

Neuromatch Academy: a 3-week, online summer school in computational neuroscience

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Software

- [Review](#) ↗
- [Repository](#) ↗
- [Archive](#) ↗

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Summary

Neuromatch Academy (<https://academy.neuromatch.io>; (van Viegen et al., 2021)) was designed as an online summer school to cover the basics of computational neuroscience in three weeks. The materials cover dominant and emerging computational neuroscience tools, how they complement one another, and specifically focus on how they can help us to better understand how the brain functions. An original component of the materials is its focus on modeling choices, i.e. how do we choose the right approach, how do we build models, and how can we evaluate models to determine if they provide real (meaningful) insight. This meta-modeling component of the instructional materials asks what questions can be answered by different techniques, and how to apply them meaningfully to get insight about brain function.

| Week 1 | Week 2 | Week 3 |
|---------------------------------------|--------------------------------------|------------------------------------|
| W1D1 <i>Model Types</i> | W2D1 <i>Deep Learning</i> | W3D1 <i>Bayesian Decision</i> |
| W1D2 <i>Project Day 1</i> | W2D2 <i>Linear Systems</i> | W3D2 <i>Hidden Dynamics</i> |
| W1D3 <i>Model Fitting</i> | W2D3 <i>Biological Neuron Models</i> | W3D3 <i>Optimal Control</i> |
| W1D4 <i>Generalized Linear Models</i> | W2D4 <i>Dynamic Networks</i> | W3D4 <i>Reinforcement Learning</i> |
| W1D5 <i>Dimensionality Reduction</i> | W2D5 <i>Project Day 2</i> | W3D5 <i>Network Causality</i> |

Table 1. 2021 Neuromatch Academy Topics. Organized chronologically by week (W) and day of week (D), e.g. week 2 day 4 = W2D4. In addition, there are two days of preparatory instruction in coding Python, the materials for which can be found in W0D1 for 2020. The schedule shown here is from 2021, which was updated by dropping Modeling Practice day (old W1D2) and a second Deep Learning day (old W3D5) in favour of two dedicated project days and changing the order to group topics better conceptually. The content for these two days can still be found [here](#).

Materials consist of highly curated recorded lectures and tutorials, organized in ‘days,’ as well as a growing number of data sets with starter notebooks for group projects (5 in 2020; 12 added in 2021). Each day constitutes one teaching module and covers one topic in computational neuroscience (see table 1). While the content is organized as a 3-week crash-course of consecutive teaching modules that build on one another, it can

be rolled out at any pace, in its entirety or as stand-alone parts, provided prerequisites for each part are met. Most days can be used as separate, independent modules and can, for example, be combined with other instructional content. To facilitate this, we not only provide general prerequisites for the entire course but also daily topic-specific prerequisites (see wiki on [OSF](#)). The material is meant to either be taught to small groups of ~10 attendees guided by a teaching assistant, for instruction in a classroom, or for usage in other (potentially for-profit) events and could also be used for self-study.

Each instruction module (day) consists of 1) an introductory lecture (~30 minutes) that broaches the topic to students and explains the general approach, followed by 2) hands-on tutorials in the form of several ipython notebooks (~3 hours) with code-completion assignments and answers, and further instruction through embedded micro-lectures, and finally 3) an outro lecture (~30 minutes) to recapitulate the covered material and provide an outlook on its applicability to neuroscience research. Each day is meant to instruct the basics of a given topic and further readings are supplied.

All tutorials are available online in a permanent [archive](#) of the 2021 edition of NMA, which has a copy of the GitHub repository, a Jupyter Book and a set of tips we gave NMA teaching assistants, as well as links to many of the data sets for the group projects. This main archive describes where all materials can be found, and provides a table of pre-requisites for each day in the course, that should help self-study and integration of the material in other courses. There is a backup of all videos in a separate [archive](#) and the most up-to-date material is planned to stay available as an online [Jupyter Book](#). The material is largely self sufficient and could be used for self-study or as parts of another course. For both purposes, the solutions to problems are provided in the OSF archive and the GitHub repository. Projects are best done in a group of students, and materials to get students started are self-contained. Each data set for group projects is introduced, usually accompanied by a video explaining what is in the data set. We also provide Python code to either download the NMA-curated data set, or set up a connection with an external data base.

