PSYC50: The Rhythmic Brain

Spring 2016

Classroom: 303 Moore Hall (*to be confirmed*)
TuTh 10:00-11:50 (10A)

Instructor: Dr. Matt van der Meer
Office Location: 259 Moore Hall
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Office Phone: 603-646-0610
Office Hours: Thu 1-2pm or by e-mail appointment
X-hour: *W 3:00-3:50 (used some weeks; check the schedule below)*

Course Description

This course explores the physiological basis and functional relevance of oscillations, which are ubiquitous in the brain. Rhythmic pattern generators in specific neurons and circuits are essential for generating repeating movements such as breathing and walking; yet, oscillations are equally prominent in neural systems for sensation, cognition, and memory. Could it be that these rhythms are a fundamental building block of information processing in neural circuits? This course provides an introduction to the detection, analysis and interpretation of oscillations in the brain. Using these tools, we will survey the origin and functional role of oscillations in a variety of neural systems across animal and human species, and ask what general principles emerge.

Course Goals

Content goals:

- Provide an introduction to some of the most studied neural systems in which oscillations seem to be important: attention in sensory systems, learning and memory in the hippocampus, action selection and motor control in the basal ganglia, binding of features across cortical areas, and others.

- Relate an understanding of specific oscillating neural systems that oscillate (above) to current theories and general principles of brain oscillations. Particular emphasis: oscillations as a “meso-scale” connecting idea that can link physiological features at the single cell level to network motifs and ultimately information processing and behavior.

- Gain an elementary understanding of brain signal processing, necessary to critically evaluate results and current ideas in the field (no specific math or programming background needed -- no need to be scared!)

Skill goals:

- Develop and practice systematic steps involved in active reading of papers in the scientific literature, including identification and critical evaluation of their central claims, relationships with broader context, and presenting their content for didactic purposes.

- Gain hands-on experience with EEG headsets that can be used to record brainwaves, including setting up and acquiring data, distinguishing artefactual signals from true brain signals, and elementary data processing and analysis workflow in MATLAB (not evaluated; see below for details).

Pre-requisites

PSYCH 6 and one of (21, 26, 27, or 28)

A basic understanding of the levels of organization of the brain is provided by PSYCH 6 and will be built on in this course. At least one 20-level course will provide a reference set of more in-depth topics in neuroscience, which in this course you will be invited to consider from the point of view of brain oscillations.

Format

Two class meetings per week. Tuesday meetings will be a primarily lecture-style introduction to that week's topic(s), with a few break-out sessions and demos mixed in. Preparation for Tuesday meetings typically is reading a chapter from the main course text, which we will unpack, clarify and discuss in class.

Thursday meetings center on the presentation and discussion of classic and current scientific literature in the field: some experimental papers, some review papers, and some opinion pieces (2 papers per meeting).

If you are presenting, you will give a short presentation on your chosen paper from the list. If you are not presenting, you will prepare two discussion questions on your chosen paper, submit them on Canvas, and raise them in class.

Paper presentations and discussions will start on Thursday in Week 3.

Several optional X-hours are scheduled to help you get started with visualization and analysis of neural data using MATLAB, a programming environment for science and engineering. This is not an assessed component of the course, and so you may skip it without affecting your course evaluation -- although you may find participating in it enriches your understanding of other course components! If you plan to do an experimental project instead of a final paper (see the section on this below), you should attend these sessions so you are prepared. Previous programming experience is helpful, but not assumed.

Course materials

The main course text, "Rhythms of the Brain" by Gyorgi Buzsaki (Paperback edition, approx. $40) is required. It is stocked at the Dartmouth bookstore and widely available online.

Further readings (van der Meer introductory text, and discussion papers for Thursdays), given in the list below, are linked to on the course Canvas site.

Grading

All graded items will be scored on a 0-100 scale, weighted, and then converted to the nearest equivalent letter grade (conversion here).

Weekly quizzes

~5 questions each week designed to guide you in your reading of the main course text, and to prepare you for the type of questions you will see on the midterm exam. Mixture of multiple-choice and short answer, to be completed on Canvas before Tuesday's class meetings.

8 weekly quizzes, lowest grade dropped, total 10% of final grade

Midterm exam

Designed as a focal point to build and test your understanding the fundamental concepts of describing, detecting, and interpreting brain oscillations. Question style and content will be very similar to that in the quizzes. Material covered will be up to the Week 5 Tuesday meeting and associated chapter.

In-class midterm exam (Thursday Week 5), 30% of final grade

The X-hour before the midterm (Wed 4/29) will be used as an optional midterm Q&A session.

Presentations

A central element of the course that facilitates extracting the main points from primary literature, relating the aims and claims to a broader perspective (the Tuesday lecture big concepts and associated reading), building an understanding of the methods and interpretations (supported by Tuesday methods tutorials), and surveying some of the central ideas related to brain oscillations.

