

The Brain & Memory

UN3445 / Course Syllabus / Fall 2019

4 points

When / Where

Mondays, 2:10-4pm, Schermerhorn 405

Instructor

Dr. Mariam Aly [ma3631@columbia.edu]

Office hours: Mondays and Fridays, 4-5pm, Schermerhorn 355D

no office hours on Friday, October 4, or on academic or university holidays

Prerequisites

UN1010 (Mind, Brain, & Behavior), UN2430 (Cognitive Neuroscience), or equivalent introductory course in neuroscience or cognitive psychology, **and** instructor's permission

Bulletin description

This seminar will give a comprehensive overview of episodic memory research: what neuroimaging studies, patient studies, and animal models have taught us about how the brain creates, stores, and retrieves memories.

Detailed description of the course

In the first part of the class, we will examine the neural underpinnings of basic memory phenomena, such as encoding, storage, and retrieval. We will then delve into theories of memory and current debates in the field. Finally, we will discuss challenges to the traditional views of "memory systems" in the brain. The readings will comprise empirical papers (which report new experiments and their results) and review papers (which summarize and synthesize a large body of research). The goal of the seminar is to arrive at a deeper understanding of what we know about memory and what we are still struggling to understand.

Each week will be devoted to a different topic. Class will begin with a brief overview (by the instructor) of the topic for that week. Most of the class will comprise student presentations and discussion. Each student is responsible for one presentation on the topic of their choice. Each student must e-mail the instructor (as soon as possible after the first class) with their top three choices, and every effort will be made to give each student one of their preferences. Each student can either thoroughly present one paper or briefly present two papers. The papers can be from the required or supplementary readings (see comprehensive reading guide).

Course goals and learning objectives

This course will give you training in reading primary research articles and review papers, the majority of what scientists read. Primary research articles and review papers are a much different reading experience than textbooks, and reading, dissecting, and critically thinking about them is a key skill for the developing scientist. This course will also enable you to engage in constructive scientific conversations and debates, which will broaden and deepen your understanding of cognitive neuroscience research, and teach you about which questions you should be asking as you read and hear about new results, and how to interpret them in the context of other studies. Furthermore, this course will enable you to learn how to effectively communicate, with both oral presentations and written work. You will learn how to review the literature and find relevant peer-reviewed papers, thus allowing you to

keep up to date in any field of science. You will also gain a deep understanding of the links between different areas of episodic memory research, and gain an appreciation of the development of this research over several decades, challenges to this research, and the latest advancements.

Role in the Psychology curriculum

PSYC UN3445 is a seminar designed particularly for undergraduates majoring in Psychology or Neuroscience & Behavior and for students participating in the Psychology Post-Baccalaureate Certificate program. It fulfills the following degree requirements:

- For the Psychology major or concentration in Columbia College and in the School of General Studies, for the Psychology minor in Engineering, and for the Psychology Post-Baccalaureate Certificate program, this class will meet the Group II (Psychobiology & Neuroscience) distribution requirement.
- For the Neuroscience and Behavior joint major, it will fulfill the fifth Psychology requirement for “one advanced psychology seminar from a list approved by the Psychology Department advisor to the program.”
- For Psychology Post-Baccalaureate students and for Psychology majors who entered Columbia in Fall 2013 or later, it will fulfill the seminar requirement.
- For the Barnard Psychology major, this class will fulfill the senior seminar requirement.

Course schedule

September 9: Introduction (no thought piece due)

Part 1: Discovering the neural underpinnings of memory

September 16: Patient studies of episodic memory
September 23: Neuroimaging studies of episodic memory
September 30: Do animals have episodic memory?
October 7: Place cells: building blocks of memory?

Part 2: Formulating theories and debates

October 14: Divisions of episodic memory
October 21: Computations of the hippocampus
October 28: Is the hippocampus fundamentally “spatial”?
No class November 4 – Academic Holiday
November 11: Organizing memories in time

Part 3: Challenges to the “memory systems” view

November 18: The role of memory systems in perception
November 25: The role of the hippocampus in imagination
December 2: How the hippocampus influences, and is influenced by, attention
December 9: Implicit memory in “declarative memory” systems

Grading

Seminars are meant to be engaging discussions. To participate in these discussions, you must carefully read the relevant papers *before* class and contribute to the conversation. Grading will be based on whether you have shown that you have read the papers, thought deeply about them, can write about them, and your contribution to class discussions.

Overview

25%: attendance and participation

25%: thought pieces (*due 6pm the evening before each class*)

25%: class presentation, including mandatory meeting with the instructor

25%: final paper, including 1-paragraph proposal (*1-paragraph proposal due by 11:59pm **Nov 11**; final paper due by 11:59pm **Dec 9***)

Attendance and Participation

Everyone is expected to attend and participate in every class. Attendance will be taken at the beginning of each class, and each student should contribute at least once (but preferably more!) to each class discussion. If participating in class is difficult for you, please see me and we can discuss other ways that you can contribute. **Attendance and participation are worth 25% of your grade.**

If you are sick and have to miss class, you must provide me with a doctor's note confirming that you have seen a physician either the day you missed class or shortly (1-2 days) before. If you have to miss class for another reason that you believe should be excused, you must e-mail me in advance of class to explain your situation.