Attendees do group projects to apply and consolidate what they learn in the lectures and tutorials, and in 2020 we provided five curated data sets (see table 2) to use for these projects, including videos describing the data and ipython notebooks to get started. In 2021 we increased the number of curated data sets, and grouped them conceptually.

| Category | Data set | Year | Contains |
|----------|--|------|---|
| Neurons | Steinmetz data (Steinmetz et al., 2019) | 2020 | neuropixels recording (waveforms, task events, spikes) in mice doing a visual discrimination task |
| | Stringer data (Stringer et al., 2019, 2021) | 2020 | activity from ~10,000 V1 neurons, recorded with calcium imaging from a mouse in total darkness |
| | Allen Institute data (no citation) | 2021 | recordings from VIP, SST, etc from mice doing a visual adaptation task, with novel or familiar images |
| fMRI | HCP data (Barch et al., 2013 ; Van Essen et al., 2013) | 2020 | fMRI time series in 7 tasks and resting state for 340 human participants, and parcellation in ROIs |
| | FSL course task (no citation) | 2021 | complements HCP data with 2 language tasks, data at voxel level |
| | HCP retinotopy (Benson et al., 2018) | 2021 | allows visualizing receptive fields across brain regions |
| | Kay natural images (Kay et al., 2008 ; Naselaris et al., 2009) | 2020 | voxels from V1/V2/V3/V4, and annotated objects |

| Category | Data set | Year | Contains |
|----------|--|------|--|
| ECoG/EEG | Bonner navigation data (Bonner & Epstein, 2017) | 2021 | activity from 12 participants watching scenes or navigation sequences |
| | Algonauts video clip data (Kriegeskorte et al., 2008) | 2021 | activity in 10 participants watching 1000+ video clips algonauts |
| | Cichy objects/animals data (Cichy et al., 2014) | 2021 | activity in 16 participants watching 92 images |
| | Miller face/house data (Kai J. Miller et al., 2016, 2015, 2017) | 2021 | ECoG recordings from participants watching faces and houses |
| | Miller finger flex data (K. J. Miller et al., 2009 ; Kai J. Miller et al., 2012) | 2021 | ECoG recordings from participants moving their fingers |
| | Schalk joystick track data (Schalk et al., 2008, 2007) | 2021 | ECoG recordings from participants moving a joystick on 2D trajectories |
| | Memory N-back data (no citation) | 2021 | ECoG recordings in participants responding to repeated house images 0, 1 or 2 stimuli back |
| Behavior | Miller motor imagery data (Kai J. Miller et al., 2010) | 2021 | ECoG recordings from participants moving and imagining to move their fingers |
| | Caltech data set (no citation) | 2021 | pose-tracking from socially interacting mice |
| | IBL data (The International Brain Laboratory et al., 2021) | 2020 | behavior of mice doing a visual detection task with a bias |

Table 2. Data sets for group projects. *Many of the data sets are available through a set of OSF repositories: [fMRI\(2020\)](#), [fMRI\(2021\)](#), [Neurons](#) and [ECoG/EEG](#).*

Statement of Need

Need for training

Neuroscience makes use of a broad range of computational techniques, but very few institutions have enough local expertise to provide meaningful instruction in all of them. As a result, most computational neuroscience researchers around the world lack appropriate training and we aim to provide that here. Additionally, by focussing on meta-modeling, i.e. which method to apply in which situation, we assure that computational methods will be used in such a way as to lead to meaningful new insights into brain function.

