Advanced Cognitive Neuroscience

Week 36: What is it all about?

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Academic regulations - objectives

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.

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Academic regulations - objectives

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.

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Academic regulations - objectives

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.

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Overall idea of the course

- We will focus on magnetoencephalography (MEG)
  - but leverage magnetic resonance imaging to do source reconstruction of the MEG signals
- We will investigate how subjective experience is build in the brain
- We will learn how to apply multivariate statistics to reduce these very rich data sets (MEG: 306,000 data points per second)
- We will learn how to facilitate the rich spatio-temporal data that MEG provides
- We will learn about the brain while doing so

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Me

Lau Møller Andersen

laumollerandersen.org

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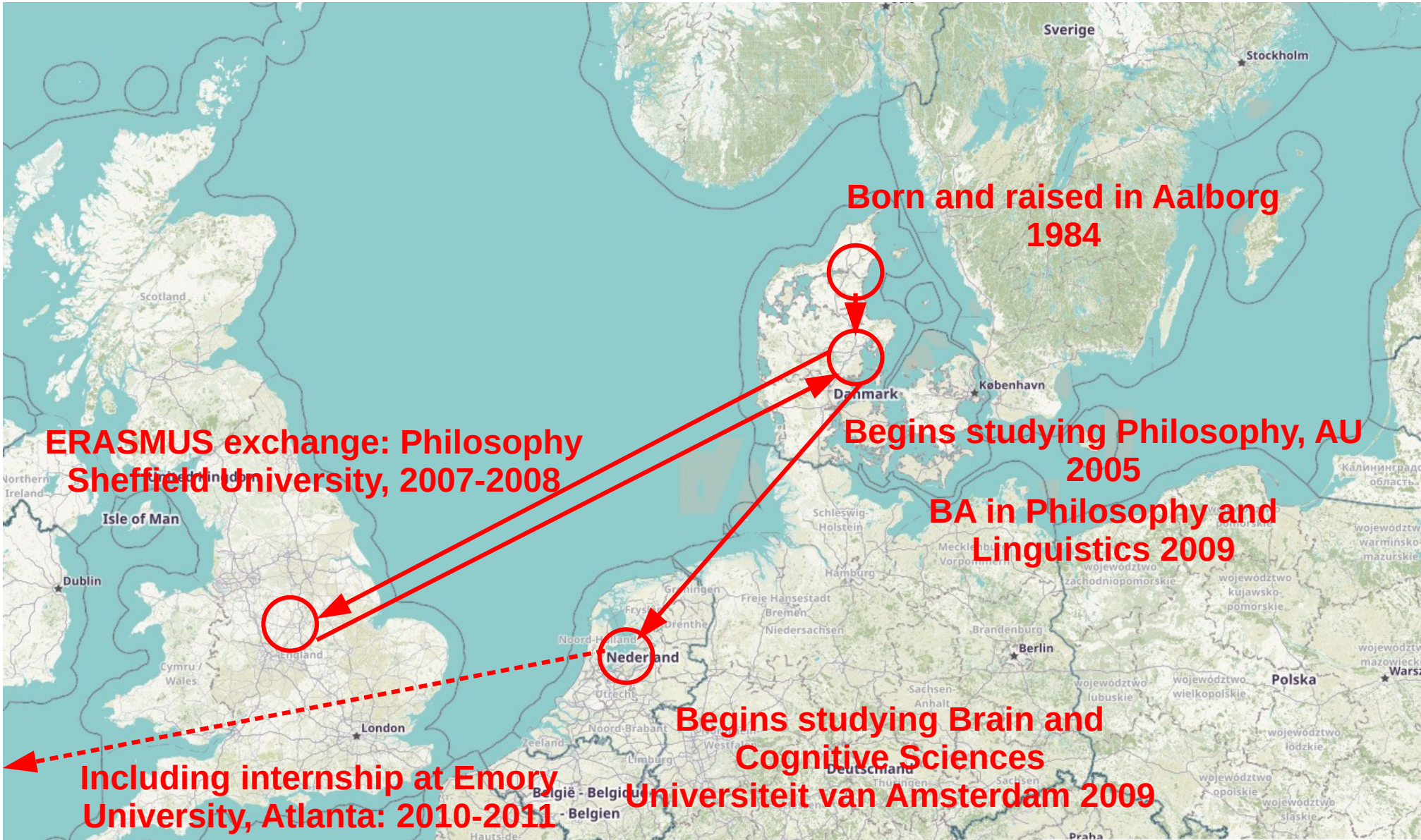
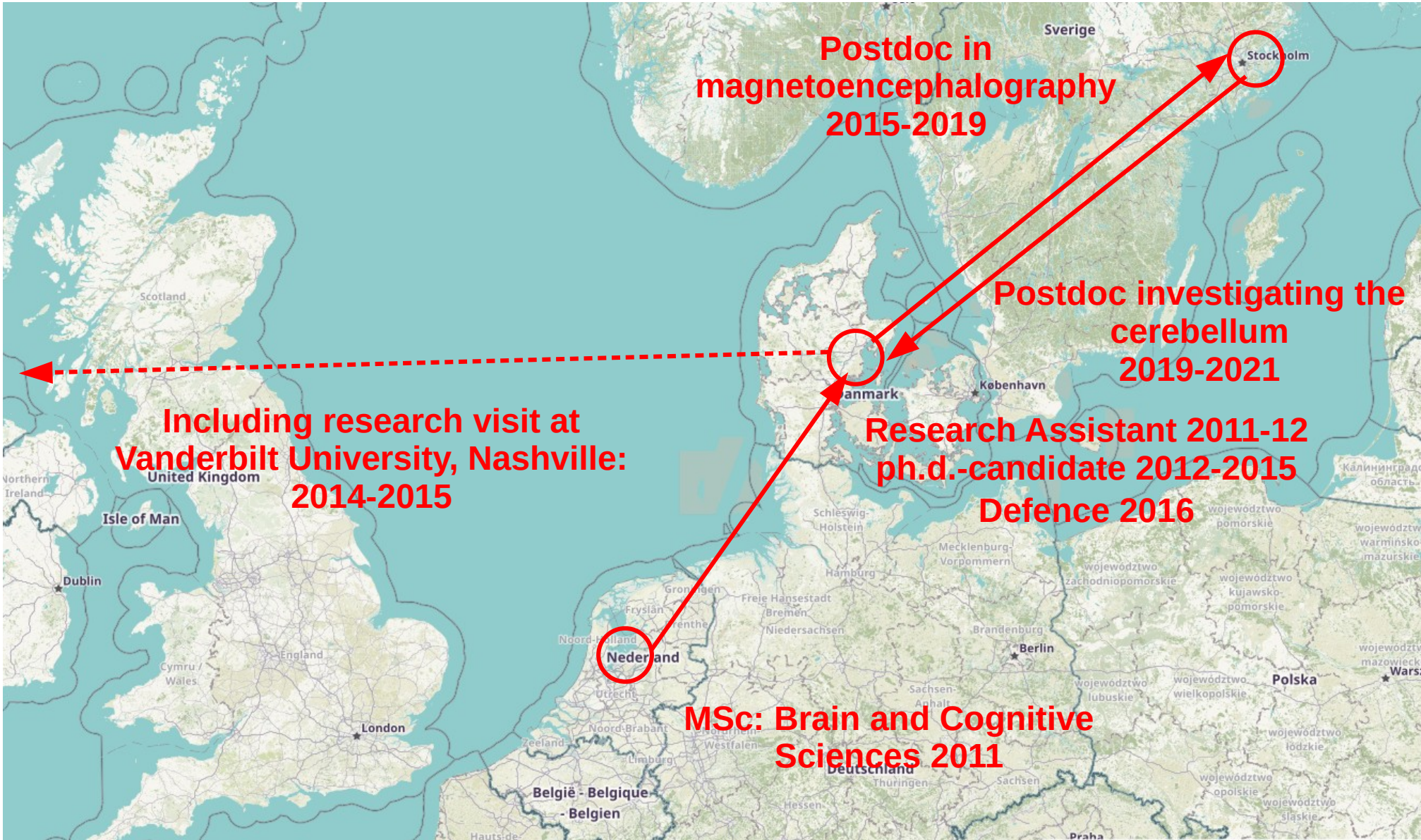
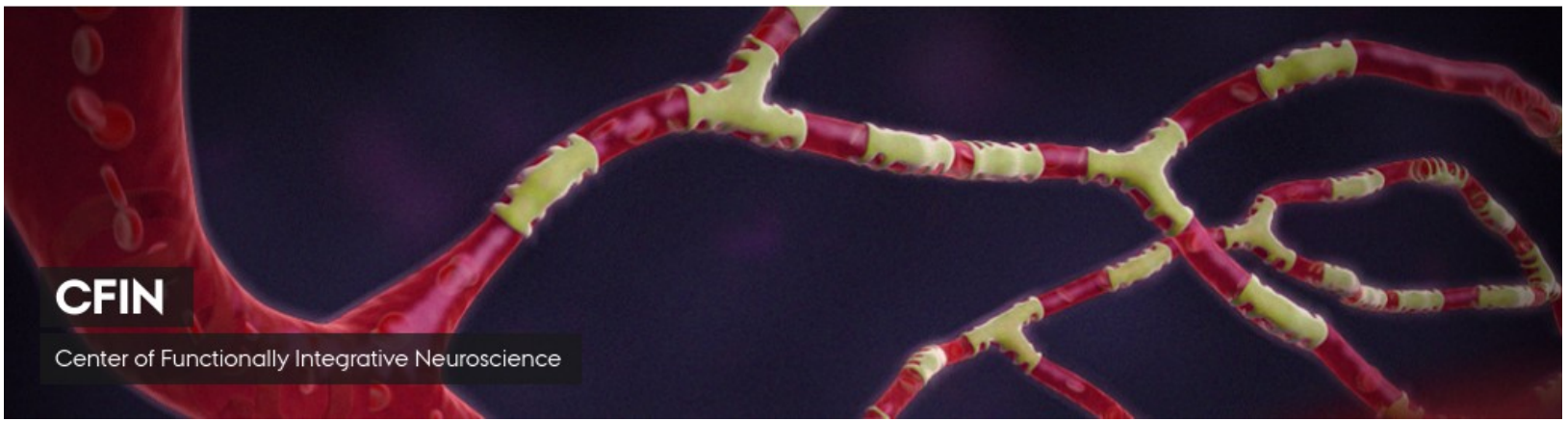

