

Psychology G4430

Learning and the Brain

Spring 2012

R 2:10 – 4 P.M. Room 405 Schermerhorn Hall

Prof. Daphna Shohamy
shohamy@psych.columbia.edu

How does past experience guide behavior? Are there different forms of learning and memory that guide behavior? If so, when do these different forms of learning take place? How do they guide choices and actions? What are the neural mechanisms that support learning, memory, and choices? These are the questions we will focus on in this seminar. We will review current theories in the cognitive neuroscience of human learning, with a particular eye towards understanding how learning and decision making – typically studied separately from each other – interact. We will review these fields with a focus on two heavily influential methods in the study of brain and behavior in humans: functional imaging and patient studies. We will debate the strengths and weaknesses of each approach and will discuss how methodological trends and limitations have shaped our view of cognitive function.

The seminar will survey recent literature on the cognitive neuroscience of learning, memory and decision making. Each weekly meeting will address a question in the field. We will begin each meeting by discussing the background and importance of that week's topic, followed by a student presentation of a recent empirical journal article that bears on this question. Finally, we will together consider how the data presented inform our understanding of that week's topic and how it relates to other questions discussed in the course.

The course will begin with an introductory lecture on how we study the brain bases of learning, surveying the broad questions that will be addressed in the seminar, and introducing the basic principles of studying brain bases of cognition in humans.

In the first half of the seminar, we will discuss what may be considered the “dogma” in the cognitive neuroscience of learning: that there are different “learning systems” dependent upon distinct brain regions. We will particularly focus on the distinction between explicit and implicit learning. Explicit learning is thought to be dependent on the medial temporal lobes and to support learning of facts and events. Implicit learning is thought to depend on other parts of the brain, particularly the basal ganglia, and to support the learning of skills, or

habits. We will discuss some of the seminal papers that support this view, as well as some recent scientific findings that raise questions and pose challenges for this view.

In the second half of the seminar, we will discuss some important variables that impact learning and the brain mechanisms supporting it, with an emphasis on the role of motivation and reward.

The reading list and weekly schedule

Readings will consist of empirical and review articles. All papers are available as downloadable pdfs by searching the PubMed archive at: <http://www.ncbi.nlm.nih.gov/entrez/query.fcgi>. The following are a sample, subject to revision to represent recent publications.

Course Schedule

Week 1 (1/19): General Introduction

Week 2 (1/26): How do we study the link between brain and behavior?

Basic methods in brain research: Animal studies, human neuropsychology and functional imaging.

We will discuss the historical development, the strengths and limitations of each of these methods, and the importance of converging evidence for informing our understanding about how the brain supports cognition and behavior.

Principles of Cognitive Neuroscience, by Dale Purves et al., (Sinauer Press, 2008). Chapter 3: Exploring cognitive processes in neural terms; pp 34-61.

Functional Magnetic Resonance Imaging, by Scott Huettel and Allen Song.

Chapter 1: An introduction to fMRI; pp 1-26

Chapter 15: Converging operations; pp 429-466.

Week 3 (2/2): Do different kinds of learning depend on different brain mechanisms?

Gabrieli, J. D. (1998). Cognitive neuroscience of human memory. *Annual Review of Psychology*, 49, 87-115.

Knowlton, B. J., Mangels, J. A., & Squire, L. R. (1996). A neostriatal habit learning system in humans. *Science*, 273(5280), 1399-1402.

Week 4 (2/9): How do we learn how to ride a bike? Habit learning and the basal ganglia

Yin, H. H. & Knowlton, B. J. (2006). The role of the basal ganglia in habit formation. *Nature Reviews Neuroscience*, 7(6), 464-476.

Foerde, K., Knowlton, B. J., & Poldrack, R. A. (2006). Modulation of competing memory systems by distraction. *Proceedings of the National Academy of Science*, 103(31), 11778-11783.

Week 5 (2/16): How do we learn to predict reward? Dopamine and reward in reinforcement learning

Schultz, W. (2006). Behavioral theories and the neurophysiology of reward. *Annual Review of Psychology*, 57, 87-115.

Schultz, W. (2000). Multiple reward signals in the brain. *Nature Reviews Neuroscience*, 1(3), 199-207.

O'Doherty, J. P. (2004). Reward representations and reward-related learning in the human brain: insights from neuroimaging. *Current Opinion in Neurobiology*, 14(6), 769-776.

Bromberg-Martin, E. S., Matsumoto, M., & Hikosaka, O. (2010). Dopamine in motivational control: rewarding, aversive, and alerting. *Neuron*, 68(5), 815-834.

Week 6 (2/23): How does feedback impact motivation? Learning from rewards vs. observation

Daw, N. D., & Shohamy, D. (2008). The Cognitive Neuroscience of Motivation and Learning. *Social Cognition*, 26, 593-620.