Need for accessible materials

Neuroscience, like any academic discipline, struggles to be more diverse and inclusive, in the social sense. We aim to remove some of the barriers to good educational materials for computational neuroscience. By making the material freely available online, we make them available to anyone worldwide; we thus remove the need to be part of geographically restricted, rich, prestigious institutions to gain access to high-level training (e.g. the notebooks have been mirrored on gitee and videos on bilibili to make the material more accessible in China). Freely accessible materials should also alleviate negative effects of systemic biases and gatekeeping leading to discrimination in access to resources. A further step towards increased diversity is made by having diverse lecturers who may serve as role models. Finally, we have added captions in English and translated them in Mandarin and

Spanish for both people with hearing difficulties and those who are not fluent in English (YouTube metrics indicate ~35% of views use captions). While our efforts do not achieve full inclusivity and diversity in neuroscience, we believe it is a step in the right direction.

Experience

In early 2020, the organizers of the in-person summer school “CoSMo” (*Computational Sensory and Motor Science*) were confronted with the COVID pandemic and decided to create an online version. They quickly realized that the school could be scaled up and be more accessible to students all over the world with more diverse backgrounds, and somehow made this happen (Blohm, 2021). They adopted the matching algorithm (Achakulvisut et al., 2020) used at the Neuromatch Conferences (NMC) for creating student groups (“pods”) for the summer school and to find mentors for project groups. The summer school team joined forces with the NMC team, called itself Neuromatch Academy and quickly got a lot of attention (Sadnicka et al., 2021). This created the current Neuromatch community (Kording, 2021), that aims to use technology and online tools to make the future of neuroscience more accessible, inclusive and positive.

A first step in building an accessible content base was to recruit a pool of lecturers and content creators with an eye towards maximizing diversity in dimensions such as gender, race and career status. This helps to reduce intrinsic forms of bias within the lectures and exercises, and also helps to broadcast the accessibility of the discipline to a wider audience.

The materials (intro, outro and micro-lectures as well as tutorials) went through several instances of quality control, before we used it in our own summer school. First, a group of content reviewers provided feedback on the material which was integrated by the primary content creators. Second, a group of skilled programmers served as tutorial editors who went through the tutorials to review and edit code and make sure it all adhered to our standards. For example, they made sure code was as simple as possible and that all plots used the same look. Third, two separate groups of content testers independently went through all the material as if they were students, providing feedback to tutorial writers who integrated this feedback. They reported errors and omissions and provided pedagogical advice on confusing or misleading parts to the rest of the team. They also made sure the micro-lectures connected with the material in the tutorials. For example, we made sure the hands-on tutorials are do-able within the time frame, while providing bonus materials for faster attendees. After this step, videos of lectures were finalized. Fourth, the tutorial and code editors once again made sure all tutorials worked, used the same style and connected with the rest of the material. Contributors to the content creation process are listed in Appendix 1. For future rounds of our summer school, we also had content testers provide structured feedback on the material during the actual summer school, and about ~90% of attendees and TA’s filled in end-of-day surveys during the actual summer school in 2020. We have and will use this feedback to further improve the materials and organization of the summer school. The most recent version of the materials can be found on GitHub <https://github.com/NeuromatchAcademy/> and in this [Jupyter Book](#). Issues can be filed on the GitHub repository, for further improvements.

Our quality-control processes ensured that the course content was well received. During the summer of 2020, we taught the Neuromatch Academy Computational Neuroscience material to 1757 interactive students in 64 countries with 191 teaching assistants, and in the summer of 2021 we taught 1873 students from 87 countries with 198 teaching assistants guiding a pod, augmented with 28 teaching assistants who specialized in project supervision. In 2020 there were also ~6000 registered observer students, and >9000 in 2021. In both years, the summer school ran 24/7 across all timezones with no major glitches. The percentage of interactive students that completed at least 50% of classes was 86% in 2020 and 58% in 2021. In 2020, of all respondents to the end-of-day survey,

94% would recommend NMA to a friend, and in 2021 we asked “Overall, how was your experience with NMA?” to which 88% of responses was either Very Good or Excellent.

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The Neuromatch Academy summer school also crucially relied on many teaching assistants, mentors and people organizing the community. Many of these people provided valuable feedback which will be used to improve the material and experience in coming summer schools. We wish to thank everyone involved in making NMA a success!

Appendix 1: Author Contributions

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Table A1: Contributions of Neuromatch Academy content creators.

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