Born and raised in Aalborg
1984
Begins studying Philosophy, AU
2005
BA in Philosophy and
Linguistics 2009
ERASMUS exchange: Philosophy
Sheffield University, 2007-2008
Including internship at Emory
University, Atlanta: 2010-2011
Begins studying Brain and
Cognitive Sciences
Universiteit van Amsterdam 2009


Postdoc in magnetoencephalography 2015-2019
Postdoc investigating the cerebellum 2019-2021
Including research visit at Vanderbilt University, Nashville: 2014-2015
Research Assistant 2011-12
ph.d.-candidate 2012-2015
Defence 2016
MSc: Brain and Cognitive Sciences 2011
Sverige
Stockholm
Scotland
United Kingdom
Isle of Man
Dublin
London
København
Berlin
Polska
Nederland
België - Belgique - Belgien
Deutschland

2021-2024



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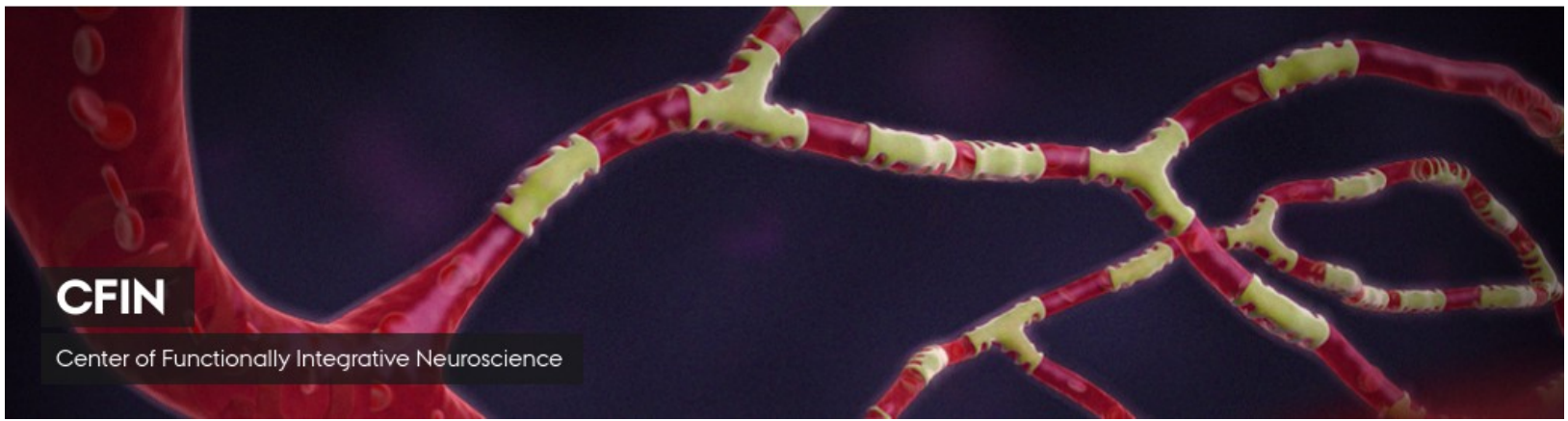
2024 – onwards

Main affiliation

Secondary affiliation



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My current interest

Review

Can EEG and MEG detect signals from the human cerebellum?

Lau M. Andersen [a b], Karim Jerbi [c d], Sarang S. Dalal [a]

The cerebellar clock: Predicting and timing somatosensory touch

Lau M. Andersen [a b c], Sarang S. Dalal [a]

Somatosensory responses to nothing: An MEG study of expectations during omission of tactile stimulations

Lau M. Andersen, Daniel Lundqvist

Research Article | Research Article: New Research, Cognition and Behavior

Detection of Threshold-Level Stimuli Modulated by Temporal Predictions of the Cerebellum

Lau M. Andersen and Sarang S. Dalal

Review

The role of the cerebellum in timing

Lau M Andersen [1 2 3], Sarang S Dalal [1]

New Results

Follow this preprint

Somatosensory timing and cerebellar-basal ganglia beta-band interactions in Parkinson's disease

Victor Pando-Naude, Lau Møller Andersen

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You

- My aim:
  - Every time I address you, I will do it with your name
  - Some times I will be wrong, and that might cause some humiliation both ways
  - Please correct me when I am wrong

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Me as a lecturer

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Me asking questions

- I will every now and then pick a student at random to answer questions
- I want to emphasise that I am only picking students that I judge are paying attention
  - i.e.: I am not trying to humiliate students not paying attention
- It is completely okay to say “I do not have an answer”; then I’ll just pass it on to someone else

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You asking questions

- Does such a thing as a stupid question exist?
- I don’t care if they do or not
- You ask a question because you want to know ...
- ... and I answer because I want to tell you

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Exam; portfolio; deadline 16-12-2025

SEE SYLLABUS FOR DETAILS

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

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

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

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Re-examination
Will be done during January (tip: stay on schedule, such that you can enjoy Christmas)

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The structure of lectures

- Wednesdays 8-10 (NB: Academic quarter)
- A mix between the general theoretical framework and formulas
- Code will be incorporated
- Group discussions
- Please don’t hold back on your questions

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The structure of classes

- Thursdays 13-15 (NB: Academic quarter)
  - In classes, you will generally be implementing code and adapting it to your analyses that go into your report
  - Last four will be presentations from study groups

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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)

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From AU’s centre of education

Regarding editing options, AU’s video platform Panopto offers a bit of editing of the material, but it is very limited. I would recommend that you download **Blackmagic’s DaVinci Resolve**, which you can get for free. It has reached a fairly high level within the industry and provides many tools even in the free version. It’s easy to use if you already have some editing experience; otherwise, there are plenty of great tutorials on YouTube that can help you get started.

