NX-436

Advanced methods for human neuromodulation

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Cursus	Sem.	Type
Neuro-X minor	H	Opt.
Neuro-X	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Session	Winter
Semester	Fall
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Lecture	2 weekly
Exercises	2 weekly
Number of positions	

Summary

Neuromodulation is an expending field especially in human translational neuroscience and neurotechnology. This course will introduce to different approaches / technologies for neuromodulation, their underlying mechanisms of action and application in humans in healthy and pathological conditions.

Content

The students will be introduced to different (invasive and non-invasive) approaches and technologies for neuromodulation, to their underlying mechanisms of action and to their application in humans in healthy and in pathological conditions such as Stroke, Parkinson's, Dementia, Traumatic Brain Injury or Depression. The course will address and elaborate together with the students on neuromodulation approaches based on e.g., electrical (invasive, non-invasive), magnetic stimulation, focussed ultrasound as well as pharmacological or opto/sonogenetic modulation. Furthermore, aspects like state-dependent, closed-loop approaches or technologies for home-based self-application, as well as safety, cost-effectivity and ethics will be addressed, and important regulatory, neuroethical and R&D aspects. The course content is organized as follows. Each week 2 x 45 min lectures and 2 x 45 min exercise.

Lecture topics:
History of neuromodulation
Non-invasive brain stimulation
- Transcranial electric stimulation such as transcranial direct current (tDCS), transcranial alternating current (tACS) or transcranial random noise (tRNS) stimulation
- Transcranial magnetic stimulation (TMS)
- Underlying technological and physiological concepts, mechanisms of action
- Behavioral impact with a focus on clinical translation.
- Technological challenges, next steps

Deep brain stimulation
- Invasive deep brain stimulation
- Novel methods of non-invasive deep brain stimulation based on transcranial temporal interference stimulation (tTIS) or focused ultrasound (fUS)
- Underlying technological and physiological concepts, mechanisms of action
- Behavioral impact with a focus on clinical translation.
- Technological challenges, next steps

Spinal cord stimulation
- Invasive and non-invasive spinal cord stimulation
- Underlying technological and physiological concepts, mechanisms of action
- Behavioral impact with a focus on clinical translation.
- Technological challenges, next steps

Neuromodulation of the peripheral nervous system including the vegetative system
- Invasive and non-invasive peripheral nervous system stimulation
- Underlying technological and physiological concepts, mechanisms of action
- Behavioral impact with a focus on clinical translation.
- Technological challenges, next steps

Neuromodulation by Opto-/Sonogenetics
- Underlying technological and physiological concepts, mechanisms of action
- Behavioral impact
- Technological challenges, next steps

Machine learning, simulations and modelling applied in the field of Neuromodulation
- Simulations and modeling of effects of neuromodulation with a focus on brain stimulation
- Personalization
- Biomarkers to determine responsiveness to neuromodulation

State-dependent, closed loop stimulation
- Challenges and oportunities

Home-based self-application
- Introduction in concept and technologies
- Opportunities, challenges and technological developments

Regulatory, ethical and R&D aspects of Neuromodulation

Learning Prerequisites

Required courses

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Learning Outcomes

By the end of the course, the student must be able to:

- Contextualise
- Assess / Evaluate
- Discuss
- Present
- Reason
- Hypothesize
- Plan
- Explain

Transversal skills

- Respect relevant legal guidelines and ethical codes for the profession.
- Take account of the social and human dimensions of the engineering profession.
- Demonstrate a capacity for creativity.
- Demonstrate the capacity for critical thinking
- Communicate effectively with professionals from other disciplines.
- Summarize an article or a technical report.
- Use a work methodology appropriate to the task.
- Access and evaluate appropriate sources of information.

Teaching methods

Interactive Lectures, Exercise

Expected student activities

Preparation of lectures including suggested literature review Active Participation in Lectures Active participation in Exercises

Assessment methods

Written Final Exam (50%)
Project presentation and evaluation (exercise) (40%)
Exercise: Paper review (10%)

Resources

Virtual desktop infrastructure (VDI)

No

Bibliography

Textbook and Review article examples for preparation.
Textbooks of Neuromodulation, Neuroscience, Neuroengineering or Neuroprosthetics e.g., Textbook of Neuromodulation (Knotkova, Rasche, Springer New York), Principles of Neural Science (Kandel et al., MCGRAW-HILL Higher Education), Neuroscience: Exploring The Brain, Enhanced Edition (Connors et al. Jones and Bartlett Publishers, Inc), Principles of Cognitive Neuroscience (Purves et al. Oxford University Press), Neuroprosthetics, Principles and Applications (Sanchez, CRC Press), Handbook of Neuroengineering (N. V. Thakor (ed.), Springer Nature Singapore Pte Ltd. 2022)
Review articles, e.g.,
Fomenko A et al. (2022), An Overview of Noninvasive Brain Stimulation: Basic Principles and Clinical Applications. Can J Neurol Sci. 2022;49(4):479-492. doi: 10.1017/cjn.2021.158.
Nitsche MA et al. Transcranial direct current stimulation: state of the art 2008. Brain Stimul. 2008;1(3):206 doi: 10.1016/j.brs.2008.06.004.
Dannhauer et al. (2024) Electric Field Modeling in Personalizing Transcranial Magnetic Stimulation Interventions. Biol Psychiatry. 2024 Mar 15;95(6):494-501. doi: 10.1016/j.biopsych.2023.11.022. Epub 2023 Dec 5.PMID:Â 38061463
Siddiqi SH, Fox MD (2024) Targeting Symptom-Specific Networks With Transcranial Magnetic Stimulation.Biol Psychiatry. 2024 Mar 15;95(6):502-509. doi: 10.1016/j.biopsych.2023.11.011.
Hummel FC, Wessel MJ Non-invasive deep brain stimulation: interventional targeting of deep brain areas in neurological disorders.(2024) Nat Rev Neurol. 2024 Jun 29. doi: 10.1038/s41582-024-00990-8. Online ahead of print.
Pellow et al. (2024) A systematic review of preclinical and clinical transcranial ultrasoundneuromodulation and opportunities for functional connectomics. Brain Stimul. 2024 Jun 14;17(4):734-751. doi: 10.1016/j.brs.2024.06.005. Online ahead of print.
Yuksel et al. (2023) Low-Intensity Focused Ultrasound Neuromodulation for Stroke Recovery: A Novel Deep Brain Stimulation Approach for Neurorehabilitation? IEEE Open J Eng Med Biol. 2023 Apr 5;4:300-318. doi: 10.1109/OJEMB.2023.3263690. eCollection 2023.
Darmani et al. (2022) Non-invasive transcranial ultrasound stimulation for neuromodulation. Clin Neurophysiol 2022 Mar:135:51-73.doi: 10.1016/j.clinph.2021.12.010.Epub 2021 Dec 31.

Ressources en bibliothèque

- Textbook of Neuromodulation (Knotkova, Rasche, Springer New York)
- Principles of Neural Science (Kandel et al., MCGRAW-HILL Higher Education)
- Neuroscience: Exploring The Brain, Enhanced Edition (Connors et al. Jones and Bartlett Publishers, Inc)
- Principles of Cognitive Neuroscience (Purves et al. Oxford University Press)
- Neuroprosthetics, Principles and Applications (Sanchez, CRC Press)
- Handbook of Neuroengineering (N. V. Thakor (ed.), Springer Nature Singapore Pte Ltd. 2022)