



**Karolinska  
Institutet**

Course syllabus for

# **Introduction to Brain Imaging in Neuroscience: With a Focus on MRI, PET, EEG and MEG Methods, 7.5 credits**

Introduktion till hjärnabbildning inom neurovetenskap: med fokus på metoderna MRI, PET, EEG och MEG, 7.5 hp

This course syllabus is valid from autumn 2024.

Please note that the course syllabus is available in the following versions:

[Autumn2023](#) , [Autumn2024](#)

|                            |  |
|----------------------------|--|
| Course code                | 2XX082   |
| Course name                | Introduction to Brain Imaging in Neuroscience: With a Focus on MRI, PET, EEG and MEG Methods |
| Credits                    | 7.5 credits  |
| Form of Education          | Higher Education, study regulation 2007  |
| Main field of study        | Medicine   |
| Level                      | Second cycle, has only first-cycle course/s as entry requirements                            |
| Grading scale              | Pass, Fail   |
| Department                 | Department of Clinical Neuroscience  |
| Decided by                 | Education committee CNS  |
| Decision date              | 2023-05-24   |
| Revised by                 | Education committee CNS  |
| Last revision              | 2023-11-15   |
| Course syllabus valid from | Autumn 2024  |

## **Specific entry requirements**

At least 120 credits in psychology, psychiatry, neuro science, medicine, or medical technology. Alternatively 60 credits within psychology, psychiatry, neuro science, medicine, or medical technology on/at Secondary level.

And proficiency in English equivalent to English B/English 6.

## **Objectives**

After taking the course, the student should be able to

- describe the function of the instruments used to perform structural magnetic resonance imaging

(sMRI), functional magnetic resonance imaging (fMRI), positron emission tomography (PET), electroencephalography (EEG) and magnetoencephalography (MEG), and to describe what aspect of the brain's structure and function these instruments register

- describe basic principles for analysis of data from measurements using sMRI, fMRI, PET, EEG and MEG
- give an overview of clinical and academic applications for each of the imaging methods
- give an overview of instruments and analysis methods used for multimodal brain imaging.

## Content

The course covers the theoretical background to the brain imaging methods sMRI, fMRI, PET, EEG and MEG, such as what aspects of the human brain's structure and function they register, and the operation principles of the imaging instruments. The course gives the student a good understanding in how the different methods are used in academic research as well as in health care. The course also addresses how the imaging methods can be combined in multimodal analyses, and discusses the interplay between development of theory, instrumentation, method, and applications.

The course begins with an introduction to brain imaging methods within neuroscience. In separate course modules, the course then offers the student a deeper understanding of the different methods sMRI, fMRI, PET, EEG and MEG, as well as combining them in multimodal brain imaging. Finally, the students will deepen their knowledge on a topic of their choice in an individual study project.

### Structural magnetic resonance imaging (sMRI), 1.5 hp

Grading scale: GU

The goal of the sMRI module is to provide the students with a solid understanding of structural magnetic resonance imaging (sMRI) and the tools available to analyse sMRI data. Firstly, the physiological basis of the sMRI signals and how they are measured will be discussed - the fundamentals of image processing will be introduced together with an overview of basic MRI physics. This module will then focus on main sMRI methods. The module will cover state-of-the-art methods for investigating brain morphology (automated segmentation of volume, cortical thickness, etc), and it will also cover methods for studying brain connectivity, including diffusion imaging. The sMRI module will also cover advanced methods for data analysis (multivariate data analysis, deep learning and graph theory) and other popular sMRI techniques such as quantitative susceptibility mapping, arterial spin labelling, etc, with a focus on future directions. Finally, several applications, including how sMRI is used today in clinical practice, will be discussed.

### Functional magnetic resonance imaging (fMRI), 1.5 hp

Grading scale: GU

In the fMRI module, the students will be introduced to the study of brain activity using magnetic resonance imaging (MRI). The neuronal and physiological basis of the functional MRI (fMRI) signals and how they are measured will be discussed. Task fMRI and resting state fMRI will be presented as methods to address research questions about: localization of brain function, brain functional connectivity, decoding within and between subject variables from patterns of activity and studying representations of percepts, actions and thoughts. Experimental design and data analysis techniques adequate to different research questions will be addressed. The students will also be introduced to fMRI applications for clinical studies and practice.

### Electroencephalography (EEG) and magnetoencephalography (MEG), 1.5 hp

Grading scale: GU

In the EEG and MEG module, the student is first introduced to the neural basis of the MEG and EEG signal. The module then focuses on how this neural signal is registered by the different sensor technologies used within the MEG and EEG fields, including current developments of next-generation

MEG and EEG sensor technologies. The data processing steps are then briefly explained, including an overview of different strategies for analysing MEG and EEG data, including evoked- and induced responses, source analysis, functional connectivity, and multivariate pattern analysis. A strong emphasis is then placed on how MEG and EEG are used in research and in clinical and commercial applications.

