Advanced cognitive neuroscience

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Office Hours: after appointment
Office: CFIN, Nørrebrogade 44, 1A

Web: **BlackBoard**
Course GitHub page
Lecture hours: Monday 12.00 - 14.00
Lecture room: 1441 - 113 (Aud. 3)
Class room: 1451 - 318
Class hours: Wednesday 13.00 - 15.00

Contents

0 Course description

Remark. *PLEASE NOTE THAT TEACHING MAY BE CONVERTED INTO ON-SITE CAMPUS TEACHING IF DISTANCING REQUIREMENTS ARE LIFTED OR INTO VIRTUAL TEACHING IF THE CAMPUS IS ONCE AGAIN PHYSICALLY CLOSED.*

For a description and regulations of the course and the program see **cognitive science program page** and the **the course page**

1 Materials and readings

- There are no text book for the course. Articles and book chapters will be available on BlackBoard.
- Slides will be available at the GitHub page on the day of the lecture.
- Practical notes will also be available at the GitHub page on the day of the practical.
- For the classes we will use Python with specialised packages, see next section.

Python packages

My recommendation would be to use Anaconda python package manager, either Anaconda or the command line only Miniconda

The following packages will be used in the course and are needed. A yml file is a available on the course GitHub page. In the *additional materials* PDF there is a description of how to install anaconda, and the environment with the packages.

The packages we will use are:

- Python 3.6+
- MNE-python https://mne.tools/stable/index.html
- Scikit-learn https://scikit-learn.org/stable/
- Braindecode https://braindecode.org/
- PyTorch https://pytorch.org/

2 Course structure

Lectures Mondays from 12.00 to 14.00 (remember the academic quarter) and corresponding classes (i.e. practical exercises) on Wednesdays 13.00-15.00.

Given the current regulations will we have one practical class with room for all. Please note that this is subject to changes if the regulations change and that this can happen swiftly.

3 Exam

EXAM DEADLINE: DECEMBER 21st

The exam consists of a portfolio containing 3-7 assignments, which the student submits to the teacher during the course. Their form (individual and/or group-based, written, product and/or oral, set and/or on a topic of the student's choice), length and deadline for submission will be announced on Blackboard by the teacher at the start of the semester.

The complete portfolio must be handed in for assessment in the Digital Exam system by a specified date. The portfolio can be written individually or in groups of up to 3 students. **Group assignments must be written in such a way that the contribution of each student can form the basis of individual assessment**. The portfolio should clearly state which sections the individual students are responsible for.

Teacher's note. A good portfolio have an intrduction and discussion/conclusion that binds the individual assignments together.

Formalia for the portfolio papers

- A selection of three paper with an introduction and discussion/conclusion is to be handed in as one joint submission.
- A paper can be maximum 7 normal pages, code goes in an appendix
- Introduction and discussion/conclusion is combined maximum of 7 normal pages.
- A normal page is 2400 charecters *including* spaces and in-text references.
- The reference list does *not* count for the pages limits.
- Citation style is APA7

Writing assignment questions

Writing assignments should include the answer to a question and any code used to answer the question should be linked to or send as a file – well commented.

If you would rather answer a question(s) you have made yourself, please email the instructor to get an approval before submitting the assignment.

Topic	**Question**
The brain	• Describe a cognitive function? • Discuss the use of fMRI and EEG/MEG for action selection?
Electrophysiology	• What are the pros and cons of EEG vs MEG? • How are ERPs related to brain structures and functions of the mind?
Oscillations	• How can oscillations be used to investigate and cognition? • Link oscillations to a cognitive function. This can be in term of frequencies and/or cortical location(s) etc.
MVPA	• Why use MVPA for statistical assessment of EEG data? • Pros and cons of linear vs non-linear MVPA models for brain imaging data
Neural Networks	• Are neural networks better than MVPA for analysis of neuroimaging data? • Can Neural networks be used to model cognition?

4 Readings

Week 0: introduction

There are no assigned readings but please install and configure git and make a GitHub account, see *Additional materials* for guide on this.

