast motion sickness scale (FMS) during the tACS session. More importantly, this mitigation effect could not be attributed to differences in side effects of the tACS

protocols (such as phosphenes and tingling). Together, these results provide unique insight regarding the neural mechanisms underlying VR-induced motion sickness, and may offer a new approach to mitigate motion sickness.

Speaker: Dr Gemma Learmouth
Title: Is it all a sham? The importance of double-blinded control conditions in electrical neurostimulation

Abstract: Placebo-controlled trials are recognised as the gold standard of evidence-based research. The inclusion of a sham (placebo) condition in non-invasive brain stimulation studies allows researchers to identify whether active stimulation elicits any neural or behavioural effects over and above expectations of treatment by the participant, and necessarily relies on the placebo condition being perceptually indistinguishable from the active condition.
However, we have recently shown that participants are able to identify active from sham stimulation protocols, even at low stimulation intensities. Secondly, statistical outputs from the questionnaire-based methods used to assess sham-blinding are often misinterpreted. In this talk I will discuss some of the potential confounds that researchers should be mindful of when carrying out non-invasive electrical stimulation studies, and which may limit confidence in its efficacy.

Session 3: Open Session

Speaker: Dr Emma Gordon
Title: Cognitive Enhancement, Neurotechnology and Authenticity

Abstract: Bioconservative bioethicists (Kass 2002, 2008; Sandel 2007; Fukuyama 2003) offer various kinds of philosophical arguments against cognitive enhancement—i.e., using medicine and technology to make ourselves epistemically "better than well" as opposed to merely treating pathologies. One notable such arguments appeals to the idea of authenticity, suggesting that there is some meaningful sense in which enhancement use is 'inauthentic'. This critique has traditionally on the use of (actual and possible) pharmacological cognitive enhancements. In this talk, I will explore how the same worry could plausibly apply to cognitive enhancement via the use of brain-computer interfaces (BCIs), and consider possible defences in favour of using BCIs to augment our cognitive capacities.

Speaker: Dr. Aleksandra Vuckovic
Title: EEG technology for neuropathic pain management

Abstract: Neuropathic pain is typically treated with medications and the effectiveness of the therapy is largely based on a subjective method of rating pain on a scale from 0 to 10. While the relation between pain sensation and brain activity is well established, our knowledge is largely based on fMRI neuroimaging, which is not convenient for practical applications. In this talk, I will present how we can use EEG both offline and online, to define diagnostic, prognostic, and monitoring markers of neuropathic pain and to deliver neurofeedback pain therapy. I will also

introduce Neurotechnology for the Chronic Pain project and how it will explore the potential of neurotechnology to advance the nonpharmacological treatment of pain.

Session 4: Clinical Applications

Speaker: Dr Cassandra Sampaio Baptista
Title: Using fMRI Neurofeedback to modulate brain function and structure in chronic stroke survivors

Abstract: Real-time functional magnetic resonance imaging (fMRI) neurofeedback allows individuals to self-modulate their ongoing brain activity. This may be a useful tool in clinical disorders which are associated with abnormal brain activity patterns.
Further, motor activity self-regulation via neurofeedback can induce rapid structural changes in white matter tracts. The direction of the structural changes was found to be related to the direction of brain activity. These findings have been extended to chronic stroke patients in a registered randomized, double-blind, sham-controlled trial. Here neuromodulation was shown to reduce the asymmetry of the corticospinal tract and improve gross hand function. Changes in the affected corticospinal tract was positively correlated to neurofeedback performance. These results demonstrate that even in chronic stroke patients, the structure of white matter tracts can be altered, potentially leading to improvements in motor impairment, and highlight the importance of further investigating white matter structure regulation and function to improve clinical outcomes.

Speaker: Prof. Jesse Dawson
Title: Vagus nerve stimulation for post stroke recovery

Abstract: Vagus nerve stimulation for the treatment of chronic upper limb deficits after ischaemic stroke was approved for clinical use in 2021 by the Food and Drug Administration in the United States of America (USA). In this session I will discuss the biological basis for this therapy, summarise clinical evidence, and discuss the next steps for implementation and clinical research.