Thought Pieces

To ensure that everyone reads the material, each student must submit a short (1 paragraph, 200-300 words) 'thought piece' via Courseworks **the evening before each class (no later than 6pm;** thought pieces must also be handed in on the week that you present – these will be much easier for you!). The thought piece should describe something you found interesting in the readings (and *why* it was so interesting), or raise substantive questions about something you found confusing (and *why* it was so hard to understand). Specifically, you should briefly summarize a point from the readings (e.g., a specific result, a theoretical viewpoint, an analysis technique; this is worth 2 points), raise a question or an observation about it (this is worth 2 points), describe what led you to that question or observation (this is worth 2 points), and what new evidence could be useful for answering the question or supporting/contradicting the observation (this is worth 2 points). This allows me to make sure everyone is on track, and get a better handle on what might be challenging in the readings. Grading will be based on your ability to follow the instructions for the thought piece (as noted above), as well as the clarity of writing (2 points). **Thought pieces are worth 25% of your grade** (each thought piece is graded out of 10, as noted above).

Class Presentation

Each student is also expected to present for one class period: choose at least one paper assigned that week (from any listed, whether required or not) and make a slide presentation to lead the class through the paper(s). Depending on class size, there may have to be more than one presenter in any given week. If this happens, the instructor will contact the individuals presenting on the same day, and they should coordinate to make sure they present different papers. **Each student is required to meet with me before their presentation so that they can receive feedback and have time to incorporate edits before their class presentation. Doing so can substantially improve your grade, and not doing so will result in an automatic 5 point deduction from your presentation.**

If it is an empirical paper, describe the question (this is worth 5 points), the method (this is worth 10 points), the results (this is worth 10 points), the conclusions (this is worth 5 points), and then bring up points for discussion (this is worth 10 points). Don't get bogged down by details in the methods, especially for neuroimaging studies: convey the critical parts of the method that we need to understand the paper.

If it is a review paper, describe the big question it attempts to answer (this is worth 5 points), the different theories it brings up (this is worth 10 points), the evidence for each (this is worth 10 points), the conclusions reached (this is worth 5 points), and then bring up points for discussion (this is worth 10 points).

Clarity of presentation (speaking and slides) is worth an additional 10 points.

Often, papers are much too comprehensive to go over in detail in a short presentation; you therefore must decide what the main points are and communicate those. If some sections in a paper are tangential to the main topic, feel free to skip them in your presentation. You can present one paper thoroughly, or two papers more briefly. You can bring in additional material as well (this is highly encouraged!). And remember: presentations are meant to be engaging, and you should try to involve your classmates as much as possible (e.g., by posing questions intermittently or asking for opinions regularly). Do your best to understand the background, main findings / arguments, and conclusions of each paper — but it's okay if you don't understand everything. You can see me in office hours to discuss difficult points before your presentation. You can also bring up challenging aspects of the paper(s) in class, and we can discuss them together. But try your best to figure things out on your own first (you can always Google things you don't know). **Your class presentation is worth 25% of your grade** (presentations are graded out of 50 points, as noted above).

Note that this presentation is **not** meant to be just a series of summaries, or a step through each figure in a paper. You must discuss the article(s) you selected, of course, but this discussion should be in the service of putting together a coherent presentation around the topic for that week. Do not just jump from figure to figure or from paper to paper. Make sure that there is a *narrative* in your presentation. Think about how to transition from topic to topic to help lead the class through the 'story' you want to tell. That means you must make sure to set up the big questions, why that research or that finding is important, what the results mean, and their bigger implications.

With respect to discussion questions in your presentation: go for questions aimed at getting students' thoughts, opinions, criticisms, concerns, or interpretation of specific issues discussed in the papers. What *doesn't* work well is just putting up a figure and asking the class if someone can explain it; that is *your* job as a presenter. The goal of class discussion is to get other students' thoughts, feelings, criticisms, and so on, *not* to ask them to present basic concepts. In other words, it is *your* job to explain the basic concepts in order to set up discussion questions for the class, and the goal of the discussion questions is to gather opinions, criticisms, and so on. Also, more targeted questions are better at eliciting answers than more vague ones. For example, "*What aspect of episodic memory do you think is the hardest to find evidence for in animals? Why?*" is better than "*Does anyone have any questions?*"

Final Paper

At the end of the course, each student must submit a final paper (10-12 pages, double-spaced, excluding references) summarizing the topic that was of most interest to them in the class and raising new questions — making sure to talk about the brain as well as behavior. What do we know now, and what do you think we still need to understand? You should feel free to bridge across topics discussed in different weeks. In your paper, you should be able to describe some findings that interested you (describing them in enough detail for a person to understand if they did not read the article you are talking about; this is worth 10 points), discuss the implications of those findings (this is worth 10 points), and raise problems with those findings and/or outstanding questions for future research (this is worth

10 points). You should then discuss ways of answering those outstanding questions, or specific experiments that could be conducted to test problematic aspects of prior work (this is worth 10 points). To do a good job on this, you must do research beyond the papers discussed in class: find new peer-reviewed articles that touch on the same topic (if you're stuck, a good place to look is in the references of articles that you read, or use Google Scholar to find articles that cited your article). Because this paper is about a whole area of research, you should read several articles carefully, and make sure to cite them: the expectation is to read and cite at least 10 articles, no more than half of which can be articles from the course reading list. Clarity of writing is worth an additional 5 points, and reading/citing enough articles (at least 5 new ones) will be worth 5 points. **Your final paper is worth 25% of your grade** (papers are graded out of 50 points, as noted above). Your final paper is due on **Monday, December 9 (by 11:59pm)**.

