Syllabus for the course «Advanced Neuroimaging Techniques»

(4 ECTS)

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1. Course Description

a. «Advanced Neuroimaging Techniques»

b. Pre-requisites

The course is based on the basic knowledge:

- Introduction to Neuroimaging Techniques

c. elective

d. Abstract

EEG (electroencephalography) is the measurement of electrical potential differences across points on the scalp using sensitive equipment. These small potential differences are the result of electrical activity within the brain and are associated with brain function. The coherent activity of cortical pyramidal neurons generates ionic currents, and these give rise to electric field and electric potential variations. The measured voltages are of μV range (microvolt, or one millionth of a Volt) and are typically recorded at multiple scalp sites simultaneously. Although other important techniques exist to study brain function, EEG offers excellent temporal resolution (millisecond scale) and moderate spatial resolution (cm scale) using modern analysis techniques such as cortical mapping. EEG remains unparalleled in ease of use.

MEG (magnetoencephalography) is a method of estimation of electrical brain activity via measurement of tiny magnetic fields that accompany changes in electric potential of the cortex. The origin of these changes in general view is same as for EEG, but, since tissues of a head are nominally transparent for magnetic fields, the topography of the signal does not suffer from anisotropy of skull, skin and neural tissue. Therefore, the spatial resolution of modern MEG systems is much better than for EEG still saving time resolution of the last one. On the other hand, tiniest magnetic fields (in range of femtoTesla or 10^{-15} Tesla) require very precise state-of-art sensors called SQUIDs (superconductive quantum interferometers) placed in liquid helium. This architecture apparently leads to high operational costs and necessary to build a special magnetic shielded camera around the magnetoencephalographic device. To sum up, MEG data processing results in the very precise spatiotemporal mapping of the brain activity in cortical areas that help scientists to construct a detailed picture of the interplay of neuronal populations, especially when complemented with other techniques.

Non Invasive Brain Stimulation techniques are able to modulate human cognitive behavior. Among these methods are transcranial electric stimulation and transcranial magnetic stimulation that both come in multiple variants. A property of both types of brain stimulation is that they modulate brain activity and in turn modulate cognitive behavior. They are optimal tools for investigating brain activity in basic research and for neurorehabilitation purposes. It includes TMS, tDCS, tACS.

fMRI (functional magnetic resonance imaging) is a neuroimaging technique which allows to visualize a brain activity-related signal across the whole brain with a millimetric resolution. fMRI requires an MRI scanner functioning with a specific protocol that extracts the BOLD (blood oxygen level dependent) signal, Although the BOLD signal hinges on the magnetic properties of blood, it has been shown to be a reliable proxy of time series of brain activity. The major drawback of the BOLD signal, besides being an indirect measure of neural activity, is that it is sluggish, i.e. it has low temporal resolution (~8s) and it is delayed (~6s). However, it is virtually, to this day, the only technique which allows whole brain visualization at a reasonable cost.

One of the course's main foci is on acquisition of the skills in the use of Brain Stimulation and Electroencephalography techniques. Therefore, it will mainly consist of 50% of hands-on learning and 50% of lectures on the related to advanced aspect of neurophysiology theory. At the end of the course we will expect participants to be able to collect, analyze and interpret EEG/MEG, TMS, tDCS, tACS, and fMRI data.

2. Learning Objectives

Learning objectives of the course "Advanced Neuroimaging" are to introduce students to the novel technology and innovations in neuroscience research, its advances and connections to other branches of science:

- Advanced aspect of mechanisms that underlay Transcranial Magnetic Stimulation (TMS) and Transcranial Electrical Stimulation (tDCS, tACS, tRNS);
- Training to the use of TMS and TES;
- Combined use of TMS and TES with Electroencephalography (EEG);
- Training to measure and analyze EEG;
- Training to analyze MEG;
- Training to analyze fMRI;

- Training to familiarize with software / hardware in EEG/MEG research

3. Learning Outcomes

After completing the study of the course "Advanced Neuroimaging" the student should:

- be able to use TMS, tDCS, tACS, tRNS in an advanced experimental setting;
- be able to combine brain stimulation with EEG technique;
- be able to measure and analyze EEG data;
- be able to analyze MEG data;
- be able to analyze fMRI data;
- be able to work with advanced software / hardware in EEG/meg research;
- be able to work with software in fMRI research

4. Course Plan

1.	Topic
2.	TMS
3.	TES
4.	EEG
5.	MEG
6.	TMS-EEG
7.	tDCS-EEG
7.	fMRI

5. Reading List

a. Required

Topic 1. Non Invasive Brain Stimulation

1. Bikson, M., Datta, A., Rahman, A., Scaturro, J., 2010. Electrode montages for tDCS and weak transcranial electrical stimulation: role of "return" electrode's position and size. Clin.Neurophysiol. 121, 1976-1978. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2983105/
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Topic 2. Electroencephalography

