

# The Neurobiology of Working Memory

Department of Psychology – Columbia University

PSYC3455 - Course Syllabus – Fall 2025

**Instructor:** Dr. Sarah DeMoya

**E-mail:** sed2182@columbia.edu

**Course Time:** Thursday 10:10 AM – 12:00 PM

**Course Location:** Schermerhorn 200C

**Office Hours:** by appointment

**Office:** Schermerhorn Extension 355D

(Friday 10:00 AM – 12:00 PM)

## Course Description:

We will spend the first half of the semester gaining a thorough understanding of what working memory is and how the brain supports it. We will begin the semester exploring the history of working memory research, including behavioral paradigms and research techniques. We will investigate the proposed cellular and network underpinnings of working memory. We will then follow the flow of information in the brain from the thalamus to the prefrontal cortex, to learn how various brain regions support working memory. We will then spend the second half of the semester investigating working memory performance across the lifespan, and in various conditions including Alzheimer's, Parkinson's, Attention-Deficit/Hyperactivity-Disorder, Autism, Depression, and Bipolar Disorder. Throughout the semester students will conduct an independent research project investigating the relationship between working memory and another cognitive function. We will wrap up the semester with students presenting their findings in an in-class, digital poster session. Throughout the semester we will read scientific research articles and review articles related to the week's topic, relying heavily on findings from human participants.

## Course Prerequisites:

Instructor permission is required to take the course. Undergraduate students should have already taken PSYC1001 and either PSYC2430, PSYC2450, or PSYC2470. Students who have not taken a prerequisite course but have taken other relevant courses should contact the instructor for approval.

## Course Role in the Department:

PSYC3455 The Neurobiology of Working Memory is a seminar designed 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, and for the Psychology Post-Baccalaureate Certificate program, this course fulfills the Group 2 (Neuroscience and Psychobiology) requirement.
- For the Neuroscience and Behavior major, this course fulfills the P5 Psychology (Advanced Psychology Seminar) requirement.

### **Coursework:**

Coursework will consist of weekly readings, weekly responses to questions about the readings, the research project (research paper and poster), and leading the class discussion.

### **Readings:**

The course readings are scientific journal articles that are selected to help you better understand how various brain regions contribute to working memory and also what happens in the brain when engaging working memory during various developmental stages or in certain neurological disorders. We will explore not only the major findings of the papers but also the methodology and experimental design. The goals of the course readings are to help you gain knowledge of relevant neuroscience history, current findings, and research techniques, and to help you to develop critical thinking around experimental design and analysis.

### **Weekly Reading Questions:**

The purpose of the weekly reading questions is to help orient you to the major takeaways from the readings (related to both the major findings and the methodology). Responses to reading questions are to be submitted Wednesday (the day before seminar) each week.

### **Research Project:**

Over the course of the semester, you will investigate the relationship between working memory and another cognitive function. You will synthesize your research into a 10-page research paper that you will submit in the second half of the semester. You will also present your findings to the class at a digital poster session during our final seminar. The first draft of your project will be submitted for peer review. Each student will review one other student's work. The goal of the research project is to help develop science communication skills (both written and oral), critical thinking, research skills, and quantitative reasoning. More detailed instructions for the research paper, the poster presentation, and the peer review can be found in the Research Project Guidelines. Example topics include but are not limited to:

- Working memory and emotion
- Working memory and attention
- Working memory and creativity
- Working memory and decision-making
- Working memory and long-term memory

### **Seminar Discussion Leader:**

Each student will have the opportunity to lead the seminar discussion once during the semester. Being the discussion leader will consist of three parts: planning the discussion, leading the discussion, and writing a reflection about the experience. The goals of being a discussion leader are to help you to practice science communication, critical thinking, and community engagement and inclusion as you plan out, lead, and reflect on the discussion. More details can be found in the Discussion Leader Guidelines.

### **Supplemental Materials:**

Various supplemental materials will be provided by the instructor on the course website.

### **Course Website:**

The most up-to-date information, including changes to the syllabus or to the class schedule, announcements, lecture slides and additional materials are contained on the course website on CourseWorks (Canvas). Be sure you are familiar with it, that you are easily able to login to the website, and that you always have the readings with you (whether printed or digital). If you have problems accessing the course website at any point during the semester, please let me know.