To make sure you are on track, you are required to submit one paragraph (~300 words) on Courseworks), describing what you intend to write about, and include at least three new references relevant for your paper, which cannot be from the class readings. This must be handed in no later than Monday, November 11 (by 11:59pm). Not handing this in will result in an automatic 5 point deduction from your final paper.

Note that **this is not a freeform paper** where you can write about anything related to the brain and/or cognition. You **cannot** just choose a new topic that we have not discussed in class and review that topic. You **must** show me that you've learned something in this class, thought about it, and can raise new observations or questions. Be sure to follow the rubric laid out above.

Additional course notes

Academic integrity

As a member of the academic community, one of your responsibilities is to uphold principles of honesty and integrity. This means that you can only present your own work on assignments and presentations — plagiarism is strictly prohibited, as is presenting work as your own when it was done by someone else. Doing so compromises your academic integrity and potentially your academic standing. This should go without saying, but **all of your work, including your oral presentation, must be in your own words. You cannot copy and paste text from articles or book chapters into your presentation or your written assignments. You cannot read from assigned papers for your presentation. Everything you present or write must be in your own words.**

If you are falling behind, don't understand the material, or are not confident about your writing or presentation, talk to me as soon as possible instead of taking measures that go against principles of academic integrity. [Columbia's Honor Code in Columbia's Guide to Academic Integrity (<http://www.college.columbia.edu/academics/academicintegrity>)].

Students with disabilities

If you are a student with special needs and require accommodation, meet me before the first class to discuss your needs. You must also contact Disability Services before the first class to register for specific accommodations (<https://health.columbia.edu/disability-services>).

**** Reading list for the class begins on the next page****

Weekly Topics and Readings

Readings come in different forms: some are required, some you get to choose from, and others are optional. I have listed many fewer papers than needed to truly understand a topic, but the supplementary readings are there to help you pursue your interests should any topic intrigue you. Assuming we all read slightly different sets of papers, we can have a very rich discussion in class! The last few pages of the syllabus are the comprehensive reading guide.

**** These readings are subject to revision. Revisions will be noted in class and on the website ****

Optional resource for the class (book)

The Hippocampus from Cells to Systems: Structure, Connectivity, and Functional Contributions to Memory and Flexible Cognition. (Eds. Deborah E. Hannula and Melissa C. Duff). Springer. p.369-403.

Free copy should be available online via Columbia – if you can't access it, ask me for a free copy

September 9 (no thought piece due)

Introduction (and how to find papers online)

Required background reading that will help during the class

Primer on hippocampal anatomy and function

Knierim JJ. (2015). The hippocampus. *Current Biology*, 25, R1107-R1125.

Understanding fMRI multivoxel pattern analysis / decoding / classification techniques:

Norman KA, Polyn SM, Detre GJ, Haxby JV. (2006). Beyond mind-reading: Multi-voxel pattern analysis of fMRI data. *Trends in Cognitive Sciences*, 10, 424-430.

Overview of the cognitive neuroscience of episodic memory (and more):

Moscovitch M, Cabeza R, Winocur G, Nadel L. (2016). Episodic memory and beyond: The hippocampus and neocortex in transformation. *Annual Review of Psychology*, 67, 105-134.

Anatomy of the medial temporal lobes (see especially Figures 2 & 3)

Lavenex P, Amaral DG. (2000). Hippocampal-neocortical interaction: A hierarchy of associativity. *Hippocampus*, 10, 420-430.

weekly readings and topics continue on the next page

September 16

Patient studies of episodic memory

Required

Moscovitch M, Nadel L, Winocur G, Gilboa A, Rosenbaum RS. (2006). The cognitive neuroscience of remote episodic, semantic, and spatial memory. *Current Opinion in Neurobiology*, 16, 179-190.

Squire LR, Zola-Morgan M. (1991). The cognitive neuroscience of human memory since H.M. *Annual Review of Neuroscience*, 14, 259-288.

Choose **one** of

McCormick C, Ciaramelli E, De Luca F, Maguire EA. (2017). Comparing and contrasting the cognitive effects of hippocampal and ventromedial prefrontal cortex damage: A review of human lesion studies. *Neuropsychologia*, 374, 295-318.

Robin J, Moscovitch M. (2017). Details, gist, and schema: Hippocampal-neocortical interactions underlying recent and remote episodic and spatial memory. *Current Opinion in Behavioral Sciences*, 17, 114-123.

Simons JS, Peers PV, Mazuz YS, Berryhill ME, Olson IR. (2010). Dissociation between memory accuracy and memory confidence following bilateral parietal lesions. *Cerebral Cortex*, 20, 479-485.