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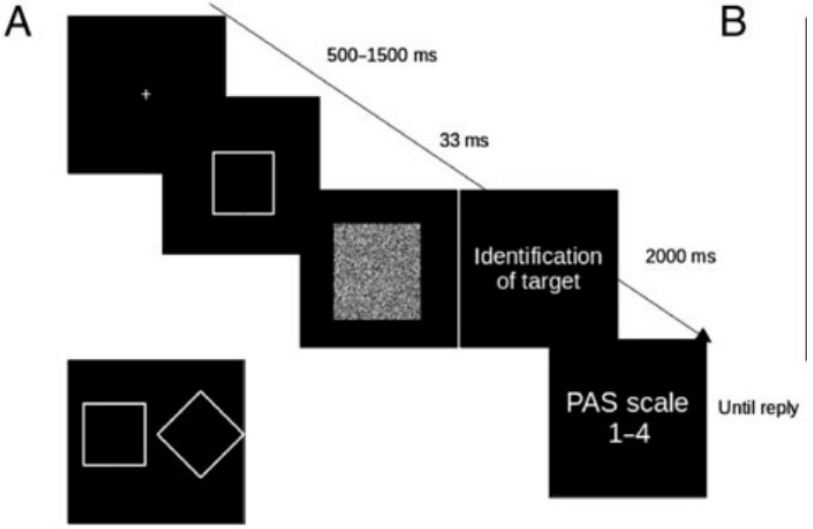
Workshop

SUBJECTIVE EXPERIENCE

from Center of Functionally Integrative Neuroscience



Andersen LM, Pedersen MN, Sandberg K, Overgaard M (2016) Occipital MEG Activity in the Early Time Range (<300 ms) Predicts Graded Changes in Perceptual Consciousness. Cerebral Cortex 26:2677–2688. https://doi.org/10.1093/cercor/bhv108

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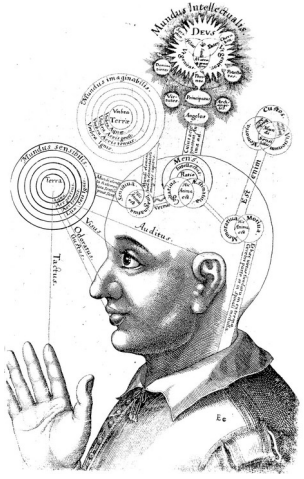
Workshop

SUBJECTIVE EXPERIENCE

Table 1 The Perceptual Awareness Scale (PAS)

Label	Description [from Ramsøy and Overgaard (2004)]
(1) No Experience (NE)	No impression of the stimulus. All answers are seen as mere guesses.
(2) Weak Glimpse (WG)	A feeling that something has been shown. Not characterized by any content, and this cannot be specified any further.
(3) Almost Clear Experience (ACE)	Ambiguous experience of the stimulus. Some stimulus aspects are experienced more vividly than others. A feeling of almost being certain about one's answer.
(4) Clear Experience (CE)	Non-ambiguous experience of the stimulus. No doubt in one's answer.



Andersen LM, Pedersen MN, Sandberg K, Overgaard M (2016) Occipital MEG Activity in the Early Time Range (<300 ms) Predicts Graded Changes in Perceptual Consciousness. Cerebral Cortex 26:2677–2688. https://doi.org/10.1093/cercor/bhv108

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

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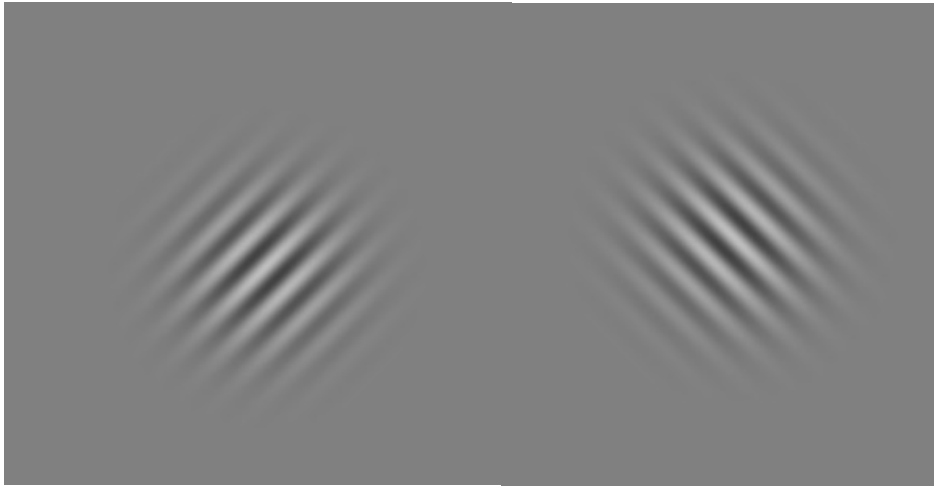
By Robert Fludd - Utriusque cosmi maioris scilicet et minoris […] historia, tomus II (1619), tractatus I, sectio I, liber X, De triplici animae in corpore visione, Public Domain, https://commons.wikimedia.org/w/index.php?curid=699073

```
#%% RUN EXPERIMENT

## initalise
experiment = Experiment()

## setting up experiment
experiment.open_GUI()
experiment.set_experiment_parameters()
experiment.check_user()
experiment.write_to_terminal('refresh_rate')
experiment.define_io_files()
experiment.write_to_terminal('setting_path')
experiment.define_texts()
experiment.create_experiment_window()
experiment.define_visual_stimuli()
experiment.present_instructions('welcome')

## practice
experiment.present_instructions('practice')
experiment.run_practice()

## experiment
experiment.set_experiment_parameters()
experiment.present_instructions('experiment')
experiment.run_experiment()

## thank you

experiment.present_instructions('thank_you')
```