Hayden, B. Y., Pearson, J. M., & Platt, M. L. (2009). Fictive reward signals in the anterior cingulate cortex. *Science*, 324(5929), 948-950.

Week 7 (3/8): Are there different kinds of motivation?

Shohamy, D. (2011). Learning and motivation in the human striatum. *Current Opinion in Neurobiology*, 21(3), 408-414.

Murayama, K., Matsumoto, M., Izuma, K., & Matsumoto, K. (2010). Neural basis of the undermining effect of monetary reward on intrinsic motivation. *Proceedings of the National Academy of Sciences*, 107(49), 20911 - 20916.

Week 8 (3/22): Beyond rewards: Why and how are we motivated to learn?

Voss, J. L., Gonsalves, B. D., Federmeier, K. D., Tranel, D., & Cohen, N. J. (2011). Hippocampal brain-network coordination during volitional exploratory behavior enhances learning. *Nature Neuroscience*, *14*(1), 115-120.

Kang, M. J., Hsu, M., Krajbich, I. M., Loewenstein, G., McClure, S. M., Wang, J. T., & Camerer, C. F. (2009). The Wick in the Candle of Learning. *Psychological Science*, *20*(8), 963-973.

Week 9 (3/29): How do motivation and reward change during adolescence?

Somerville, L. H., & Casey, B. (2010). Developmental neurobiology of cognitive control and motivational systems. *Current Opinion in Neurobiology*, *20*(2), 236-241.

Van Leijenhorst, L., Zanolie, K., Van Meel, C. S., Westenberg, P. M., Rombouts, S. A. R. B., & Crone, E. A. (2010). What motivates the adolescent? Brain regions mediating reward sensitivity across adolescence. *Cerebral Cortex*, *20*(1), 61-69.

Week 10 (4/5): Beyond learning: how does reward impact cognition?

Chiew, K. S., & Braver, T. S. (2011). Positive affect versus reward: emotional and motivational influences on cognitive control. *Frontiers in Cognition*, *2*(279).

Savine, A. C., & Braver, T. S. (2010). Motivated cognitive control: reward incentives modulate preparatory neural activity during task-switching. *The Journal of Neuroscience*, *30*(31), 10294-10305.

Week 11 (4/12): Beyond learning: how do we make decisions?

Kable, J.W. & Glimcher, P.W. (2009). The neurobiology of decision: consensus and controversy. *Neuron*, *63*(6), 733-745.

Figner, B., Knoch, D., Johnson, E.J., Krosch, A.R., Lisanby, S.H., Fehr, E., & Weber, E.U. (2010). Lateral prefrontal cortex and self-control in intertemporal choice. *Nature Neuroscience*, *13*(5), 539-539.

Hare, T.A. , Camerer, C.F., & Rangel, A. (2009). Self-control in decision-making involves modulation of the vmPFC valuation system. *Science*, *324*(5927), 646-648.

Week 12 (4/19): How does social context impact learning?

Jones, R. M., Somerville, L. H., Li, J., Ruberry, E. J., Libby, V., Glover, G., Voss, H. U., Ballon, D. J. & Casey, B. J. (2011). Behavioral and neural properties of social reinforcement learning. *The Journal of Neuroscience*, 31(37), 13039-13045.

Week 13/14 (double class; 4/26): Class presentation of term paper research

Course requirements and grading

Requirements:

- Class participation: Prior to each class, students are expected to read the assigned papers. Students are encouraged to seek out additional research or theoretical papers that are relevant to the topic and to bring these up during the class discussion. All class participants are expected to actively contribute to the discussion.
- Class presentation: Each student will be responsible for presenting at least once during the semester. Presentations should be relatively brief (30-40 minutes), concise, and critical. The presentation should focus on providing a clear presentation of (a) Question – what is the main question the paper addresses, (b) Methods – how did the researchers address this question (c) Results and (d) Critique and Conclusions.
- Written assignments:
 - o **Questions**: What would you like to learn about in this class? Before the second week students are required to email me a list of 5 questions that they are curious about on the topic of learning and the brain. Students are encouraged to think about these questions broadly in terms of general interest and to *not* build on prior knowledge of the literature.
 - o **Opinion/Critical Reviews**: During the semester, each student will select two topics they are particularly interested in for which to submit a briefly written critical review. The review will be no longer than two pages and will briefly describe your opinion on the paper: Did you like it, or not? Why not? What is your opinion on the theory, approach, findings, or conclusion?
 - o **Term Paper**: Term papers addressing a question discussed during the seminar can be written either as research proposals, or as review papers. The final paper will be 10-12 pages long and will be submitted by the last class. During the last two classes, each student will present their topic to the class in the form of a brief (10-15 min) oral presentation.

Grading:

- Class participation will count towards 25% of the final grade.
- Class presentations will count towards 25% of the final grade.

- Written assignments will count towards 50% of the final grade, as follows:
 - Question assignment – 5%
 - Critical reviews – 20% (10% each)
 - Term paper – 25%