St. Laurent M, Moscovitch M, Jadd R, McAndrews MP. (2014). The perceptual richness of complex memory episodes is compromised by medial temporal lobe damage. *Hippocampus*, 24, 560-576.

Vargha-Khadem F, Gadian DG, Watkins KE, Connelly A, Van Paesschen W, Mishkin M. (1997). Differential effects of early hippocampal pathology on episodic and semantic memory. *Science*, 277, 376-380.

Optional

Clark IA, Maguire EA. (2016). Remembering preservation in hippocampal amnesia. *Annual Review of Psychology*, 67, 51-82.

Palombo DJ, Sheldon S, Levine B. (2018). Individual differences in autobiographical memory. *Trends in Cognitive Sciences*, 22, 583-597.

Vargha-Khadem F, Isaacs E, Mishkin M. (1994). Agnosia, alexia, and a remarkable form of amnesia in an adolescent boy. *Brain*, 117, 683-703.

Verfaellie M, Keane MM. (2017). Neuropsychological investigations of human amnesia: Insights into the role of the medial temporal lobes in cognition. *Journal of the International Neuropsychological Society*, 23, 732-740.

weekly readings and topics continue on the next page

September 23

Neuroimaging studies of episodic memory

Required

Davachi L. (2006). Item, context, and relational episodic encoding in humans. *Current Opinion in Neurobiology*, 16, 693-700.

Mitchell KJ, Johnson MK. (2009). Source monitoring 15 years later: What have we learned from fMRI about the neural mechanisms of source memory? *Psychological Bulletin*, 135, 638-677.

Choose **one** of

Buckner RL, Wheeler ME. (2001). The cognitive neuroscience of remembering. *Nature Reviews Neuroscience*, 2, 624-634.

Paller KA, Wagner AD. (2002). Observing the transformation of experience into memory. *Trends in Cognitive Sciences*, 6, 93-102.

Polyn SM, Natu VS, Cohen JD, Norman KA. (2005). Category-specific cortical activity precedes retrieval during memory search. *Science*, 310, 1963-1966.

Rissman J, Greely HT, Wagner AD. (2010). Detecting individual memories through the neural decoding of memory states and past experience. *Proceedings of the National Academy of Sciences*, 107, 9849-9854.

Rissman J, Wagner AD. (2012). Distributed representations in memory: Insights from functional brain imaging. *Annual Review of Psychology*, 63, 101-128.

Simons JS, Spiers HJ. (2003). Prefrontal and medial temporal lobe interactions in long-term memory. *Nature Reviews Neuroscience*, 4, 637-648.

Wagner AD, Shannon BJ, Kahn I, Buckner RL. (2005). Parietal lobe contributions to episodic memory retrieval. *Trends in Cognitive Sciences*, 9, 445-453.

Optional

Aly M, Turk-Browne NB. (2016). Attention promotes episodic encoding by stabilizing hippocampal representations. *Proceedings of the National Academy of Sciences*, 113, E420-E429.

Fell J, Axmacher N. (2011). The role of phase synchronization in memory processes. *Nature Reviews Neuroscience*, 12, 105-118. [*EEG, intracranial EEG, and MEG studies of memory*]

Lee H, Chun MM, Kuhl BA. (2016). Lower parietal encoding activation is associated with sharper information and better memory. *Cerebral Cortex*, 27, 2486-2499.

weekly readings and topics continue on the next page

September 30

Do animals have episodic memory?

Required

Clayton NS, Griffiths DP, Emery NJ, Dickinson A. (2001). Elements of episodic-like memory in animals. *Philosophical Transactions of the Royal Society B*, 356, 1483-1491.

Crystal JD. (2010). Episodic-like memory in animals. *Behavioural Brain Research*, 215, 235-243.

Suddendorf T, Corballis MC. (2010). Behavioural evidence for mental time travel in nonhuman animals. *Behavioural Brain Research*, 215, 292-298.

Choose **one** of

Allen TA, Fortin NJ. (2013). The evolution of episodic memory. *Proceedings of the National Academy of Sciences*, 110, 10379-10386.

Babb SJ, Crystal JD. (2006). Episodic-like memory in the rat. *Current Biology*, 16, 1317-1321.

Ergorul C, Eichenbaum H. (2004). The hippocampus and memory for "what", "where", and "when". *Learning & Memory*, 11, 397-405.

Fugazza C, Pogány Á, Miklósi Á. (2016). Recall of others' actions after incidental encoding reveals episodic-like memory in dogs. *Current Biology*, 26, 3209-3213.

Fortin NJ, Wright SP, Eichenbaum H. (2004). Recollection-like memory retrieval in rats is dependent on the hippocampus. *Nature*, 431, 188-191.

Lewis A, Berntsen D, Call J. (2019). Long-term memory of past events in great apes. *Current Directions in Psychological Science*, 28, 117-123.

Templer VL, Hampton RR. (2013). Episodic memory in nonhuman animals. *Current Biology*, 23, R801-R806.

Optional

Jelbert SA, Clayton NS. (2017). Comparing the non-linguistic hallmarks of episodic memory systems in corvids and children. *Current Opinion in Behavioral Sciences*, 17, 99-106.