## **Positron emission tomography, 1.5 hp**

Grading scale: GU

In this module the students will be introduced to brain imaging using the nuclear imaging technique Positron Emission Tomography (PET). The basic principles of radioligands and their development will be described, as well as their application in neuroscience research and clinical applications.

Experimental design and data analysis techniques adequate to different research questions and clinical applications will be addressed. The areas will range from basic research to understand the central nerve system's physiology and pathophysiology of various diseases to development and evaluation of current and novel treatment strategies, and also the use of PET in a clinical setting in differential diagnosis of various diseases.

## **Multimodal brain imaging, 1.0 hp**

Grading scale: GU

Multimodal imaging has become a powerful way to investigate the human brain, link brain structure to brain function, and understand human behaviour.

In this module, the student is introduced to common strategies to combine sMRI, fMRI, PET, EEG and MEG data. Instrumentation for multimodal studies is then described, together with the most popular methods for multimodal, including examples from multimodal imaging of neurological and psychiatric disorders. The student is finally introduced to emerging multimodal imaging techniques and future directions, including recent techniques for brain stimulation and their combination with sMRI, fMRI, EEG and MEG.

## **Individual study project, 0.5 hp**

Grading scale: GU

At the end of the course the students deepen their knowledge in a particular topic of brain imaging in neuroscience with a individual study project. The student chooses an area and writes a short research proposal (1-2 pages) about it, accompanied by a short presentation in small groups.

## **Teaching methods**

The teaching methods used in this course are self-study, teacher-led lectures and group discussions, and an individual advanced study project. Attendance is mandatory and requires active participation. The course is conducted online with the support of the Karolinska Institute digital learning platform. Via this platform, the student has access to different types of course content, such as lecture slides and recommended literature, and can also interact with other students within the course and with the course teachers, for example during group discussions.

## **Examination**

Learning objectives are examined partly through a written quiz in connection with each course topic, active participation in the compulsory course meetings, and through an individual project. During the last part of the course, the student presents and discusses her/his project in small groups together with teachers and other students.

Each of the six course modules is graded with a Pass or Fail grade. To pass the course, a pass grade is

required for all course modules including the individual advanced study project.

#### *Number of examinations*

Students who do not pass the regular examination have the right to participate in five additional examinations. If the student has completed six failed exams/tests, no further examinations are given. The times the student has participated in one and the same test are counted as examination sessions. Examination assignments submitted too late are not considered. Students who have not submitted in time are referred to the re-examination session.

#### *Absence from or non-fulfillment of mandatory course elements*

The examiner decides whether, and if so how, absence from compulsory course elements can be made up for. Study results cannot be reported until the student has participated in compulsory course elements or compensated for any absence in accordance with instructions from the examiner. Absence from a compulsory course element could mean that the student can not retake the element until the next time the course is offered.

#### *Possibility of exemption from the syllabus' regulations on examination*

If there are special grounds, or a need for adaptation for a student with a disability, the examiner may decide to deviate from the syllabus' regulations on the examination form, the number of examination opportunities, the possibility of supplementation or exemptions from the compulsory section/s of the course etc. Content and learning outcomes as well as the level of expected skills, knowledge and attitudes may not be changed, removed or reduced.

## **Transitional provisions**

Examination will be provided for one year after a possible closure of the course or with a new syllabus.

## **Other directives**

The course is offered in English.

Course evaluation will be carried out in accordance with the guidelines established for education at Karolinska Institutet.

## **Literature and other teaching aids**

### **Mandatory literature**

#### ***Mandatory literature for sMRI, fMRI, EEG/MEG, multimodal modules***

*Op de Beeck*

#### **Introduction to Human Neuroimaging**

Cambridge University Press, 2019

LIBRIS-ID:v544gm5tsk6w0drb

#### ***Mandatory literature for PET module***

*Hooker, JM*

#### **Human Positron Emission Tomography Neuroimaging**

*Carson, RE*

2019

URL: [Länk](#)

Ingår i:

**Annual review of biomedical engineering**

Palo Alto, CA : Annual Reviews Inc., 1999-  
ISSN:1545-4274 LIBRIS-ID:11243398  
4 (2019) :21, s. 551-581

## Recommended literature

### *Recommended literature for sMRI*

#### **Neuroimaging in Dementia**

*Barkhof, Frederik.; Fox, Nick C.; Bastos-Leite, António J.; Scheltens, Philip.*

1. : Berlin, Heidelberg : Springer Berlin Heidelberg, 2011

ISBN:9783642008184 LIBRIS-ID:12214863

URL: [Table of Contents / Abstracts](#)

[Library search](#)

#### **Brain Mapping: The Systems**

*Arthur W. Toga*

Academic Press, 2000

LIBRIS-ID:12311334

*Hornak, Joseph P.*

#### **The Basics of MRI**

J.P. Hornak., 1996-2020

URL: [Länk](#)