### **Course Objectives:**

This course is designed to help you to develop the follow Core Competencies: written communication, community engagement and inclusivity, creativity and innovation, critical thinking, knowledge, oral communication, quantitative literacy, and research. At the completion of this course students will be equipped to:

- Describe working memory and the brain regions that support it.
- Discuss prevailing theories for how working memory is supported at the neuronal and network level.
- Discuss behavioral paradigms and research techniques used to study working memory.
- Describe changes to working memory over the lifespan.
- Describe working memory impairments in Alzheimer's Disease, Parkinson's Disease, Attention-Deficit/Hyperactivity-Disorder, Autism Spectrum Disorder, Depression, and Bipolar Disorder.
- Find, read, interpret, and synthesize information from primary research articles.
- Communicate science, both in written and oral form, to the general public.
- Engage in discussion about scientific findings.
- Provide meaningful feedback to peers and also reflect on one's own work.

**Course Schedule:** Any changes will be announced in class and posted as an announcement on CourseWorks. Students should complete the assigned reading before coming to class.

**September 4<sup>th</sup>, 2024: Seminar 1. Course Intro:** defining working memory, behavioral paradigms, research techniques

**September 11<sup>th</sup>, 2024: Seminar 2. Working memory:** Models of working memory

1. Baddeley A. (2003). Working memory: looking back and looking forward. *Nature reviews. Neuroscience*, 4(10), 829–839. <https://doi.org/10.1038/nrn1201>
2. Ritakallio, L. et al. (2024). Self-reported strategy use in working memory tasks. *Sci Rep* 14, 4893. <https://doi.org/10.1038/s41598-024-54160-3>

**September 18<sup>th</sup>, 2024: Seminar 3. Working memory:** neural mechanisms (delay cells, persistent firing) and synaptic mechanisms (dendritic spines, neurotransmitter- and neuromodulator-gated receptors)

1. Goldman-Rakic P. S. (1996). Regional and cellular fractionation of working memory. *Proceedings of the National Academy of Sciences of the United States of America*, 93(24), 13473–13480. <https://doi.org/10.1073/pnas.93.24.13473>
2. Cools, R., & Arnsten, A. F. T. (2022). Neuromodulation of prefrontal cortex cognitive function in primates: the powerful roles of monoamines and acetylcholine. *Neuropsychopharmacology : official publication of the American College of Neuropsychopharmacology*, 47(1), 309–328. <https://doi.org/10.1038/s41386-021-01100-8>

**September 25<sup>th</sup>, 2024: Seminar 4. Working memory:** the thalamus and the visual cortex

1. Chen X, Sorenson E, Hwang K. Thalamocortical contributions to working memory processes during the n-back task. *Neurobiol Learn Mem*. 2023 Jan;197:107701. doi: 10.1016/j.nlm.2022.107701. Epub 2022 Nov 23. <https://doi.org/10.1016/j.nlm.2022.107701>
2. Teng, C., & Kravitz, D. J. (2019). Visual working memory directly alters perception. *Nature human behaviour*, 3(8), 827–836. <https://doi.org/10.1038/s41562-019-0640-4>

**October 2<sup>nd</sup>, 2024: Seminar 5. Working memory:** the parietal cortex and the anterior cingulate cortex

1. Berryhill, M. E., Chein, J., & Olson, I. R. (2011). At the intersection of attention and memory: the mechanistic role of the posterior parietal lobe in working memory. *Neuropsychologia*, 49(5), 1306–1315. <https://doi.org/10.1016/j.neuropsychologia.2011.02.033>
2. Lenartowicz A, McIntosh AR. The role of anterior cingulate cortex in working memory is shaped by functional connectivity. *J Cogn Neurosci*. 2005 Jul;17(7):1026-42. <https://doi.org/10.1162/0898929054475127>

**October 9<sup>th</sup>, 2024: Seminar 6. Working memory:** the prefrontal cortex

1. Barbey, A. K., Koenigs, M., & Grafman, J. (2013). Dorsolateral prefrontal contributions to human working memory. *Cortex; a journal devoted to the study of the nervous system and behavior*, 49(5), 1195–1205. <https://doi.org/10.1016/j.cortex.2012.05.022>

2. Mian, M. K., Sheth, S. A., Patel, S. R., Spiliopoulos, K., Eskandar, E. N., & Williams, Z. M. (2014). Encoding of rules by neurons in the human dorsolateral prefrontal cortex. *Cerebral cortex (New York, N.Y. : 1991)*, 24(3), 807–816. <https://doi.org/10.1093/cercor/bhs361>

**October 16<sup>th</sup>, 2024: Seminar 7. Working memory: the hippocampus and the amygdala**

1. Goodrich, R. I., Baer, T. L., Quent, J. A., & Yonelinas, A. P. (2019). Visual working memory impairments for single items following medial temporal lobe damage. *Neuropsychologia*, 134, 107227. <https://doi.org/10.1016/j.neuropsychologia.2019.107227>
2. Morgan, B., Terburg, D., Thornton, H. B., Stein, D. J., & van Honk, J. (2012). Paradoxical facilitation of working memory after basolateral amygdala damage. *PloS one*, 7(6), e38116. <https://doi.org/10.1371/journal.pone.0038116>