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Topic 3. Magnetoencephalography

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Topic 4. Functional magnetic resonance

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b. Optional

6. Grading System

The current grade (Gtest) is given by the teacher as grade for control tests (5 questions for each topic). The class grade (Gclass) is given by the teacher for attendance and activity during class hours. The self-research grade (GResearch) is given by the teacher for the results of scientific research. The cumulative grade (Gcumulative) for the student’s achievements during the course is calculated by the end of the course on the basis of the current grade, the class grade, and the self research grade:

Gcumulative = 0.3 *Gtest + 0.3 * Gclass + 0.4 * Gresearch.

The examination grade (Gexam) is given by the teacher during the final examination.

The final grade (Gfinal) is calculated on the basis of the cumulative grade and the examination grade:

Gfinal = 0.6 * Gcumulative (1 to 10) + 0.4 * Gexam (1 to 10)

The grades are rounded up arithmetically.

If the cumulative grade of a student equals 8, 9 or 10, the student can opt that the final grade be given equal to the cumulative grade:

Gfinal = Gcumulative

If the student is eligible for this option, he/she has to inform the teacher about his/her decision concerning the final grade before the examination.

Table of Grade Correspondence

Ten-point Grading	Scale Five-point Grading Scale	
1 - very bad 2 – bad 3 – no pass	Unsatisfactory – 2	FAIL
4 – pass 5 – highly pass	Satisfactory – 3	PASS
6 – good 7 – very good	Good – 4	
8 – almost excellent 9 – excellent 10 – perfect	Excellent – 5	

The final grade, which is the resultant grade for the course, goes to the certificate of Master’s degree.

7. Guidelines for Knowledge Assessment

Type of grading	**Type of work**	**Characteristics**
Continuous	Paper presentation	Talk on the seminar on the topic related to the lectures, 60 minutes each
Continuous	Attendance	Evaluation of attendance

		lectures and seminars
Final	Exam part 1	Theoretical questions on the topic
Final	Exam part 2	Practice test on TMS, TES and EEG

Continuous assessment:

Paper presentations. Students have to present one paper or to make a short literature review on the subject that is relevant to the course topics. Presentations can be made by groups of student but not more than 3 people in each group. Presentation should last 45 minutes and then 15 minutes discussions take place. Main criteria for evaluation are relevance of the topic, understanding of the material and presentation skills.

Attendance. Attendance will be evaluated as a percentage of seminars and lectures that a student was present on.

Final assessment is the final exam.

Theory. This exam will cover all topics that have been discussed during seminars. It will consist of multiple-choice, short answer questions and one essay question with opportunity to choose between topics. The main source to prepare the exam is based on the articles suggested during the course.

Practice. This exam will test students' skills for practicing and for being acknowledged on TMS, TES, EEG, fMRI and MEG (software). The main source to prepare the exam is strictly based on the level of attendance and test questions.

Final exam sample "open questions" questions:

Decide whether the statement is true or false:

1- What is Theta Burst Stimulation?

2- What is tACS?

3- Potential artifacts in EEG measurements?

4- What is the aim of averaging of trials / evoked responses in EEG analysis?

Hands-on test:

Hands-on test of 20 to 30 minutes on TMS and/or EEG setup-analysis (e.g. localization of motor cortex or subject preparation for EEG session).

Final exam questions (contents):

1. Basic principles of TMS
2. TMS for basic research
3. TMS for clinical application
4. TMS as perturbation approach
5. Repetitive TMS protocols
6. Online and offline TMS
7. Basic principles of TES
8. TES for basic research
9. TES for clinical application
10. Online and offline TES
11. tDCS, tRNS, tACS principles
12. TES on cognition
13. TMS on cognition
14. What is EEG?
15. Main components of EEG Laboratory
16. EEG measurement
17. Capturing electrode locations
18. Stimulus Presentation Software
19. Synchronization problem in experiments
20. Recording Software
21. EEG Preprocessing methods
22. Steady State Visual Evoked Potentials
23. Oddball paradigm
24. Sensitivity analysis
25. SPM functionality
26. Source reconstruction in MEG

8. Methods of Instruction

- The following educational technologies are used in the study process:
- Lectures involving continuous use of multimedia presentations.
- Seminars involving team oral discussions and paper presentations.
- Hands-on sessions
- Homework assignments
- Self-study of recommended literature

9. Special Equipment and Software Support (if required)

The course requires a computer or laptop, projector, and acoustic systems for multimedia presentations and video. The Centre for Cognition and Decision Making (CDM) will provide access to TMS and EEG laboratories.