McKenzie S, Keene CS, Farovik A, Bladon J, Place R, Komorowski R, Eichenbaum H. (2016). Representation of memories in the cortical-hippocampal system: Results from the application of population similarity analyses. *Neurobiology of Learning and Memory*, 134, 178-191.

Morris RGM. (2001). Episodic-like memory in animals: Psychological criteria, neural mechanisms, and the value of episodic-like tasks to investigate animal models of neurodegenerative disease. *Philosophical Transactions of the Royal Society B*, 356, 1453-1465.

weekly readings and topics continue on the next page

October 7

Place cells: building blocks of memory?

Required

Buffalo EA. (2015). Bridging the gap between spatial and mnemonic views of the hippocampal formation. *Hippocampus*, 25, 713-718.

Moser M-B, Rowland DC, Moser EI. (2015). Place cells, grid cells, and memory. *Cold Spring Harbor Perspectives in Biology*, 7; a021808, 1-16. doi: 10.1101/cshperspect.a021808

Choose **one** of

Eichenbaum H, Dudchenko P, Wood E, Shapiro M, Tanila H. (1999). The hippocampus, memory and, place cells: Is it spatial memory or a memory space? *Neuron*, 23, 209-226.

Knierim JJ. (2015). From the GPS to HM: Place cells, grid cells, and memory. *Hippocampus*, 25, 719-725.

Knierim JJ, Lee I, Hargreaves EL. (2006). Hippocampal place cells: Parallel input streams, subregional processing, and implications for episodic memory. *Hippocampus*, 16, 755-764.

Milivojevic B, Doeller CF. (2013). Mnemonic networks in the hippocampal formation: From spatial maps to temporal and conceptual codes. *Journal of Experimental Psychology: General*, 142, 1231-1241.

Miller JF et al. (2013). Neural activity in human hippocampal formation reveals the spatial context of retrieved memories. *Science*, 342, 1111-1114.

Rolls ET, Wirth S. (2018). Spatial representations in the primate hippocampus, and their functions in memory and navigation. *Progress in Neurobiology*, 171, 90-113.

Optional

Horner AJ, Bisby JA, Zotow E, Bush D, Burgess N. (2016). Grid-like processing of imagined navigation. *Current Biology*, 26, 842-847.

Omer DB, Maimon SR, Las L, Ulanovsky N. (2018). Social place-cells in the bat hippocampus. *Science*, 359, 218-224.

weekly readings and topics continue on the next page

October 14

Divisions of episodic memory

Required

Eichenbaum H, Yonelinas AP, Ranganath C. (2007). The medial temporal lobe and recognition memory. *Annual Review of Neuroscience*, 30, 123-152.

Wixted JT, Squire LR. (2011). The medial temporal lobe and the attributes of memory. *Trends in Cognitive Sciences*, 15, 210-217.

Choose one of

Bird CM, Shallice T, Cipolotti L. (2007). Fractionation of memory in medial temporal lobe amnesia. *Neuropsychologia*, 45, 1160-1171.

Bowles B, Crupi C, Mirsattari SM, Pigott SE, Parrent AG, Pruessner JC, Yonelinas AP, Kohler S. (2007). Impaired familiarity with preserved recollection after anterior temporal-lobe resection that spares the hippocampus. *Proceedings of the National Academy of Sciences*, 104, 16382-16387.

Brown MW, Warburton EC, Aggleton JP. (2010). Recognition memory: Material, processes, and substrates. *Hippocampus*, 20, 1228-1244.

Mayes A, Montaldi D, Migo E. (2007). Associative memory and the medial temporal lobes. *Trends in Cognitive Sciences*, 11, 126-135.

Parks CM, Yonelinas AP. (2009). Evidence for a memory threshold in second-choice recognition memory responses. *Proceedings of the National Academy of Sciences*, 106, 11515-11519.

Ranganath C. (2010). A unified framework for the functional organization of the medial temporal lobes and the phenomenology of episodic memory. *Hippocampus*, 20, 1263-1290.

Yonelinas AP, Aly M, Wang W-C, Koen JD. (2010). Recollection and familiarity: Examining controversial assumptions and new directions. *Hippocampus*, 20, 1178-1194.

Optional

Quamme JR, Weiss DJ, Norman KA. (2010). Listening for recollection: A multi-voxel pattern analysis of recognition memory retrieval strategies. *Frontiers in Human Neuroscience*, Volume 4, Article 61, 1-17.

Savage MM, Fortin NJ, Owens CB, Yonelinas AP, Eichenbaum H. (2007). Recognition memory: Opposite effects of hippocampal damage on recollection and familiarity. *Nature Neuroscience*, 11, 16-18.

weekly readings and topics continue on the next page

October 21

Computations of the hippocampus

Required

Deuker L, Doeller CF, Fell J, Axmacher N. (2014). Human neuroimaging studies on hippocampal CA3 region — integrating evidence for pattern separation and completion. *Frontiers in Cellular Neuroscience*, Volume 8, Article 64, 1-9.