**October 23<sup>rd</sup>, 2024: Seminar 8. Working Memory: the cerebellum and the basal ganglia**

1. Brissenden, J. A., Tobyne, S. M., Halko, M. A., & Somers, D. C. (2021). Stimulus-Specific Visual Working Memory Representations in Human Cerebellar Lobule VIIb/VIIIa. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 41(5), 1033–1045. <https://doi.org/10.1523/JNEUROSCI.1253-20.2020>
2. Trutti AC, Sjoerds Z, Boag RJ, Walstra SLY, Miletić S, Isherwood SJS, Bazin PL, Hommel B, Habli S, Tse DHY, Håberg AK, Forstmann BU. Investigating working memory updating processes of the human subcortex using 7T MRI. *Elife*. 2025 Jun 25;13:RP97874. <https://doi.org/10.7554/eLife.97874>

**October 30<sup>th</sup>, 2024: Seminar 9. Working memory: Alzheimer's Disease and Parkinson's Disease**

1. Huntley JD, Hampshire A, Bor D, Owen A, Howard RJ. Adaptive working memory strategy training in early Alzheimer's disease: randomised controlled trial. *Br J Psychiatry*. 2017 Jan;210(1):61-66. doi: 10.1192/bjp.bp.116.182048. Epub 2016 Oct 6. PMID: 27758836; PMCID: PMC5209631. <https://doi.org/10.1192/bjp.bp.116.182048>
2. Liu, W., Wang, C., He, T., Su, M., Lu, Y., Zhang, G., Münte, T. F., Jin, L., & Ye, Z. (2021). Substantia nigra integrity correlates with sequential working memory in Parkinson's disease. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, 41(29), 6304–6313. Advance online publication. <https://doi.org/10.1523/JNEUROSCI.0242-21.2021>

**November 6<sup>th</sup>, 2024: Seminar 10. PEER REVIEW DAY**

1. DeMaria A. N. (2003). What constitutes a great review?. *Journal of the American College of Cardiology*, 42(7), 1314–1315.  
<https://doi.org/10.1016/j.jacc.2003.08.020>
2. Purdue University Online Writing Lab. *Giving feedback for peer review*. Retrieved from  
[https://owl.purdue.edu/owl/general\\_writing/the\\_writing\\_process/feedback/giving%20feedback\\_peer%20review.html](https://owl.purdue.edu/owl/general_writing/the_writing_process/feedback/giving%20feedback_peer%20review.html)
3. Lucey, B. (2013, September 27). *Peer review: how to get it right – 10 tips*. The Guardian. Retrieved from <https://www.theguardian.com/higher-education-network/blog/2013/sep/27/peer-review-10-tips-research-paper>

### **November 13<sup>th</sup>, 2024: Seminar 11. Working memory: Depression and Bipolar Disorder**

1. Cao W, Liao H, Cai S, Peng W, Liu Z, Zheng K, Liu J, Zhong M, Tan C, Yi J. Increased functional interaction within frontoparietal network during working memory task in major depressive disorder. *Hum Brain Mapp*. 2021 Nov;42(16):5217-5229. doi: 10.1002/hbm.25611. Epub 2021 Jul 30. <https://doi.org/10.1002/hbm.25611>.
2. Gruber, O., Tost, H., Henseler, I., Schmael, C., Scherk, H., Ende, G., Ruf, M., Falkai, P., & Rietschel, M. (2010). Pathological amygdala activation during working memory performance: Evidence for a pathophysiological trait marker in bipolar affective disorder. *Human brain mapping*, 31(1), 115–125.  
<https://doi.org/10.1002/hbm.20849>

### **November 20<sup>th</sup>, 2024: Seminar 12. Working memory: Attention-Deficit/Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD)**

1. Fassbender, C., Schweitzer, J. B., Cortes, C. R., Tagamets, M. A., Windsor, T. A., Reeves, G. M., & Gullapalli, R. (2011). Working memory in attention deficit/hyperactivity disorder is characterized by a lack of specialization of brain function. *PloS one*, 6(11), e27240. <https://doi.org/10.1371/journal.pone.0027240>
2. Sato, J., Safar, K., Vogan, V. M., & Taylor, M. J. (2023). Functional connectivity changes during working memory in autism spectrum disorder: A two-year longitudinal MEG study. *NeuroImage. Clinical*, 37, 103364.  
<https://doi.org/10.1016/j.nicl.2023.103364>