Try out the experiment on your own computer

https://github.com/ualsbombe/2025_advanced_cognitive_neuroscience/blob/main/experiment/subjective_experience_v0.py



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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.
- 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)

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Study groups

Katharina Hellmund	0
Daniel Aakjær Lundgaard	0
Louise Brix Pilegaard Hansen	0
Ingrid Sofia Mikaela Backman	0
Ramona Tanovic	0
Elisius Krustrup Lyng Pedersen	1
Emil Frej Brunbjerg	1
Mads Munch Mikkelsen	1
Márton Kardos	1
Sára Anna Szabó	1
Ditlev Kræn Andersen	2
Niels Værbak	2
Malene Jensen	2
Gréta Harsányi	2
Bíborka Saldinger	2
Matilda Sif Rhys-Kristensen	3
Ida Munch Andresen	3
Nadia Hajighassem	3
Glorija Gabija Stvol	3
Santa Vintere	3

Søren Søndergaard Meiner	4
Johanne Sejrskild Rejsenhus	4
Ane Iben Lodahl	4
Barbora Ferusová	4
Bryan William Roemelt	4
Mattis Thierion Lund	5
Sofie Bøjgaard Thomsen	5
Peter Houe Wisnewski	5
Laura Sørine Voldgaard	5
Carl Emil Grum-Nymann	6
Hannah Mai Højgaard	6
Liv Drasbek	6
Julie Bang Mikkelsen	6
Christian Westh Stenbro	7
Magnus Severin Ringgaard Pou	7
Yosuf Ismael Qasim Barzinji	7
Amalie Overgaard Stevnhøj Pe	7

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Presentation topics

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

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Choosing them

- Getting a random seed from random.org (between 0 and 255)

```
import random

random.seed('from random.org')

k = 8
population = range(k)
samples = random.sample(population, k=k)

print(samples)
```

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Student counsellors

Christian: Cognitive Science

Charlotte: Linguistics and Cognitive Semiotics

Sofia: Scandinavian Languages and Literature

Pernille: Experience Economy and Cultur Of Events

https://studerende.au.dk/en/studies/subject-portals/arts/counselling/student-counsellor/nordiskeng

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The course plan

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)

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The course plan

Week 37:

No Teaching

Readings: None

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The course plan

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

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The course plan

Week 39:

MEG workshop: Measuring and predicting visual subjective experience (see below)

Readings: Chapters 5-7, Puce A, Hari R (2023)

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The course plan

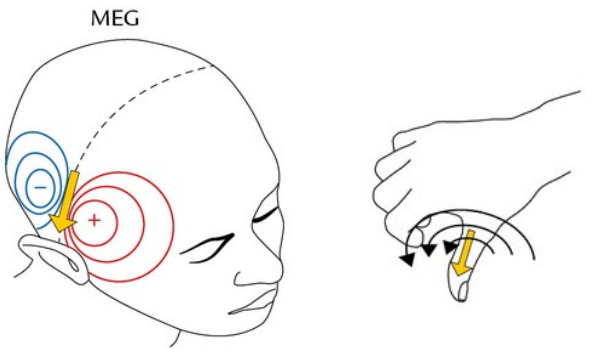
Week 40:

Lesson 2: Basic physiology and Evoked responses

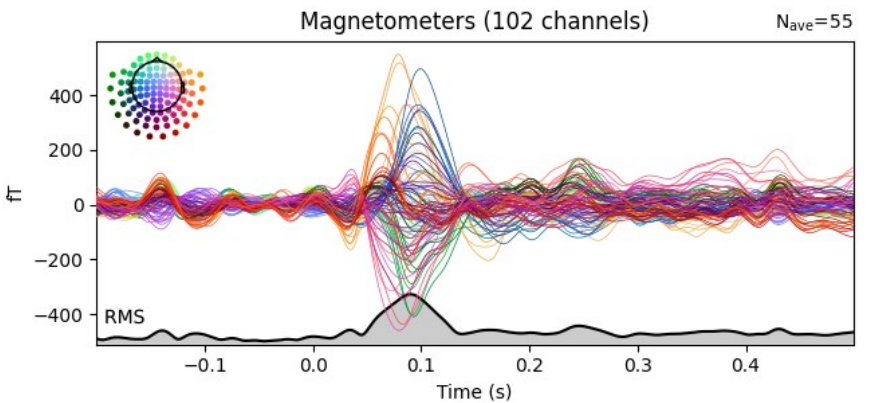
Class 2: Evoked responses to different levels of subjective experience