Presenting, 20% of final grade (average of all presentations; evaluated using this rubric)

Discussion questions, 10% of final grade (lowest grade dropped; evaluated using this rubric)

The goal is to have everyone do two presentations and submit five sets of discussion questions, but depending on enrollment we may have to change things around a bit.

Final paper (literature synthesis, grant proposal, or experimental project report)

An opportunity to synthesize elements from the course into a coherent whole, and to explore your favorite topic in more depth.

Due Thu 6/2 before midnight. Late submissions will incur a 10% penalty per 24 hours, with a hard cutoff Sunday 6/5 midnight.

30% of course grade (evaluated using this rubric)

Optionally, you are welcome to submit a bullet-point outline, or more advanced draft as you wish, to me before midnight on Tue 5/31 at the latest. Then I will get comments back to you before the weekend.

Preliminary schedule (see the Canvas course site for the up-to-date version!)

Date	Topic, in-class activities	To do before class meeting
Week 1		
Tue 3/29	Welcome, overview, introduction with big ideas and motivating examples; course practicalities, Q&A, getting to know your textbook, short intake survey, Emotiv EEG headset hands-on	nothing!
Wed 3/30	*Optional X-hour: getting started with visualizing & analyzing brain signals in MATLAB*	*(install MATLAB on your computer)*
Thu 3/31	Brain rhythms: why you should care (presenter: MvdM)	read van der Meer Ch1, *practice discussion Qs due*
Week 2		
Tue 4/5	Describing and analyzing oscillations; sources of oscillations in the brain (presenter: MvdM)	read van der Meer Ch2 and Ch3; *Q1 due*
Wed 4/6	*Optional X-hour: spectral analysis (1)*	
Thu 4/7	Where do brain rhythms come from? In-class problem sets and discussion (big picture review papers); "how to read a paper" tutorial	*read papers; discussion questions due* (no presentations)
Week 3		
Tue 4/12	Brain rhythms as a clock for the brain (presenter: MvdM)	read Buzsaki Ch5; *Q2 due*
Wed 4/13	*Optional X-hour: spectral analysis (2)*	
Thu 4/14	Why are there (so many) brain rhythms? Presentations & discussion.	*read papers; discussion questions due, or present*
Week 4		
Tue 4/19	Synchrony (presenter: MvdM)	read Buzsaki Ch6; *Q3 due*
Wed 4/20	*Optional X-hour: analyzing relationships between multiple signals (1)*	
Thu 4/21	Discoordination in schizophrenia: a case study of the clinical relevance of brain oscillations. Presentations & discussion.	*read papers; discussion questions due, or present*
Week 5		
Tue 4/26	Sleep (presenter: MvdM)	read Buzsaki Ch7; *Q4 due*
Wed 4/27	*Optional X-hour: midterm Q&A*	
Thu 4/28	In-class midterm	relax! If you've done the quizzes and kept up with the reading, you'll be fine
Week 6		
Tue 5/3	Learning (presenter: MvdM)	read Buzsaki Ch8; *Q5 due*
Wed 5/4	*Optional X-hour: real-time signal processing*	
Thu 5/5	Rhythms for memory and replay. Presentations &	*read papers; discussion*

	discussion.	*questions due, or present*
Week 7		
Tue 5/10	The gamma glue (presenter: MvdM)	read Buzsaki Ch9; *Q6 due*
Wed 5/11	*Optional X-hour: start your own EEG project!*	
Thu 5/12	Binding & communication through coherence. Presentations & discussion.	*read papers; discussion questions due, or present*
Week 8		
Tue 5/17	State-dependence (presenter: MvdM)	read Buzsaki Ch10; *Q7 due*
	NO optional X-hour. Work on bullet point outline & sources for final paper. Send outline to MvdM for comments.	
Thu 5/19	State-dependence and subsequent memory effects. Presentations & discussion.	*read papers; discussion questions due, or present*
Week 9		
Tue 5/24	Navigation in real and memory space (presenter: MvdM)	read Buzsaki Ch11; *Q8 due*
	NO optional X-hour. Work on draft of final paper. Send to MvdM by midnight 5/25 if you want comments before the weekend.	
Thu 5/26	Theta oscillations in the hippocampus. Presentations & discussion.	*read papers; discussion questions due, or present*
Week 10		
Tue 5/31	No class: work on final paper!	
	final paper due Thu 6/2 before midnight	

Preliminary reading list (see the Canvas course site for the up-to-date version!)

<u>Week 1</u>

Thursday: van der Meer (unpublished manuscript) Brainwaves: an introduction, Ch1

<u>Week 2</u>

Tuesday: van der Meer (unpublished manuscript) Brainwaves: an introduction, Ch2+3

Thursday theme: where do brain rhythms come from?