### **November 27<sup>th</sup>, 2024: NO CLASS (THANKSGIVING)**

### **December 4<sup>th</sup>, 2024: Seminar 13. Course Wrap Up and Poster Presentations**

#### **Grades:**

Your overall course grade will be determined by your effort in the following areas:

- **In-class preparation and participation** **20%**
  - Weekly reading questions (10%)
  - In-class contributions (10%)
- **Leading class discussion** **30%**
  - Plan for the discussion (10%)
  - Leading the discussion (10%)
  - Reflection of the discussion (10%)
- **Research project** **50%**
  - Research paper (30%)
  - Poster presentation (10%)
  - Peer review of another student's work (10%)

**Letter Grade Assignment:**

99-100%: A+	87-89.9%: B+	77-79.9%: C+	67-69.9%: D+	<60%: F
94-98.9%: A	84-86.9%: B	74-76.9%: C	64-66.9%: D	
90-93.9%: A-	80-83.9%: B-	70-73.9%: C-	60-63.9%: D-	

**Note about A+ grades:** A+ grades are earned by portion of students who have achieved high mastery of the material. If extra credit opportunities are provided, they cannot be used to move a student from an A to an A+ grade.

**Course Policies:** please read the following policies carefully!

**Disability Services:**

Students must register with their school's Disability Services office in order to receive disability-related accommodations and must complete the testing accommodation request form. More information is available at:

**Columbia:** <https://health.columbia.edu/content/disability-services>

**Barnard:** <https://barnard.edu/disabilityservices/register-cards>

**Religious Observance:**

If you are going to miss class(es) due to religious observance, you must notify me during the first week of class so that accommodations can be made.

**Seminar Attendance and Participation:**

Attendance and active participation are a critical component of your grade. Attendance will be taken each seminar. Each unexcused absence will result in lowering of your grade, e.g. A will become a B+ following two unexcused absences. 75% attendance is required to pass the class.

Seminar will be discussion based. This is your chance to share your perspective, thoughts, critiques, and questions. We will be relying on one another's contributions to have lively discussions about the week's topic, focusing heavily on the readings. Active participation is expected from all students.

### **Electronics Policy:**

It is strongly encouraged that you take hand-written notes. If you need to use a device, please be respectful of your classmates and your instructor by only accessing the document for class and not using the device to message or access the internet. Coming to class is of no value if you are not paying attention to the lecture. Messaging friends, watching videos online, and browsing social media are not appropriate for the classroom. Remember to silence your phones before class.

### **Unreadable File Submission:**

Any assignments that have unreadable files will automatically receive a 0% score. It is a student's responsibility to make sure that submissions are done in a proper manner and double check that files are readable and accessible to the teaching team. To avoid the penalty for unreadable file submission, try to work on the assignments ahead of time and give yourself enough time to check that the files submitted are accessible/readable.

### **Late Assignments:**

Any assignment that is turned in late will have a late penalty applied, with a 10% deduction in points for each day after the deadline that it is turned in. Assignments turned in late by 5 or more days will receive a max score of 50%. Assignments are not accepted after the last day of class (Monday, December 8<sup>th</sup> at 11:59 PM). Courseworks will automatically apply this deduction in points. If there are extenuating circumstances (death in the family, etc.) please notify me immediately. I cannot make accommodations if I don't know what's going on or if something occurs after the due date. Note: to avoid the penalty for late submissions, do not wait until the last minute to submit an assignment. Courseworks is sometimes slow to upload. Submitting in advance of the deadline is your best bet.

### **Academic Honesty:**

Academic honesty is taken very seriously. Columbia students commit to the Honor Code as follows: "I affirm that I will not plagiarize, use unauthorized materials, or give or receive illegitimate help on assignments, papers, or examinations. I will also uphold equity and honesty in the evaluation of my work and the work of others. I do so to sustain a community built around this Code of Honor." All suspected cases of dishonest behavior will be reported to Student Conduct and Community Standards. All submissions will be run through TurnItIn.

### **Sexual Respect:**

Any form of gender-based misconduct will not be tolerated. "Columbia University is committed to fostering an environment that is free from gender-based discrimination and harassment, including sexual assault and all other forms of gender-based misconduct." Visit this website for more information: <http://sexualrespect.columbia.edu/>

### **Zoom Class Link:**

If you need to join class via Zoom because of illness please email Dr. DeMoya for the class link. Importantly, to be admitted to class you must email Dr. DeMoya by one hour before the seminar explaining why you are unable to attend in person. (The earlier you can notify

me the better. You do not have to divulge personal details such as why you are sick, etc.)  
Failing to communicate with Dr. DeMoya before class regarding your absence will result in  
an unexcused absence. The same level of participation is expected if you join via Zoom.