Readings: Chapters 3, 10 & 12, Puce A, Hari R (2023)

$$\boldsymbol{b}(t) = \begin{bmatrix} b_1(t) \\ b_2(t) \\ \vdots \\ b_M(t) \end{bmatrix}$$



Adapted from Figure 1.2: Puce A, Hari R (2023) MEG–EEG PRIMER, 2nd edition. Oxford University Press, Incorporated, United States



https://mne.tools/stable/auto_tutorials/evoked/20_visualize_evoked.html#plotting-signal-traces

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The course plan

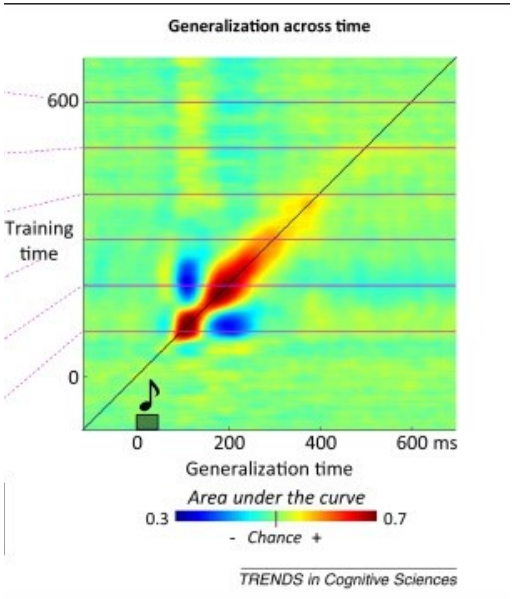
Week 41:

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. 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

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The course plan

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

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The course plan

Week 43:

Lesson 4: Forward modelling and dipole estimation

Class 4: Creating a forward model

Readings:

FieldTrip video: https://www.youtube.com/watch?v=3Q8HLHNieuI

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

$$\boldsymbol{s}(\boldsymbol{r},t) = \begin{bmatrix} \boldsymbol{s}_x(\boldsymbol{r},t) \\ \boldsymbol{s}_y(\boldsymbol{r},t) \\ \boldsymbol{s}_z(\boldsymbol{r},t) \end{bmatrix}$$

$$\boldsymbol{L}(\boldsymbol{r}) = [\boldsymbol{l}_x(\boldsymbol{r}), \boldsymbol{l}_y(\boldsymbol{r}), \boldsymbol{l}_z(\boldsymbol{r})]$$

$$\boldsymbol{b}(t) = \int_{\Omega} \boldsymbol{L}(\boldsymbol{r}) \boldsymbol{s}(\boldsymbol{r},t) d^3r$$

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The course plan

Mid-term evaluation

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The course plan

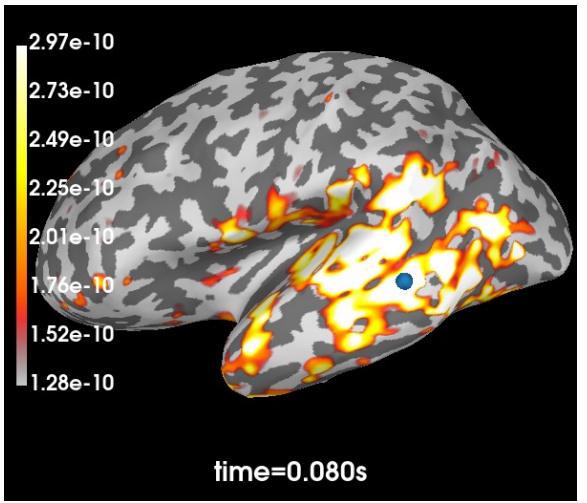
Week 44:

Lesson 5: Inverse modelling: Minimum-norm estimate

Class 5: Predicting subjective experience in source space

Readings: Chapter 3 Sekihara K., Nagarajan S (2008)

$$\hat{\boldsymbol{\nu}}_{vox}(t) = \boldsymbol{L}_V^T(\boldsymbol{G} + \epsilon \boldsymbol{I})^{-1}\boldsymbol{b}(t)$$



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https://mne.tools/stable/auto_tutorials/inverse/40_mne_fixed_free.html#fixed-orientation

The course plan

Week 45:

Lesson 6: Inverse modelling: Beamforming

Class 6: Predicting subjective experience in source space, continued

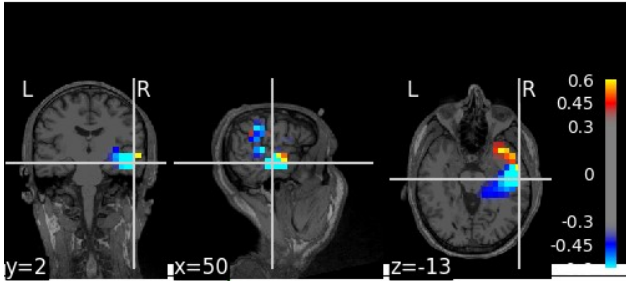
Readings:

