NeurotechEU Summer School on EEG Functional Connectivity

-Course Plan-

Target audience and prerequisite

The summer school target audiences is Masters students and PhD candidates in neuroscientific disciplines, bioengineering, clinical or neuro psychology, data science, and neurobiological sciences.

Dates, duration and location

On-site participation: May 28th - 30th 2024; 3 days

Off-line learning for ECTS accreditation: attendees who are aiming to receive 2 ECTS accreditation are requested to read preparatory material that will be available by April 2024 and the completion of a final assignment by June 21st, 2024.

On-site teaching will take place at Reykjavik University, Reykjavik, Iceland.

Hosting institution

Reykjavik University, by the Institute for Biomedical and Neural Engineering

Program fees and funding

• No fee for applicants from NeurotechEU partner institutions

• 350 Euro for each applicant outside of the NeurotechEU consortium

The sending university bears the costs for accommodation and travel.

Contacts (for pre-course administrative issues)

Ragnheiður Þórhallsdóttir: nteu@ru.is

Contacts for Summer school and related Scientific issues:

Paolo Gargiulo paolo@ru.is

Mahmoud Hassan hassan@ru.is

How to apply – Deadline February 22nd 2024

- Students from NeurotechEU partners apply through their university.
- For non-NeurotechEU students, contact Ragnheiður Þórhallsdóttir: ragnheidurth@ru.is at Reykjavik University.

Curriculum contents and learning outcomes

The human brain is a complex and dynamic network. In a highly interconnected system such as the brain, it is essential to move away from thinking in terms of isolated brain regions and, instead, embrace the language of networks. In this perspective, the unit of consideration is the network itself, not individual brain areas. Consequently, the identification of brain networks from neuroimaging data has emerged as a highly promising avenue in brain research, be it in cognitive or clinical neuroscience (Fornito, Zalesky, and Breakspear 2015).

Among the existing neuroimaging techniques, electroencephalography (EEG) signals provide unique direct and noninvasive access to the electrophysiological activity of the entire brain, at the millisecond level. The standard approach for conducting EEG Functional Connectivity (FC) analyses involves calculating correlations (in the broadest sense) between signals recorded in sensor space. However, interpreting this connectivity proves challenging, as signals are significantly influenced by the volume conduction effect, and multiple scalp electrodes can capture activity originating from the same brain source. The computation of FC between reconstructed brain sources, a method known as EEG source connectivity (Hassan and Wendling 2018), has been demonstrated to mitigate these effects.

During this educational school, we will provide all the necessary theoretical and practical tools for computing brain networks at the cortical level using scalp EEG. This includes: data preprocessing, inverse solution, functional connectivity, quantification using graph theory methods, and statistical analysis (ex: group analysis or tracking dynamics of brain networks).

This educational school will also provide the entire pipeline starting from the data collection, using our EEG platform (Aubonnet et al. 2022) and incorporating the best practices to collect high-quality data to cutting-edge methods to analyze EEG networks. We will end this course with concrete applications on real data in cognitive and clinical neuroscience, along with tools that can be used to combine EEG with machine learning algorithms, such as connectome predictive modeling (Kabbara et al. 2022).

Aubonnet, R., A. Shoykhet, D. Jacob, G. Di Lorenzo, H. Petersen, and P. Gargiulo. 2022. “Postural Control Paradigm (BioVRSea): Towards a Neurophysiological Signature.” *Physiological Measurement* 43 (11): 115002.

Fornito, Alex, Andrew Zalesky, and Michael Breakspear. 2015. “The Connectomics of Brain Disorders.” *Nature Reviews Neuroscience* 16 (3): 159.

Hassan, Mahmoud, and Fabrice Wendling. 2018. “Electroencephalography Source Connectivity: Aiming for High Resolution of Brain Networks in Time and Space.” *IEEE Signal Processing Magazine* 35 (3): 81–96. https://doi.org/10.1109/MSP.2017.2777518.

Kabbara, Aya, Gabriel Robert, Mohamad Khalil, Marc Verin, Pascal Benquet, and Mahmoud Hassan. 2022. “An Electroencephalography Connectome Predictive Model of Major Depressive Disorder Severity.” *Scientific Reports* 12 (1): 1–14.

Curriculum content:

- Electroencephalography (EEG) data collection
- EEG preprocessing
- EEG functional connectivity
- Combining EEG and machine learning

The learning objectives for successful completion of the course will be the following:

Knowledge:

- Describe best practices and guidelines for the use of EEG in cognitive and clinical neuroscience
- Describe the concept of brain functional connectivity and EEG source connectivity methods
- Explain the different algorithms to assess EEG brain network dynamics

Skills-Based Learning Objectives:

- Acquire basic skills in EEG data collection and data processing
- Attain basic skills in utilizing EEG source connectivity methods
- Demonstrate rudimentary ability to integrate EEG functional connectivity data with machine learning techniques.
- Acquire practical skills in the assessment of EEG brain network dynamics, demonstrating the ability to choose and implement suitable algorithms based on specific contexts.

Competency-based Learning Objectives:

- Develop general ability to employ different algorithms to assess the dynamic nature of EEG brain networks.

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Program Coordinators

- **Prof. Paolo Gargiulo**

Prof. Gargiulo is a full professor at Reykjavik University expert in electrophysiological signal processing with a special interest in EEG basic and advanced data analysis.

