Syllabus - Advanced Cognitive Neuroscience - Autumn 2025

Lau Møller Andersen

Table of contents

Semester plan

Lecturer: Lau Møller Andersen

Lectures: Wednesdays 8-10 (1485-240)
Classes: Thursdays 13-15 (1485-240)

Lectures will be a combination of students presenting on set topics and the lecturer presenting topics. The topics presented by the lecturer will be of a more technical nature, whereas the student-led topics will be more conceptual

Textbooks

The main textbook is: Puce A, Hari R (2023) MEG–EEG PRIMER, 2nd edition. Oxford University Press, Incorporated, United States. It can be purchased through Stakbogladen. Unlimited digital versions can also be borrowed from the Royal Library

Chapters from: Sekihara Kensuke, Nagarajan Srikatan S (2008) Adaptive Spatial Filters for Electromagnetic Brain Imaging, 1st ed. 2008. Springer Berlin Heidelberg, Berlin, Heidelberg will also be used. Available online at the Royal Library

Puce and Hari's introduction is a general and gentle conceptual introduction, whereas Sekihara and Nagajaran's book is more equation oriented

Lectures and classes

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Week 36:
Lesson 0: What is it all about?
Class 0: Setting up UCloud and installing MNE-Python
Readings: Chapters 1-2 & 4, Puce A, Hari R (2023)

Week 37:
No Teaching
Readings: None

Week 38:
Lesson 1: Workshop paradigm: Measuring visual subjective experience + MR Recordings
Class 1: Running an MEG analysis of visual responses
Readings:
Ramsøy TZ, Overgaard M (2004) Introspection and subliminal perception.
    Phenomenology and the Cognitive Sciences 3:1-23.
    https://doi.org/10.1023/B:PHEN.0000041900.30172.e8

Sergent C, Baillet S, Dehaene S (2005)
    Timing of the brain events underlying access to consciousness
    during the attentional blink.
    Nature neuroscience 8:1391-400. https://doi.org/10.1038/nn1549

Week 39:
MEG workshop: Measuring and predicting visual subjective experience (see below)
Readings: Chapters 5-7, Puce A, Hari R (2023)

Week 40:
Lesson 2: Basic physiology and Evoked responses
Class 2: Evoked responses to different levels of subjective experience
Readings: Chapters 3, 10 & 12, Puce A, Hari R (2023)

Week 41:
Lesson 3: Multivariate statistics
Class 3: Predicting subjective experience in sensor space
Readings:
King J-R, Dehaene S (2014) Characterizing the dynamics of mental
    representations: the temporal generalization method.
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Trends in Cognitive Sciences 18:203-210.
https://doi.org/10.1016/j.tics.2014.01.002

Sandberg K, Andersen LM, Overgaard M (2014) Using multivariate decoding to go beyond contrastive analyses in consciousness research.
Front Psychol 5:1250. https://doi.org/10.3389/fpsyg.2014.01250

Week 42:
Autumn Break
Readings: Go dig up potatoes instead!

Week 43:
Lesson 4: Forward modelling and dipole estimation
Class 4: Creating a forward model and fitting dipoles
Readings:
FieldTrip video: https://www.youtube.com/watch?v=3Q8HLHNieuI

Chapters 1-2 Sekihara K., Nagarajan S (2008)

Mid-term evaluation

Week 44:
Lesson 5: Inverse modelling: Minimum-norm estimate
Class 5: Predicting subjective experience in source space
Readings: Chapter 3 Sekihara K., Nagarajan S (2008)

Week 45:
Lesson 6: Inverse modelling: Beamforming
Class 6: Predicting subjective experience in source space, continued
Readings:
FieldTrip video: https://www.youtube.com/watch?v=pE0WAKd_Ve4

From a signal perspective: https://www.youtube.com/watch?v=A1n5Hhwtz78

Chapter 4 Sekihara K., Nagarajan S (2008)

Week 46:
Lesson 7: What about that other cortex? - the cerebellar one
Class 7: Oral presentations (part 1)
Readings:
Sokolov AA, Miall RC, Ivry RB (2017) The Cerebellum:
Adaptive Prediction for Movement and Cognition.