Womelsdorf T, Valiante TA, Sahin NT, Miller KJ, Tiesinga P (2014) Dynamic circuit motifs underlying rhythmic gain control, gating and integration. *Nature Neuroscience* 17(8): 1031-1039

Buzsaki G, Anastassiou CA, Koch C (2012) The origin of extracellular fields and currents -- EEG, ECoG, LFP and spikes. *Nature Reviews Neuroscience* 13:407-420

<u>Week 3</u>

Tuesday: Buzsaki Ch 5 (system of rhythms)

Thursday theme: why are there (so many) brain rhythms?

Buzsaki et al (2013) Scaling Brain Size, Keeping Timing: Evolutionary Preservation of Brain Rhythms. *Neuron.*

VanRullen and Koch (2003) Is perception discrete or continuous? *Trends in Cognitive Sciences.*

Lakatos et al. (2008) Entrainment of Neuronal Oscillations as a Mechanism of Attentional Selection. *Science*.

<u>Week 4</u>

Tuesday: Buzsaki Ch 6 (synchrony)

Thursday theme: Schizophrenia and discoordination

Uhlhaas & Singer (2015) Oscillations and Neuronal Dynamics in Schizophrenia: The Search for Basic Symptoms and Translational Opportunities. *Biol Psychiatry* 77:1001–1009 (review)

Gandal et al. (2012) Gamma synchrony: Towards a translational biomarker for the treatment-resistant symptoms of schizophrenia *Neuropharmacology* 62: 1504-1518 (review)

Tada et al (2014) Differential Alterations of Auditory Gamma Oscillatory Responses Between Pre-onset High-risk Individuals and First-episode Schizophrenia *Cereb Cortex* (primary literature)

<u>Week 5</u>

Tuesday: Buzsaki Ch 7 (sleep)

Thursday: no reading – midterm exam

<u>Week 6</u>

Tuesday: Buzsaki Ch 8 (learning)

Thursday theme: memory and replay

Marshall et al. (2006) Boosting slow oscillations during sleep potentiates memory. *Nature* 444, 610-613

Bendor & Wilson (2012) Biasing the content of hippocampal replay during sleep. *Nature Neuroscience* 15(10): 1439-1446

<u>Week 7</u>

Tuesday: Buzsaki Ch 9

Thursday theme: the binding problem

Bosman et al. (2012) Attentional stimulus selection through selective synchronization between monkey visual areas. *Neuron* 75(5): 875–888

Siegle et al. (2014) Gamma-range synchronization of fast-spiking interneurons can enhance detection of tactile stimuli. *Nature Neuroscience* 17(10): 1371-1379.

Fries (2015) Rhythms for Cognition: Communication through Coherence. *Neuron* 88: 220-235.

Week 8

Tuesday: Buzsaki Ch 10

Thursday theme: state-dependence

Song et al. (2014) Behavioral Oscillations in Attention: Rhythmic α Pulses Mediated through θ Band. *Journal of Neuroscience* 34(14): 4837-4844

Sederberg et al. (2003) Theta and gamma oscillations during encoding predict subsequent recall. *Journal of Neuroscience* 23(34): 10809-10814

Week 9

Tuesday: Buzsaki Ch 11

Thursday theme: encoding and retrieval in the hippocampus

Zhang et al. (2016) Spatial Sequence Coding Differs during Slow and Fast Gamma Rhythms in the Hippocampus. *Neuron* 89(2):398–408

Siegle et al. (2014) Enhancement of encoding and retrieval functions through theta phase-specific manipulation of hippocampus. *eLife 3:e03061*

Week 10

No reading, work on final paper!

Academic Honor

By now you will be familiar with Dartmouth's Academic Honor principle. Applied to this course, the Principle implies you are welcome to discuss all components of the course with your classmates; however any work that you submit should reflect your own understanding of the material. For instance, it is fine to discuss the quiz questions with your classmates, for the purpose of building your own motivation and justification for your chosen answers; it is not OK so simply copy someone else's choices. Similarly, for the final paper, you must submit work that is your own, making sure to cite your sources correctly to avoid plagiarism.

Religious Observances

Some students may wish to take part in religious observances that occur during this academic term. If you have a religious observance that conflicts with your participation in the course, please meet with me before the end of the second week of the term to discuss appropriate accommodations.

Student Needs

Students with disabilities who may need disability-related academic adjustments and services are encouraged to see me privately as early as possible in the term. Students requiring disability-related academic adjustments and services must consult the Student Accessibility Services office (205 Collis Student Center, 646-9900, Student.Accessibility.Services@Dartmouth.edu). Once SAS has authorized services, students must show the originally signed SAS Services and Consent Form and/or a letter on SAS letterhead to their professor. As a first step, if students have questions about whether they qualify to receive academic adjustments and services, they should contact the SAS office. All inquiries and discussions will remain confidential.