- **Prof. Mahmoud Hassan**

Prof. Hassan is an adjunct professor at Reykjavik University and specializes in EEG functional connectivity and the development of new advanced tools to analyze EEG in cognitive and clinical neuroscience.

Prof Garguilo and Prof. Hassan are also co-founders of Heila-labs https://heilalabs.com/, a start-up company aiming at promoting EEG in concrete clinical applications.

Selected Publications

Aubonnet, R., **Hassan, M.,** Mheich, A., Di Lorenzo, G., Petersen, H., & **Gargiulo, P.** (2023). Brain network dynamics in the alpha band during a complex postural control task. *Journal of Neural Engineering*, *20*(2), 026030.

Barollo, F., **Hassan, M.**, Petersen, H., Rigoni, I., Ramon, C., **Gargiulo, P.**, & Fratini, A. (2022). Cortical pathways during postural control: New insights from functional EEG source connectivity. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *30*, 72-84.

Barollo, F., Friðriksdóttir, R., Edmunds, K. J., Karlsson, G. H., Svansson, H. Á., **Hassan, M.**, ... & **Gargiulo, P.** (2020). Postural control adaptation and habituation during vibratory proprioceptive stimulation: an HD-EEG investigation of cortical recruitment and kinematics. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *28*(6), 1381-1388.

Hassan, M., & Wendling, F. (2018). Electroencephalography source connectivity: aiming for high resolution of brain networks in time and space. *IEEE Signal Processing Magazine*, *35*(3), 81-96.

Lecturers/Trainers

Ceon Ramon

Ceon Ramon is an affiliate professor in the Department of Electrical and Computer Engineering at the University of Washington and is also associated with the Regional Epilepsy Center at the University of Washington. Expert in the modeling of the electrical activity of the human brain since the 1980s. His research efforts have been largely involved with neuroscience, particularly in the areas of modeling the electrical activity of the brain, cortical phase transitions, and EEG data analysis with applications to epilepsy and visual cognition.

Paolo Gargiulo

Paolo Gargiulo is a full Professor at - Reykjavik University. He studied at TU Wien and finished his PhD in 2009. He developed at Landspitali a 3D-Printing service to support surgical planning with over with a significant impact on the Icelandic health care system and he currently cooperates with institutions in Italy and UK to establish similar infrastructures. Paolo Gargiulo is the director of the Institute of Biomedical and Neural Engineering and medical technology center at the University Hospital Landspitali/ Reykjavik University. Paolo´s lab currently includes the following facilities: high density Electroencephalographic system (256-EEG), Postural control platform and Virtual reality system and 3D printing and additive manufacturing center.

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Romain Aubonnet

Postdoctoral fellow at Laboratory of Psychophysiology and Cognitive Neuroscience, Tor Vergata University of Rome. Expert in EEG data analysis, brain connectivity, brain network dynamics, applied to postural control and/or mental disorders.

Lorena Guerrini

PhD candidate at Reykjavik University since 2022, in the Institute of Biomedical and Neural Engineering. Focus on postural control strategies, motor control, and brain signal analysis. Expertise in our innovative BioVRSea setup and acquisition of over one year of data.

Federica Pescaglia

PhD student at Reykjavik University's Institute of Biomedical and Neural Engineering, specializing in postural and motor control, and brain signal analysis. Actively involved in acquiring a significant dataset using the innovative BioVRSea setup.

[Mahmoud Hassan](#)

Adjunct professor at Reykjavik University, co-founder of Heila-Labs, and founder of MINDIG. Expert in EEG source connectivity in cognitive and clinical neuroscience.

Sahar Allouch

Scientist at MINDIG (France). Expert in EEG signal processing, analytical variability, and brain connectivity.

Ahmad Mheich

Scientist at MINDIG (France) and postdoctoral fellow at CHUV, Lausanne. Expert in EEG data analysis, brain network similarity, and brain network dynamics.

Academic structure

5.1 All participants to the summer school will receive a certificate of attendance at the end of the school.

5.2. For those who request the 2 ECTS accreditation. 8 hours of preparatory reading materials will be sent prior to the course. Participants will attend summer school for 3 full days at Reykjavik University totaling 21 hours. Following the summer school, a written assignment based on the reading material and experience in class will be given to the candidate. The assignment will be in the form of a full write-up of the project idea that is developed, or an essay on a particular topic of interest related to the course to be completed after the in-person classes (approx. 1500 words) that is due on June 21, 2024 at 12:00 CET to be delivered by email to Paolo at paolo@ru.is.

5.2.1 Assessment procedure (ECTS accreditation). Pass/fail

IMPORTANT: *If the participant would like to accrue ECTS for this course, it is the student's responsibility to reach out to their academic advisor to determine if the ECTS can be transferred to their home institution.*

5.3. Structure of the program (schedule and workload per any distinct academic sections included in the course).

The summer school will be organized over 3 full days as follows:

- Day 1: Data collection and Preprocessing (7 H)
- Day 2: From EEG to cortical brain network / Dynamic connectivity (7 H)
- Day 3: Application in cognitive and clinical neuroscience / connectome predictive modeling (7 H)

5.4. Resources made available (e.g., facilities, …)

- Full equipment for recording EEG (64-channels (ANT Neuro) system)
- Well-established Python tools for EEG analysis

5.5 Learning outcomes and self-evaluation

At the end of the course, the participants will be kindly asked to fill out an evaluation questionnaire shared during the course. The questionnaire assesses students' learning outcomes and their level of satisfaction with the entire course.