Yassa MA, Stark CEL. (2011). Pattern separation in the hippocampus. *Trends in Neurosciences*, 34, 515-525.

Choose **one** of

Bakker A, Kirwan CB, Miller M, Stark CEL. (2008). Pattern separation in the human hippocampal CA3 and dentate gyrus. *Science*, 319, 1640-1642.

Berron D, Schutze H, Maass A, Cardenas-Blanco A, Kuijf HJ, Kumaran D, Duzel E. (2016). Strong evidence for pattern separation in human dentate gyrus. *Journal of Neuroscience*, 36, 7579-7579.

Duncan K, Ketz N, Inati SJ, Davachi L. (2012). Evidence for area CA1 as a match/mismatch detector: A high-resolution fMRI study of the human hippocampus. *Hippocampus*, 22, 389-398.

Horner AJ, Bisby JA, Bush D, Lin W-J, Burgess N. (2015). Evidence for holistic episodic recollection via hippocampal pattern completion. *Nature Communications*, 6:7462. doi: 10.1038/ncomms8462

Kirwan CB, Hartshorn A, Stark SM, Goodrich-Hunsaker NJ, Hopkins RO, Stark CEL. (2012). Pattern separation deficits following damage to the hippocampus. *Neuropsychologia*, 50, 2408-2414.

Knierim JJ, Neunuebel JP. (2016). Tracking the flow of hippocampal computation: Pattern separation, pattern completion, and attractor dynamics. *Neurobiology of Learning and Memory*, 129, 38-49.

LaRocque KF, Smith ME, Carr VA, Witthoft N, Grill-Spector K, Wagner AD. (2013). Global similarity and pattern separation in the human medial temporal lobe predict subsequent memory. *Journal of Neuroscience*, 33, 5466-5474.

Optional

Guzowski JF, Knierim JJ, Moser EI. (2004). Ensemble dynamics of hippocampal regions CA3 and CA1. *Neuron*, 44, 581-584.

Kent BA, Hvoslef-Eide M, Saksida LM, Bussey TJ. (2016). The representational-hierarchical view of pattern separation: Not just hippocampus, not just space, not just memory? *Neurobiology of Learning and Memory*, 129, 99-106.

weekly readings and topics continue on the next page

October 28

Is the hippocampus fundamentally “spatial”?

Required

Eichenbaum H, Cohen NJ. (2014). Can we reconcile the declarative memory and spatial navigation views on hippocampal function? *Neuron*, 83, 764-770.

Maguire EA, Mullally SL. (2013). The hippocampus: A manifesto for change. *Journal of Experimental Psychology: General*, 4, 1180-1189.

Choose **one** of

Bird CM, Capponi C, King JA, Doeller CF, Burgess N. (2010). Establishing the boundaries: The hippocampal contribution to imagining scenes. *Journal of Neuroscience*, 30, 11688-11695.

Eichenbaum H. (2016). What versus where: Non-spatial aspects of memory representation by the hippocampus. *Current Topics in Behavioral Neurosciences*, 450, 1-17.

Ekstrom AD, Ranganath C. (2018). Space, time, and episodic memory: The hippocampus is all over the cognitive map. *Hippocampus*, 28, 680-687.

Nadel L. (1991). The hippocampus and space revisited. *Hippocampus*, 1, 221-229.

Robin J. (2018). Spatial scaffold effects in event memory and imagination. *WIREs Cognitive Science*, 23, e1462, 1-15.

Rueckemann JW, Buffalo EA. (2017). Spatial responses, immediate experience, and memory in the monkey hippocampus. *Current Opinion in Behavioral Sciences*, 17, 155-160.

Schiller D, Eichenbaum H, Buffalo EA, Davachi L, Foster DJ, Leutgeb S, Ranganath C. (2015). Memory and space: Towards an understanding of the cognitive map. *Journal of Neuroscience*, 35, 13904-13911.

Optional

Bird CM & Burgess N. (2008). The hippocampus and memory: Insights from spatial processing. *Nature Reviews Neuroscience*, 9, 182-194.

weekly readings and topics continue on the next page

November 11

Organizing memories in time

Required

Cohn-Sheehy BI, Ranganath C. (2017). Time regained: How the human brain constructs memory for time. *Current Opinion in Behavioral Sciences*, 17, 169-177.

Eichenbaum HB. (2013). Memory on time. *Trends in Cognitive Sciences*, 17, 81-88.

Choose **one** of

Barnett AJ, O'Neil EB, Watson HC, Lee ACH. (2014). The human hippocampus is sensitive to durations of events and intervals within a sequence. *Neuropsychologia*, 64, 1-12.

Clewett D, Davachi L. (2017). The ebb and flow of experience determines the temporal structure of memory. *Current Opinion in Behavioral Sciences*, 17, 186-193.

DuBrow S, Davachi L. (2014). Temporal memory is shaped by encoding stability and intervening item reactivation. *Journal of Neuroscience*, 34, 13998-14005.

Folkerts S, Rutishauser U, Howard MW. (2018). Human episodic memory retrieval is accompanied by a neural contiguity effect. *Journal of Neuroscience*, 38, 4200-4211.