- Git: https://git-scm.com/
- GitHub: https://github.com

Additional readings & resources

- Video: Git Tutorial for Beginners: Command-Line Fundamentals

Week 1: the brain and brain data.

- Lerch, J. P., van der Kouwe, A. J. W., Raznahan, A., Paus, T., Johansen-Berg, H., Miller, K. L., Smith, S. M., Fischl, B., & Sotiropoulos, S. N. (2017). Studying neuroanatomy using MRI. *Nature Neuroscience*, *20*(3), 314–326. https://doi.org/10.1038/nn.4501
- Logothetis, N. K. (2008). What we can do and what we cannot do with fMRI. *Nature*, *453*, 869–78. https://doi.org/10.1038/nature06976
- Hallett, M. (2000). Transcranial magnetic stimulation and the human brain. *Nature*, *406*, 147–50. https://doi.org/10.1038/35018000

Additional readings & resources

- Arthurs, O. J., & Boniface, S. (2002). How well do we understand the neural origins of the fMRI BOLD signal? *Trends in Neurosciences*, *25*(1), 27–31. https://doi.org/10.1016/S0166-2236(00)01995-0

Week 2: electrophysiology

- Baillet, S. (2017). Magnetoencephalography for brain electrophysiology and imaging. *Nature Neuroscience*, *20*(3), 327–339. https://doi.org/10.1038/nn.4504
- Maris, E. (2012). Statistical testing in electrophysiological studies: Statistical testing in electrophysiological studies. *Psychophysiology*, *49*(4), 549–565. https://doi.org/10.1111/j.1469-8986.2011.01320.x
- Sassenhagen, J., & Draschkow, D. (2019). Cluster-based permutation tests of MEG/EEG data do not establish significance of effect latency or location. *Psychophysiology*, e13335. https://doi.org/10.1111/psyp.13335

Additional readings & resources

- Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., Goj, R., Jas, M., Brooks, T., Parkkonen, L., & Hämäläinen, M. (2013). MEG and EEG data analysis with MNE-Python. *Frontiers in neuroscience*, *7*, 267. https://doi.org/10.3389/fnins.2013.00267

- Video: EEG Analysis with the MNE Software by Alex Gramfort
- Video: MEG/EEG Toolkit Course 2018 Statistical testing of electrophysiological data
- http://www.fieldtriptoolbox.org/faq/how_not_to_interpret_results_from_a_cluster-based_permutation_test/

Week 3: oscillations

- Jensen, O., Spaak, E., & Zumer, J. M. (2014). Human brain oscillations: From physiological mechanisms to analysis and cognition. In S. Supek & C. J. Aine (Eds.), *Magnetoencephalography: From signals to dynamic cortical networks* (pp. 359–403). Springer Berlin Heidelberg
- Cohen, M. X. (2014). *Analyzing neural time series data: Theory and practice*. The MIT Press, chapters: 10-12

Additional readings and resources

- Video: MEG/EEG Toolkit Course 2018 Fundamentals of neuronal oscillations and synchrony

Week 4: oscillations cont.

- Varela, F., Lachaux, J. P., Rodriguez, E., & Martinerie, J. (2001). The brainweb: Phase synchronization and large-scale integration. *Nat Rev Neurosci*, *2*(4), 229–39. https://doi.org/10.1038/35067550
- Fries, P. (2005). A mechanism for cognitive dynamics: Neuronal communication through neuronal coherence. *Trends in cognitive sciences*, *9*, 474–480. https://doi.org/10.1016/j.tics.2005.08.011

Additional readings and resources

- Fries, P. (2015). Rhythms for Cognition: Communication through Coherence. *Neuron*, *88*(1), 220–235. https://doi.org/10.1016/j.neuron.2015.09.034

Week 5: connectivity

- Bassett, D. S., & Sporns, O. (2017). Network neuroscience. *Nat Neurosci*, *20*, 353–364. https://doi.org/10.1038/nn.4502
- Ju, H., & Bassett, D. S. (2020). Dynamic representations in networked neural systems. *Nature Neuroscience*. https://doi.org/10.1038/s41593-020-0653-3