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)

$$\hat{s}(r,t) = \frac{l^T(r)R^{-1}b(t)}{[l^T(r)R^{-1}l(r)]}$$



https://mne.tools/stable/auto_tutorials/inverse/50_beamformer_lcmv.html#on-mri-slices-orthoview-2d

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The course plan

Week 46:

Lesson 7: What about that other cortex? - the cerebellar one

Class 7: Oral presentations (part 1)

Readings:

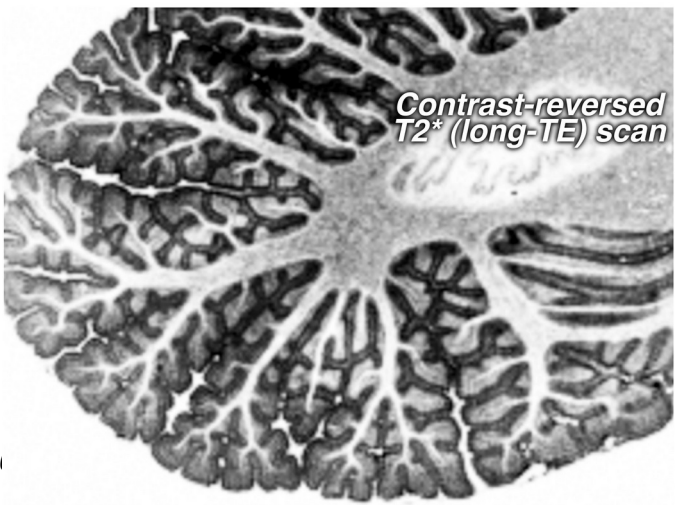
Sokolov AA, Miall RC, Ivry RB (2017) The Cerebellum:
Adaptive Prediction for Movement and Cognition.
Trends in Cognitive Sciences 21:313–332. https://doi.org/10.1016/j.tics.2017.02.005

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


RESEARCH ARTICLE | BIOPHYSICS AND COMPUTATIONAL BIOLOGY |

The human cerebellum has almost 80% of the surface area of the neocortex

Martin I. Sereno, Jörn Diedrichsen, Mohamed Tachrount, Guilherme Testa-Silva, Helen d'Arceuil, and Chris De Zeeuw -2 Authors Info & Affiliations



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The course plan

Week 47:

Lesson 8: Guest lecture: Laura Bock Paulsen: Respiratory analyses

Class 8: Oral presentations (part 2)

Readings: To be announced

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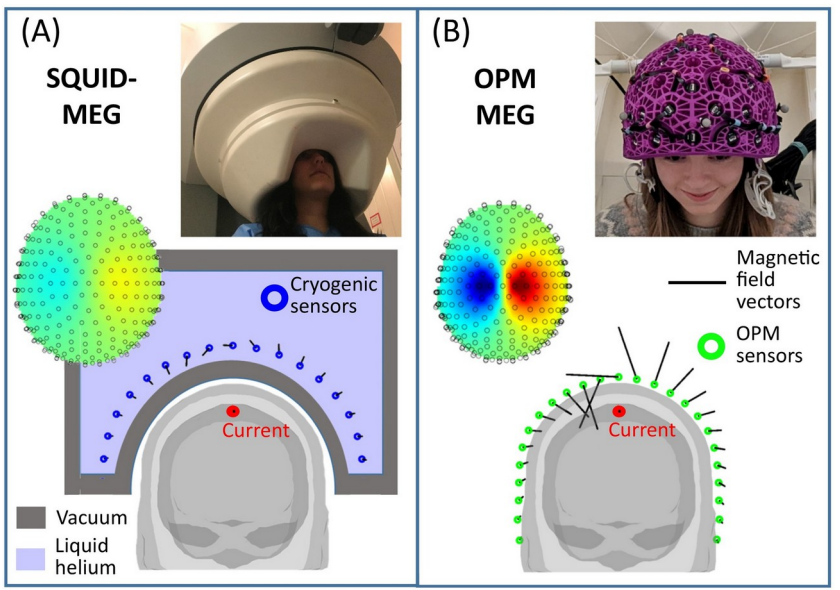
The course plan

Week 48:
Lesson 9: Sensors of the future
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



Trends in Neurosciences

Brookes MJ, Leggett J, Rea M, et al (2022) Magnetoencephalography with optically pumped magnetometers (OPM-MEG): the next generation of functional neuroimaging. Trends in Neurosciences 45:621–634. https://doi.org/10.1016/j.tins.2022.05.008

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OPMs in Aarhus

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OPMs in Aarhus

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OPMs in Aarhus

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Final evaluation

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Week 49:
Lesson 0 again: What was it all about?
Class 10: Work on your portfolios
Readings: Baillet S (2017) Magnetoencephalography for brain electrophysiology and imaging. Nat Neurosci 20:327–339. https://doi.org/10.1038/nn.4504