Trends in Cognitive Sciences 21:313-332. https://doi.org/10.1016/j.tics.2017.02.005

Andersen LM, Dalal SS (2024) The role of the cerebellum in timing.
Current Opinion in Behavioral Sciences 59:101427.
https://doi.org/10.1016/j.cobeha.2024.101427

Week 47:
Lesson 8: Guest lecture: Laura Bock Paulsen: Respiratory analyses
Class 8: Oral presentations (part 2)
Readings: To be announced

Week 48:
Lesson 9: Guest lecture: Barbara Pomiechowska:
Using OPM-MEG to study brain and cognitive development in infancy
Class 9: Oral presentations (part 3)
Readings:
Boto E, Holmes N, Leggett J, et al (2018)
Moving magnetoencephalography towards real-world applications with a wearable system.
Nature. https://doi.org/10.1038/nature26147

Video: https://spectrum.ieee.org/a-new-wearable-brain-scanner

Tierney TM, Levy A, Barry DN, et al (2021)
Mouth magnetoencephalography: A unique perspective
on the human hippocampus. NeuroImage 225:117443.
https://doi.org/10.1016/j.neuroimage.2020.117443

Final evaluation

Week 49:
Lesson 0 again: What was it all about?
Class 10: Oral presentations (part 4)
Readings: Baillet S (2017) Magnetoencephalography for brain electrophysiology
and imaging. Nat Neurosci 20:327-339. https://doi.org/10.1038/nn.4504

Workshop

We will have 8 study groups with 4-5 people in each. We will have one participant from each group being the subject for the MR and the MEG

The workshop will take place at Aarhus University Hospital (Skejby). We meet at entrance J.
September 19: acquisition of anatomical MR images for source reconstruction

September 22-24: acquisition of MEG data. The paradigm and the protocol for the MEG preparation and MEG data acquisition will also be made available on github, as well as notebooks and other materials

Dependencies

Running analyses on the server: UCLoud

To run MNE-Python locally, install MNE-Python from Miniconda (recommended; we will do this during Class 0). This will allow you to create advanced source model plots

Portfolio exams

The portfolio consists of three assignments

1) *Video explainer to your peers:* **Individual assignment (25 % of grade)**:

   - Task: Make a video explainer of maximally 5 minutes; this should explain the underlying processes that give rise to a measurable magnetic field outside the head. The following concepts should be included: *post-synaptic potentials*, *current dipole*, *open field vs closed field*, *radial and tangential sources*, *volume conduction* and *evoked responses*. In general the level of the video explainer should be aimed at your peers and the relevant materials can be found in Chapters 1-3 of the textbook.

   - Evaluation criteria: to what degree are the concepts listed above **clearly**, **succinctly** and **correctly** described
   - Deadline for receiving feedback: Week 41 (Thursday 23.59)

2) *Report on MEG acquisition and MEG analysis:* **Project group assignment (50 % of grade)**:

   - Task: The report must include an **introduction**, based on relevant literature; operationalisable **hypotheses**; a clear **methods** section, which must describe the experiment and the data acquisition procedure; a succinct **results** section with both behavioural data and MEG data; a **discussion** addressing limitations and the suitability of the method for investigating subjective experience. Data from all 8 participants **must** be used and **at least one** analysis **must** be based on multivariate statistics. A maximum of 6 pages per co-author. Code as appendix.
   - Evaluation Criteria: to what degree has **relevant** literature been chosen for the introduction; to what degree has **operationalisable** hypotheses been formulated; to what degree has the methods section **clearly** described the experiment and the data acquisition procedure; to what degree are the results **succinctly** described; to what degree are the limitations and the suitability of the method **relevantly** described. (**Remember** to use all participants and to use a multivariate analysis)
   - Deadline for receiving feedback: Week 46 (Thursday 23.59)

3) *Oral presentation on set topic:* **Project group assignment (25 % of grade)**:

- Task: Present on one of the topics below; note that the topics are assigned randomly to project groups during the course. The topics all have fixed dates.
- Topics:
  - The visual system, as understood through MEG
    - Based on chapter 14, Puce A, Hari R (2023) (**summary text**)
    - one other text of your own choice among the ones presented in Figures 14.5, 14.8, 14.10 or 14.12 (**experiment text**)
  - The auditory system, as understood through MEG
    - Based on chapter 13, Puce A, Hari R (2023) (**summary text**)
    - one other text of your own choice among the ones presented in Figures 13.4 or 13.8 (**experiment text**)
  - The somatosensory system, as understood through MEG
    - Based on chapter 15, Puce A, Hari R (2023) (**summary text**)
    - one other text of your own choice among the ones presented in Figures 15.7, 15.8 or 15.9 (**experiment text**)
  - Cognitive components and change detection
    - Based on chapter 18, Puce A, Hari R (2023) (**summary text**)
    - one other text of your own choice among the ones presented in Figures 18.2, 18.4 or 18.5 (**experiment text**)
  - Links between respiration, behaviour and MEG
    - Kluger DS, Gross J (2021) Respiration modulates oscillatory neural network activity at rest. PLOS Biology 19:e3001457. https://doi.org/10.1371/journal.pbio.3001457 (**summary text**)
    - Kluger DS, Balestrieri E, Busch NA, Gross J (2021) Respiration aligns perception with neural excitability. eLife 10:e70907. https://doi.org/10.7554/eLife.70907 (**experiment text**)
  - Development as understood through MEG
    - Chen Y-H, Saby J, Kuschner E, et al (2019) Magnetoencephalography and the infant brain. NeuroImage 189:445–458. https://doi.org/10.1016/j.neuroimage.2019.01.059 (**summary text**)
    - Kuhl PK, Ramírez RR, Bosseler A, et al (2014) Infants' brain responses to speech suggest Analysis by Synthesis. Proceedings of the National Academy of Sciences 111:11238–11245. https://doi.org/10.1073/pnas.1410963111 (**experiment text**)
  - Language comprehension as understood through MEG
    - Salmelin R (2010) MEG and Reading: From Perception to Linguistic Analysis. In: MEG: An Introduction to Methods. Oxford University Press, New York (**summary text**)