Week 6: machine learning

- King, J.-R., Gwilliams, L., Holdgraf, C., Sassenhagen, J., Barachant, A., Engemann, D., Larson, E., & Gramfort, A. (2018). Encoding and Decoding Neuronal Dynamics: Methodological Framework to Uncover the Algorithms of Cognition, 19. https://hal.archives-ouvertes.fr/hal-01848442

- Bzdok, D. (2017). Classical Statistics and Statistical Learning in Imaging Neuroscience. *Frontiers in Neuroscience*, *11*, 543. https://doi.org/10.3389/fnins.2017.00543

Week 7: machine learning cont.

- Molnar, C. (2020). *Interpretable machine learning*. Lulu.com. https://christophm.github.io/interpretable-ml-book/, chapters: 2 & 4
- Haufe, S., Meinecke, F., Görgen, K., Dähne, S., Haynes, J.-D., Blankertz, B., & Bießmann, F. (2014). On the interpretation of weight vectors of linear models in multivariate neuroimaging. *NeuroImage*, *87*, 96–110. https://doi.org/10.1016/j.neuroimage.2013.10.067

Week 8: machine learning as signal processing

- Blankertz, B., Tomioka, R., Lemm, S., Kawanabe, M., & Muller, K.-R. (2008). Optimizing spatial filters for robust EEG single-trial analysis. *IEEE Signal processing magazine*, *25*(1), 41–56
- Kriegeskorte, N. (2008). Representational similarity analysis – connecting the branches of systems neuroscience. *Frontiers in Systems Neuroscience*. https://doi.org/10.3389/neuro.06.004.2008
- Cichy, R. M., Pantazis, D., & Oliva, A. (2014). Resolving human object recognition in space and time. *Nature Neuroscience*, *17*(3), 455–462. https://doi.org/10.1038/nn.3635

Week 9: neural networks

- LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, *521*, 436–444. https://doi.org/10.1038/nature14539
- Nielsen, M. A. (2015). *Neural networks and deep learning* (Vol. 2018). Determination press San Francisco, CA. http://neuralnetworksanddeeplearning.com/, chapters: 1-2

Week 10: neural networks cont.

- Lawhern, V. J., Solon, A. J., Waytowich, N. R., Gordon, S. M., Hung, C. P., & Lance, B. J. (2016). EEGNet: A Compact Convolutional Network for EEG-based Brain-Computer Interfaces. *arXiv e-prints*. https://doi.org/10.1088/1741-2552/aace8c
- Goodfellow, I. J., Pouget-Abadie, J., Mirza, M., Xu, B., Warde-Farley, D., Ozair, S., Courville, A., & Bengio, Y. (2014, June 10). *Generative Adversarial Networks*. arXiv: `1406.2661 [cs, stat]`. Retrieved April 23, 2020, from http://arxiv.org/abs/1406.2661
- Kriegeskorte, N., & Douglas, P. K. (2018). Cognitive computational neuroscience. *Nat Neurosci*, *21*(9), 1148–1160. https://doi.org/10.1038/s41593-018-0210-5

Week 11: summary and Q & A

- No readings.

5 Exercises and portfolio papers

For the practical classes there will be coding exercises for the topic we are having, where some will be covered in class and some are out-of-class activities with peer feedback. There will also be possibilities to write parts of the portfolio papers in the practical classes and get feedback on argument structures, materials selected, and similar questions.

The portfolio papers handed in doing the semester will be given peer feedback.

Remark. *The portfolio papers will **NOT** be given any official feedback doing the semester, as this would count as an exam attempt!*

Lecture	Exercise	Portfolio papers
0	Git & GitHub	
1	Programming exercises, Data structures, & MNE-python	
2	Writing paper 1	
3	Wavelets & Multitapers	Paper 1
4	Coherence & Intertrail phase coherence	
5	Writing paper 2	
6	MVPA pipeline	
7	MVPA & brain data	Paper 2
8	PCA, SPoC, & CSP	
9	Shallow Neural nets	
10	Neural nets and Brain data	
11	Writing paper 3	Paper 3