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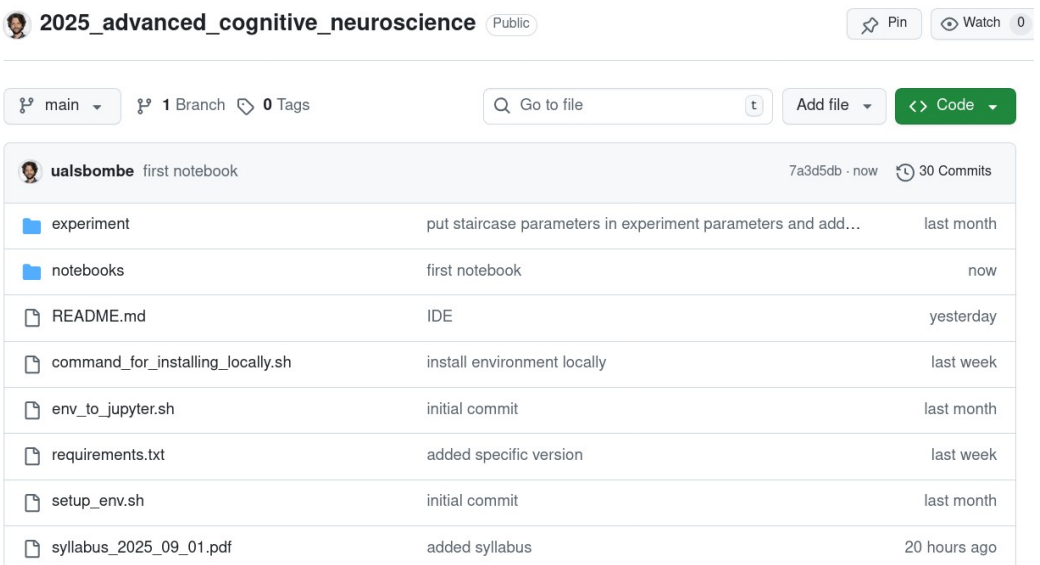
Keeping up to date - github

- https://github.com/ualsbombe/2025_advanced_cognitive_neuroscience/tree/main
- Notebooks will be made available here; upload to your member files on UCloud



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The course plan

Week 36:
Lesson 0: What is it all about?
Class 0: Setting up UCloud and installing MNE-Python

Week 37:
No Teaching

Week 38:
Lesson 1: Workshop paradigm: Measuring visual subjective experience + MR Recordings
Class 1: Running an MEG analysis of visual responses

Week 39:
MEG workshop: Measuring and predicting visual subjective experience (see below)

Week 40:
Lesson 2: Basic physiology and Evoked responses
Class 2: Evoked responses to different levels of subjective experience

Week 41:
Lesson 3: Multivariate statistics
Class 3: Predicting subjective experience in sensor space
Deadline for feedback: Video Explainer

Week 42:
Autumn Break

Week 43:
Lesson 4: Forward modelling and dipole estimation
Class 4: Creating a forward model

Week 44:
Lesson 5: Inverse modelling: Minimum-norm estimate
Class 5: Predicting subjective experience in source space

Week 45:
Lesson 6: Inverse modelling: Beamforming
Class 6: Predicting subjective experience in source space, continued

Week 46:
Lesson 7: What about that other cortex? - the cerebellar one
Class 7: Oral presentations (part 1)
Deadline for feedback: Lab report

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

Week 48:
Lesson 9: Sensors of the future
Class 9: Oral presentations (part 3)

Week 49:
Lesson 0 again: What was it all about?
Class 10: Oral presentations (part 4)

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Next lecture – workshop paradigm

- How to measure subjective experience
  - behaviourally
  - electrophysiologically
- What is the paradigm doing?
  - homework: test the paradigm on your own computer (in a psychopy env)

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Reading questions

- Ramsøy and Overgaard 2004
  - Why it is important that the subjects take part in constructing the scale?
    - You could have a look at the discussion of *sensitivity* and *exhaustiveness* in: Dienes Z (2007) Subjective measures of unconscious knowledge. In: Chakrabarti RB and BK (ed) Progress in Brain Research. Elsevier, pp 49–269
- Sergent et al. 2005
  - How does the attentional blink paradigm work?
  - Why are the continous scale points collapsed into seen/unseen?
  - What are the important components according to Sergent et al.?

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Next class – setting up UCloud and local environment

README

Advanced Cognitive Neuroscience; Autumn 2025

This is the readme for the course Advanced Cognitive Neuroscience run at the Cognitive Science programme at Aarhus University 2025.

All code is tested using Coder Python version **1.103.1**

Some text and code shamelessly stolen from Laura Bock Paulsen's repository: https://github.com/laurabpaulsen/CogNeuro2025/tree/main/EEG_LAB#readme

Overview

This repository contains the notebooks necessary to the course and the MEG lab. The following important files are included:

- `setup_env.sh` : This is a Bash script that sets up a virtual environment for the project. It installs the necessary packages and saves them in a folder called `env`.
- `env_to_jupyter.sh` : This is a Bash script that installs the virtual environment as a kernel in in Jupyter Notebooks. This is necessary for running the notebooks using the virtual environment.
- `requirements.txt` : This file lists the packages that are installed in the virtual environment, which the scripts have been tested on.

Some advanced plotting of brains and such will sadly not work on UCloud, so you would want to create a local environment as well. There will be instructions for that as well.

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