Magnetomyography (MMG) Workshop

Advanced Research Centre
University of Glasgow
9th October 2023
10:00-17:00

10:00 – 10:30	***Meet & Greet over coffee***	
10:30 – 10:50	Prof. Simon Hanslmayr	Welcoming and Introduction
10:50 – 11:10	Prof. Hadi Heidari	Scalable Muscle Measurements with Miniaturised Magnetic Sensors
11:10 – 11:30	Prof. Justus Marquetand	Clinical Applications of MMG
11:30 – 11:50	Dr. Nima Noury	Uncovering Motor Unit Activity in Magnetomyography
11:50 – 12:10	Dr. Leonardo Gizzi	Validating MMG for Prosthetic Control
12:10 – 13:40	***Lunch Break & Networking***	
13:40 – 14:00	Dr. Thomas Klotz	Can MMG enhance our window on neuromuscular physiology?
14:00 – 14:20	Dr. Thomas Middelmann	Optically Pumped Magnetometers for Magnetomyography - Benefits & Challenges
14:20 – 14:40	Noel Mckenna	Neuranics - Commercialisation Opportunities for Biomagnetism in Consumer Electronics and metaverse markets
14:40 – 15:40	***Demo/Tea Break***	
15:40 – 16:00	Magnetic Shields Ltd	Magnetic Shielded Products
16:00 – 16:20	COMSOL Representative	COMSOL Multiphysics Software
16:20 – 17:00	Round Table Discussion	
17:00 – 19:00	***Visiting University Campus & Dinner***	

Speakers, titles and abstracts

Speaker 1: Prof. Simon Hanslmayr, Professor at the school Psychology and Neuroscience at the university of Glasgow and scientific advisor to Braingrade GmbH.

Title: Welcoming Speech

Abstract: Thoughts, feelings, or a face we attend to are produced by orchestrated neural firing patterns in distributed brain networks. Precise timing of this neural activity is required in order to represent information in brain networks, and to form lasting memories. Neural oscillations establish such precise timing, which is why I chose to investigate oscillations to understand how the brain implements cognition. To this end my research primarily focuses on attention and memory processes in healthy populations, but I am also interested in how these processes are affected in clinical populations, like patients suffering from Schizophrenia or Post-Traumatic-Stress-Disorder (PTSD). In order to study neural oscillations in humans my lab uses a broad array of electrophysiological and imaging methods from the global scale, such as EEG/MEG, fMRI, combined EEG-fMRI, to the local scale such as intracranial EEG and single unit recordings in humans. Going beyond correlating oscillations with cognition, we also study the causal role of oscillations by externally perturbing the brain via rhythmic sensory stimulation (i.e. flickering or amplitude modulated sounds), rhythmic transcranial magnetic stimulation (rTMS) and transcranial electrical stimulation (TES) and investigate the impact of such oscillatory perturbations on cognition. Finally, we integrate the findings of both data streams (i.e. correlative and causal) via computational models. These models make specific predictions which we test in correlational and causal experiments. My aim with this multidisciplinary, multimodal and multiscale approach is to draw a detailed picture of how the human brain perceives, stores and retrieves information.

Speaker 2: Prof. Hadi Heidari, Professor of Nanoelectronics and Head of Research (Electronic & Nanoscale Engineering), University of Glasgow

Title: Scalable Muscle Measurements with Miniaturised Magnetic Sensors

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.

Biography: (PhD, SMIEEE, FHEA, FRSA, MIET, CEng) is Professor of Nanoelectronics in the James Watt School of Engineering at the University of Glasgow, United Kingdom. He is the Head of the Electronics and Nanoscale Engineering Division and holds an EPSRC Open Fellowship. His Microelectronics Lab (meLAB) conducts pioneering research on integrated micro/nanoelectronics design for medical (wearables and implantables) and industrial (quantum computing and ultrasound systems) applications. His Microelectronics Lab (meLAB)Centre for Medical and Industrial Ultrasonic (C-MIU) group is part of the Communications, Sensing and Imaging (CSI) group, as well as Centre for Quantum Technology, where he leads modern cryoelectronics for quantum computing. Prof Heidari is the CTO and co-founder of Neuranics, a deep-neurotech company which is building next-generation magnetic sensors for wearable neural interfaces.