### *Recommended literature for fMRI*

*Chen, Jingyuan E.*

#### **Functional Magnetic Resonance Imaging Methods**

*Glover, Gary H.*

2015

URL: [Länk](#)

Ingår i:

#### **Neuropsychology Review**

1998-

LIBRIS-ID:8856623

URL: [Table of Contents / Abstracts](#)

25 (2015) :3, s. 289313

*Rosen, Bruce R*

#### **fMRI at 20 : Has it changed the world?**

*Savoy, Robert L*

2012

URL: [Länk](#)

Ingår i:

#### **Neuroimaging**

InTech, 2010

LIBRIS-ID:14931198

15 (2012) :62, s. 1316-24

*Poldrack, R.A.*

**Progress and Challenges in Probing the Human Brain**

*Farah, M.J.*

2015

URL: [Länk](#)

Ingår i:

**Nature**

London : Nature Publishing Group, 1997-

ISSN:1476-4687 LIBRIS-ID:10307483

526 (2015) :7573, s. 371-379

***Recommended literature for PET***

*Vernaleken, Piel M*

**Positron emission tomography in CNS drug discovery and drug monitoring**

*Rösch, F*

2014

URL: [Länk](#)

Ingår i:

**Journal of medicinal chemistry**

1963-

ISSN:1520-4804 LIBRIS-ID:4414509

URL: [Table of Contents / Abstracts](#)

26 (2014) :57, s. 9232-58

*Laruelle, M*

**Imaging synaptic neurotransmission with in vivo binding competition techniques : A critical review**

2000

URL: [Länk](#)

Ingår i:

**Journal of cerebral blood flow & metabolism**

1981-

ISSN:1559-7016 LIBRIS-ID:11241905

URL: [Fritt tillgänglig via](#)

20 (2000) :3, s. 423-51

***Recommended literature for EEG/MEG***

*Baillet, Sylvain*

**Magnetoencephalography for brain electrophysiology and imaging.**

2017

URL: [Länk](#)

Ingår i:

**Nature : Neuroscience**

London : Nature Publishing Group, 1998-  
 LIBRIS-ID:9999938  
 20 (2017) s. 327339

*Supek, Selma.*

**Magnetoencephalography : From Signals to Dynamic Cortical Networks**

*Aine, Cheryl J.*

Berlin, Heidelberg : Springer Berlin Heidelberg, 2014 - XXI, 1013 p. 266 illus., 215 illus. in color.  
 ISBN:9783642330452 LIBRIS-ID:16951042

URL: [Table of Contents / Abstracts](#)

[Library search](#)

***Recommended literature for multimodal brain imaging***

*Kriegeskorte, N*

**Representational similarity analysis : Connecting the branches of systems neuroscience**

*Mur, M.; Bandettini, P*

2008

URL: [Länk](#)

Ingår i:

**Frontiers in systems neuroscience**

LIBRIS-ID:11607101

URL: [Fritt tillgänglig via](#)

2 (2008) :4,

*Cichy, R.M.*

**Resolving human object recognition in space and time**

*Pantazis, D; Oliva, A*

2014

URL: [Länk](#)

Ingår i:

**Nature : Neuroscience**

New York : Nature Publishing Co., 1998-

ISSN:1097-6256 LIBRIS-ID:2388812

17 (2014) :3, s. 455-62

*McKeith, IG*

**Diagnosis and management of dementia with Lewy bodies : Fourth consensus report of the DLB Consortium**

2017

URL: [Länk](#)

Ingår i:

**Neurology : official journal of the American Academy of Neurology**

New York : Ovid, 1995-

ISSN:1526-632X LIBRIS-ID:4419207

URL: [Fritt tillgänglig via](#)

4 (2017) :89, s. 88-100

*Jack, CR*

**NIA-AA Research Framework : Toward a biological definition of Alzheimer's disease**

2018

URL: [Länk](#)

Ingår i:

**Alzheimer's & dementia : the journal of the Alzheimer's Association.**

2005-

ISSN:1552-5279 LIBRIS-ID:11249824

14 (2018) :4, s. 535-562

*Thompson, Alan J*

**Diagnosis of multiple sclerosis : 2017 revisions of the McDonald criteria**

2018

URL: [Länk](#)

Ingår i:

**The Lancet Neurology**

New York, NY : Lancet Publishing Group, 2002-

LIBRIS-ID:9033699

URL: [Table of Contents / Abstracts](#)

17 (2018) :2, s. 162-173

*Wardlaw, Joanna M*

**Neuroimaging standards for research into small vessel disease and its contribution to ageing and neurodegeneration**

2013

URL: [Länk](#)

Ingår i:

**The Lancet Neurology**

New York, NY : Lancet Publishing Group, 2002-

LIBRIS-ID:9033699

URL: [Table of Contents / Abstracts](#)

12 (2013) :8, s. 822-838