    - van Vliet M, Rinkinen O, Shimizu T, et al (2025) Convolutional networks can model the functional modulation of the MEG responses associated with feed-forward processes during visual word recognition. eLife 13:RP96217. https://doi.org/10.7554/eLife.96217 (**experiment text**)
  - Subjective experience as understood through MEG
    - Aru J, Bachmann T, Singer W, Melloni L (2012) Distilling the neural correlates of consciousness. Neuroscience & Biobehavioral Reviews 36:737–746. https://doi.org/10.1016/j.neubiorev.2011.12.003 (**summary text**)
    - Shafto JP, Pitts MA (2015) Neural Signatures of Conscious Face Perception in an Inattentional Blindness Paradigm. J Neurosci 35:10940–10948. https://doi.org/10.1523/JNEUROSCI.0145-15.2015 (**experiment text**)
  - Evaluation Criteria:

Criteria	Specifics	Percentage of score
Clear agenda	The structure is clear throughout; e.g. *method*, *results* and *interpretation* are clearly separated	10
Time management	30 min for the presentation; 15 min for Q&A. Make sure to allot time for each part of the chapter	5
Understanding of MEG fundamentals - e.g. basic physics, sensor types, source reconstruction	Make sure to use the right terminology and explain succinctly what terms mean	20
Clear presentation of summary text	Extract core concepts from the chapter and explain core figures	20
Clear appraisal of experiment text	Summarise the study, explain the experimental design, explain results, the interpretation of the results and the limitations of the study	20
Visual design	Coherent design, legible slides and no unnecessary information	5

Criteria	Specifics	Percentage of score
Presentation skills	No reading aloud, control of the material	10
Handling of Q&A	How do you engage with the questions of fellow students? e.g. do you get the question, can you answer it and so on?	10

Order of student presentations

- Part 1
  - **Presentation 0**: The visual system, as understood through MEG **(Study group 0)**
  - **Presentation 1**: The auditory system, as understood through MEG **(Study group 5)**
- Part 2
  - **Presentation 2**: The somatosensory system, as understood through MEG **(Study group 3)**
  - **Presentation 3**: Cognitive components and change detection **(Study group 7)**
- Part 3
  - **Presentation 4**: Links between respiration, behaviour and MEG **(Study group 6)**
  - **Presentation 5**: Development as understood through MEG **(Study group 1)**
- Part 4
  - **Presentation 6**: Language comprehension as understood through MEG **(Study group 2)**
  - **Presentation 7**: Subjective experience as understood through MEG **(Study group 4)**

Feedback practice

To give you the opportunity to improve your videos (1) and your reports (2):

- I will give dedicated feedback on the individual videos **if** they are handed in on time
- I will give dedicated feedback on the reports **if** they are handed in on time **and if** they are handed in as a group

From the academic regulations

Description of qualifications

Purpose:

The purpose of the course is for students to acquire advanced knowledge about the structure and function of the brain, with a focus on how brain function contributes to cognitive function. The focus of the course is on advanced experimental methods in cognitive neuroscience, and students will conduct their own cognitive neuroimaging/cognitive neurophysiology research. Students will learn advanced statistical methods for analysing data acquired from the measurement of neural processes, with a focus on modelling techniques for relating neural data to cognitive functions.

The course includes 1) theory of neural and cognitive processes; 2) advanced statistical methodologies for analysing neuroimaging data; and 3) discussion of the theoretical relationships between neurobiological and cognitive brain processes.

This course builds on students' knowledge of cognition, and their skills and competencies in using statistical methods.

Academic objectives:

In the evaluation of the student's performance, emphasis is placed on the extent to which the student is able to:

Knowledge:

- describe the anatomy and physiology of the human brain, and explain the brain basis of cognitive function
- contrast different cognitive neuroscience methods in terms of their strengths and weaknesses, and use this knowledge to develop appropriate experimental research for investigating different cognitive functions of the brain.

Skills:

- run experiments using neuroimaging and/or neurophysiological measurement equipment
- use advanced statistical methods to make inferences about cognitive brain functions from neuroimaging and/or neurophysiological data.

Competences:

- independently identify the appropriate measurement technology and experimental designs for investigating different cognitive functions
- identify cases in which statistical methods taught in the course can be applied to domains outside of cognitive neuroscience.