Hsieh L-T, Gruber MJ, Jenkins LJ, Ranganath C. (2014). Hippocampal activity patterns carry information about objects in temporal context. *Neuron*, 81, 1165-1178.

Palombo DJ, Verfaellie M. (2017). Hippocampal contributions to memory for time: Evidence from neuropsychological studies. *Current Opinion in Behavioral Sciences*, 17, 107-113.

Ranganath C. (2019). Time, memory, and the legacy of Howard Eichenbaum. *Hippocampus*, 29, 146-161.

Optional

Eichenbaum HB. (2014). Time cells in the hippocampus: A new dimension for mapping memories. *Nature Reviews Neuroscience*, 15, 732-744.

Sakon JJ, Naya Y, Wirth S, Suzuki WA. (2014). Context-dependent incremental timing cells in the primate hippocampus. *Proceedings of the National Academy of Sciences*, 111, 18351-18356.

weekly readings and topics continue on the next page

November 18

The role of memory systems in perception

Required

Baxter M. (2009). Involvement of medial temporal lobe structures in memory and perception. *Neuron*, 61, 667-677.

Suzuki WA. (2009). Perception and the medial temporal lobe: Evaluating the current evidence. *Neuron*, 61, 657-666.

Choose **one** of

Aly M, Ranganath C, Yonelinas AP. (2013). Detecting changes in scenes: The hippocampus is critical for strength-based perception. *Neuron*, 78, 1127-37.

Barese MD, Groen IIA, Lee ACH, Yeung L-K, Brady SM, Gregori M, Kapur N, Bussey TJ, Saksida LM, Henson RNA. (2012). Intact memory for irrelevant information impairs perception in amnesia. *Neuron*, 75, 157-167.

Gaffan D. (2002). Against memory systems. *Philosophical Transactions of the Royal Society of London, B*, 357, 1111-1121.

Murray EA, Bussey TJ, Saksida LM. (2007). Visual perception and memory: A new view of medial temporal lobe function in primates and rodents. *Annual Review of Neuroscience*, 30, 99-122.

Lee ACH, Yeung L-K, Barese MD. (2012). The hippocampus and visual perception. *Frontiers in Human Neuroscience*, Volume 6, Article 91, 1-17.

Mullally SL, Intraub H, Maguire EA. (2012). Attenuated boundary extension produces a paradoxical memory advantage in amnesic patients. *Current Biology*, 22, 261-268.

Yonelinas AP. (2013). The hippocampus supports high-resolution binding in the service of perception, working memory, and long-term memory. *Behavioural Brain Research*, 254, 34-44.

Optional

Graham KS, Barese MD, Lee ACH. (2010). Going beyond LTM in the MTL: A synthesis of neuropsychological and neuroimaging findings on the role of the medial temporal lobe in memory and perception. *Neuropsychologia*, 48, 831-853.

Nadel L, Peterson MA. (2013). The hippocampus: Part of an interactive posterior representational system spanning perceptual and memorial systems. *Journal of Experimental Psychology: General*, 142, 1242-1254.

Olsen RK, Moses SN, Riggs L, Ryan JD. (2012). The hippocampus supports multiple cognitive processes through relational binding and comparison. *Frontiers in Human Neuroscience*, Volume 6, Article 146, 1-13.

weekly readings and topics continue on the next page

November 25

The role of the hippocampus in imagination

Required

Addis DR, Schacter DL. (2012). The hippocampus and imagining the future: Where do we stand? *Frontiers in Human Neuroscience*, Volume 5, Article 173, 1-15.

Buckner RL. (2010). The role of the hippocampus in prediction and imagination. *Annual Review of Psychology*, 61, 27-48.

Choose **one of**

Addis DR, Wong AT, Schacter DL. (2007). Remembering the past and imagining the future: Common and distinct neural substrates during event construction and elaboration. *Neuropsychologia*, 45, 1363-1377.

Hassabis D, Kumaran D, Vann SD, Maguire EA. (2007). Patients with hippocampal amnesia cannot imagine new experiences. *Proceedings of the National Academy of Sciences*, 104, 1726-1731.

Keven N, Kurczek J, Rosenbaum RS, Craver CF. (2017). Narrative construction is intact in episodic amnesia. *Neuropsychologia*, 110, 104-112.

Roberts RP, Schacter DL, Addis DR. (2018). Scene construction and relational processing: Separable constructs? *Cerebral Cortex*, 28, 1729-1732.

Zeidman P, Maguire EA. (2016). Anterior hippocampus: The anatomy of perception, imagination, and episodic memory. *Nature Reviews Neuroscience*, 17, 173-182.

Optional

De Luca F, Benuzzi F, Bertossi E, Braghittoni D, di Pellegrino G, Ciaramelli E. (2017). Episodic future thinking and future-based decision-making in a case of retrograde amnesia. *Neuropsychologia*, 110, 92-103.