Speaker 3: PD Dr. Justus Marquetand, Department of Neural Dynamics and Magnetoencephalography, Hertie-Institute for Clinical Brain Research, University of Tübingen, Tübingen, Germany. [2]MEG-Center, University of Tübingen, Tübingen, Germany. [3]Institute for Modelling and Simulation of Biomechanical Systems, Pfaffenwaldring 5a, 70569 Stuttgart, Germany

Title: Clinical Application of Magnetomyography

Abstract: Currently, only a handful of studies provide an outlook on where magnetomyography can be used in daily clinical practice. This contribution will provide an overview of the current possibilities, future opportunities, as well as the limitations of magnetomyography for daily clinical routine. To offer a more vivid picture of this, an explanation of how and why conventional invasive electromyography is performed will be provided, giving insight into the physician's perspective.

Biography: Justus Marquetand is a consultant in neurology with a clinical and scientific focus in clinical neurophysiology and epileptology; after working for about ten years at the Neurological University Clinic in Tübingen, he is currently a junior research group leader at the Hertie Institute for Clinical Brain Research in Tübingen and a clinical-scientific advisor at the University of Stuttgart. Lately, he completed his habilitation (on the subject of quantum sensor technology) and decided to take a break from clinical work to devote himself more intensively to science. He currently supervises 14 doctoral, master and bachelor students and coordinates various scientific consortia in the field of quantum technology.

Speaker 4: Dr. Nima Noury, Department of Neural Dynamics and Magnetoencephalography, Hertie-Institute for Clinical Brain Research, University of Tübingen, Tübingen, Germany. 2MEG-Center, University of Tübingen, Tübingen, Germany

Title: Uncovering Motor Unit Activity in Magnetomyography

Abstract: Investigating distinct motor units (MUs) is an essential part of studying motor activity. Over the last decade, advances in signal processing have provided us with methods to decompose multi-channel non-invasive EMG recordings to underlying MU activities. Here, we asked whether such methods are appliable to multi-channel

MMG recordings. Specifically, we applied a convolutive-ICA method to squid, QuSpin, and 4He MMG recordings of the right abductor digitiminimi (ADM) muscle. Our results show that such a decomposition is possible in all these MMG recordings.

Biography: Nima Noury, born in 1983, did his bachelor and master in electrical engineer at Shahid Beheshti and Sharif universities in Tehran, Iran. After working couple of years as an engineer, he left Iran to do his PhD in Neuroscience at the lab of Dr Markus Siegel in Tübingen, Germany. His thesis was on transcranial electrical stimulation and simultaneous MEG recordings. Since 2019, he is a postdoc at the lab of Dr Siegel.

Speaker 5: Dr. Leonardo Gizzi, Senior Expert at Department of Biomechatronic Systems at Fraunhofer IPA | Head of the Neuromechanics Laboratory and Senior Research Associate at SimTech - Cluster of Excellence | University of Stuttgart

Title: Validating MMG for Prosthetic Control

Abstract: Traditionally, human-machine interfaces utilize mechanical or –at best- electromyography-based control paradigms to translate the will of a subject into mechanical actuation. The next frontier is to overcome the limitations of EMG-based control in favour of the newly-developed magnetic sensing. In this talk, I report the progress of QHMI consortium in the acquisition, processing and interpretation of magnetomyographic signals. In our current setup, we are exploring the possibility to use optically-pumped-magnetometers (OPM) sensors to interface with the central nervous system and to drive machines. I will focus on the premises, the technical challenges, the lessons and the wins of our research and provide a perspective in the next iterations of quantum-based man-machine interfaces.

Biography: My research focuses on human movement, with a special emphasis on the relationship between sensory input and motor output. I am working on overcoming the limitations of traditional EMG using quantum sensors. With this technology, I investigate also the feasibility of MMG-based Human machine interfaces.

I studied Biomedical Engineering and obtained my PhD Health and Sport Sciences (human Physiology) in 2010. In 2011 I moved to Germany (UMG Göttingen); there I directed the “Motor Physiology and Biomechanics“. In 2016 I moved the Stuttgart University (IMSB). Here I founded and directed the Neuromechanics Laboratory of the SimTech Cluster of Excellence.

Since January 2022, I joined the Department of Biomechatronic Systems of the Fraunhofer Institute for Manufacturing Engineering and Automation, in Stuttgart. Here, I serve as Senior Research Scientist and I am part of the Qsens Cluster4Future Project QHMI].

Speaker 6: Dr. Thomas Klotz, Research Assistant, Institute of Modelling and Simulation of Biomechanical System, University of Stuttgart, Germany

Title: Can MMG enhance our window on neuromuscular physiology?