Rosenbaum RS, Gilboa A, Levine B, Winocur G, Moscovitch M. (2009). Amnesia as an impairment of detail generation and binding: Evidence from personal, fictional and semantic narratives in K.C. *Neuropsychologia*, 47, 2181-2187.

weekly readings and topics continue on the next page

December 2

How the hippocampus influences, and is influenced by, attention

Required

Aly M, Turk-Browne NB. (2017). How hippocampal memory shapes, and is shaped by, attention. In *The Hippocampus from Cells to Systems: Structure, Connectivity, and Functional Contributions to Memory and Flexible Cognition*. (Eds. Deborah E. Hannula and Melissa C. Duff). Springer. p.369-403.

Muzzio IA, Kentros C, Kandel E. (2009). What is remembered? Role of attention on the encoding and retrieval of hippocampal representations. *The Journal of Physiology*, 587, 2837-2854.

Choose **one** of

Aly M, Turk-Browne NB. (2016). Attention stabilizes representations in the human hippocampus. *Cerebral Cortex*, 26, 783-796.

Cosman JD, Vecera SP. (2013). Learned control over distraction is disrupted in amnesia. *Psychological Science*, 24, 1585-1590.

Kentros CG, Agnihotri NT, Streater S, Hawkins RD, Kandel ER. (2004). Increased attention to spatial context increases both place field stability and spatial memory. *Neuron*, 42, 283–295.

Muzzio IA, Levita L, Kulkarni J, Monaco J, Kentros C, Stead M, Abbott LF, Kandel ER. (2009). Attention enhances the retrieval and stability of visuospatial and olfactory representations in the dorsal hippocampus. *PLoS Biology*, Volume 7, e1000140. 1–20.

Rowland DC, Kentros CG. (2008). Potential anatomical basis for attentional modulation of hippocampal neurons, *Annals of the New York Academy of Sciences*, 1129, 213-224.

Stokes MG, Atherton K, Patai EZ, Nobre AC. (2012). Long-term memory prepares neural activity for perception. *Proceedings of the National Academy of Sciences*, 109, E260-E367.

Summerfield JJ, Lepsien J, Gitelman DR, Mesulam MM, Nobre AC. (2006). Orienting attention based on long-term memory experience. *Neuron*, 49, 905-916.

Optional

Fenton AA, Lytton WW, Barry JM, Lenck-Santini PP, Zinyuk LE, Kubík S, Bureš J, Poucet B, Muller RU, Olypher AV. (2010). Attention-like modulation of hippocampus place cell discharge. *Journal of Neuroscience*, 30, 4613–4625.

Hutchinson JB, Turk-Browne NB. (2012). Memory-guided attention: Control from multiple memory systems. *Trends in Cognitive Sciences*, 16, 576-579.

Kelemen E, Fenton AA. (2010). Dynamic grouping of hippocampal neural activity during cognitive control of two spatial frames. *PLoS Biology*, Volume 8, e1000403, 1–14.

weekly readings and topics continue on the next page

December 9

Implicit memory in “declarative memory” systems

Required

Hannula DE, Greene AJ. (2012). The hippocampus re-evaluated in unconscious learning and memory: At a tipping point? *Frontiers in Human Neuroscience*, Volume 6, Article 80, 1-20.

Henke K. (2010). A model for memory systems based on processing modes rather than consciousness. *Nature Reviews Neuroscience*, 11, 523-532.

Choose one of

Chun MM, Phelps EA. (1999). Memory deficits for implicit contextual information in amnesic subjects with hippocampal damage. *Nature Neuroscience*, 2, 844-847.

Covington NV, Brown-Schmidt S, Duff MC. (2018). The necessity of the hippocampus for statistical learning. *Journal of Cognitive Neuroscience*, 30, 680-697.

Hannula DE, Ranganath C. (2009). The eyes have it: Hippocampal activity predicts expression of memory in eye movements. *Neuron* 63, 592-599.

Hannula DE, Ryan JD, Tranel D, Cohen NJ. (2007). Rapid onset relational memory effects are evident in eye movement behavior, but not in hippocampal amnesia. *Journal of Cognitive Neuroscience*, 19, 1690-1705.

Ryan JD, Althoff RR, Whitlow S, Cohen NJ. (2000). Amnesia is a deficit in relational memory. *Psychological Science*, 11, 454-461.

Ryals AJ, Wang JX, Polnaszek KL, Voss JL. (2015). Hippocampal contribution to implicit configuration memory expressed via eye movements during scene exploration. *Hippocampus*, 25, 1028-1041.

Turk-Browne NB, Scholl BJ, Johnson MK, Chun MM. (2010). Implicit perceptual anticipation triggered by statistical learning. *Journal of Neuroscience*, 30, 11177-11187.

Optional

Giesbrecht B, Sy JL, Guerin SA. (2013). Both memory and attention systems contribute to visual search for targets cued by implicitly learned context. *Vision Research*, 85, 80-89.

Schapiro AC, Kustner LV, Turk-Browne NB. (2012). Shaping of object representations in the human medial temporal lobe based on temporal regularities. *Current Biology*, 22, 1622-1627.

Reading for when the class is over and you miss it

Lisman J, Buzsáki G, Eichenbaum H, Nadel L, Ranganath C, Redish AD. (2017). Viewpoints: how the hippocampus contributes to memory, navigation, and cognition. *Nature Neuroscience*, 20, 1434-1447.

Note: This is an excellent Q & A with some of the leaders in the field. Highly recommend!