Abstract: The great variability of human motion requires the coordinated interplay of the nervous system and the musculoskeletal system. Yet, only a crude understanding of the mechanisms enabling motions exists. A fundamental challenge for investigating the neuromuscular system in-vivo is the lack of sophisticated experimental methodologies providing insights how the performance of muscles is mechanistically linked to the biophysical function of the body. Magnetomyography (MMG) is a currently emerging methodology with great potential to enable new insights on the function of the neuromuscular system and to become a new diagnostics tool in clinical neurology. This talk explores the potential of MMG to study the function of individual motor units based on the predictions of a biophysical skeletal muscle model. It is shown that MMG is superior to electromyography (EMG), i.e., the current gold standard, for the robust identification of the discharge patterns of individual motor units as well as for motor unit number estimation. Further, this talk presents estimates how limitations of current MMG systems, e.g., regarding the density of sensor arrays or the bandwidth of magnetometers, as well as measurement artifacts, e.g., caused by motions, affect the performances of MMG-based motor unit investigations. Thus, the presented results provide guidance for the development of the next generation of MMG recording systems.

Biography: Thomas Klotz did his Ph.D. in biomedical engineering. He is a post-doctoral researcher at the Institute for Modelling and Simulation of Biomechanical Systems, University of Stuttgart, Germany. His research focuses on computational modelling of the neuromuscular system, magnetomyography and bio-signal processing.

Speaker 7: Thomas Middelmann, Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany

Title: Optically Pumped Magnetometers for Magnetomyography - Benefits and Challenges

Abstract: Biomagnetic measurements of muscles increasingly gained attention in recent years. While before hardly any sensors other than SQUIDs could be considered for non-invasive biomagnetic measurements, since a few years optically pumped magnetometers (OPMs) are available as small, flexibly placeable and highly sensitive magnetic field sensors. Since the demands on the sensor arrangement vary depending on both the subject and the muscle being studied, flexibility is particularly important for Magnetomyography (MMG). Additionally, the small size of these OPMs enables to measure in table-top shields instead of shielded rooms, making transfer to medical practice much more realistic. Along with these new developments come high and diverse requirements for the new sensors, in terms of e.g., spatial resolution, bandwidth, dynamic range and vectorial measurement capability combined with the required high sensitivity. The talk summarizes recent developments, supported by the results from measurements and local sensor development in PTB’s OPM lab.

Biography: Thomas Middelmann studied physics at the Technical University of Berlin (Germany), the Rijksuniversiteit Groningen (Netherlands) and the Fritz-Haber-Institute of the Max-Planck-Society, Berlin. He received the Diploma in physics in 2007 from the Technical University of Berlin and the PhD degree in physics for his work on the high-accuracy correction of the blackbody radiation shift in optical atomic strontium clocks from the Leibniz University of Hannover (Germany) in 2013. Since 2008 he has been a staff member of the Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, and later Berlin (both Germany) where he has worked in the fields of quantum optics, interferometry and (bio-) magnetic measurements. Since 2019 he has been leading the “Optical Magnetometry” group at PTB in Berlin, which develops and uses optically pumped magnetometers to explore new application fields, such as e.g., magnetomyography.

Speaker 8: Noel Mckenna, CEO at Neuranics Ltd

Title: Neuranics - Commercialisation Opportunities for Bio-magnetism in Consumer Electronics and metaverse markets

Abstract: As a deep-tech spinout from the University of Glasgow, Neuranics aims to disrupt human-machine interfacing technology, thereby advancing healthcare technologies as well as gaming and metaverse applications. Neuranics core technology is underpinned by a prototype of a highly sensitive and low-profile spintronic sensor that can measure minute magnetic signals, in room temperature. Neuranics is the first company to miniaturise magnetic sensor technology to such an extent that it can be embedded into consumer electronic products and has files two strong patents to protect its position. There are many applications for this technology in high-volume smart watches, sports fitness devices, gaming devices, Metaverse interface devices and medical monitoring devices. Neuranics will be seeking to work with existing high-volume consumer device manufacturers to design these sensors into the next generation of their products.

Biography: An entrepreneurial, commercially astute, and highly influential CEO with 28 years comprehensive experience driving unprecedented business success within the international electronics industry. Robust record of achievement in roles to C-Level including as Founder of a multi-award-winning start-up company APT Ltd. Considerable experience in building lasting relationships with Tier 1 companies in the gaming, consumer electronics and broadcasting world, building a strong network of global contacts. Innate leadership ability, recruiting and managing world-class engineers in the development of leading-edge security products, bringing core technology to a winning position. Skilled negotiator, able to articulate complex issues and positively impact an international business environment.