**The Neurobiology of Working Memory**

PSYC UN3455

Course Syllabus - Fall 2023

**Instructor:** Dr. Sarah DeMoya **Seminar Time:** TBD

**E-mail**: [sed2182@columbia.edu](mailto:ih2194@columbia.edu) **Seminar Location:** TBD

**Office Hours:** TBD **Number of Credits:** TBD

**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 visual cortex 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 in childhood, in aging, and in various conditions including Parkinson’s, ADHD, and schizophrenia. 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 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 Parkinson’s disease, ADHD, and schizophrenia.
* 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 Prerequisites:**

Instructor permission is required to take the course. Undergraduate students should have already taken an introductory psychology or neuroscience course. 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:**

This seminar is 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 will meet the Group 2 (Neuroscience and Psychobiology) distribution requirement.

- For the Neuroscience and Behavior joint major, it will fulfill the Psychology requirement for an advanced psychology seminar.

- For Psychology Post-Baccalaureate students and for Psychology majors, it will fulfill the seminar requirement.

**Course Schedule:**

**Seminar 1. Course Intro:** forms of working memory, behavioral paradigms, research techniques

1. D'Esposito, M., & Postle, B. R. (2015). The cognitive neuroscience of working memory. *Annual review of psychology*, *66*, 115–142. <https://doi.org/10.1146/annurev-psych-010814-015031>
2. Eriksson, J., Vogel, E. K., Lansner, A., Bergström, F., & Nyberg, L. (2015). Neurocognitive Architecture of Working Memory. *Neuron*, *88*(1), 33–46. <https://doi.org/10.1016/j.neuron.2015.09.020>

**Seminar 2. Working memory:** neural mechanisms (delay cells, persistent firing)

1. Curtis, C. E., & D'Esposito, M. (2003). Persistent activity in the prefrontal cortex during working memory. *Trends in cognitive sciences*, *7*(9), 415–423. <https://doi.org/10.1016/s1364-6613(03)00197-9>
2. Goldman-Rakic P. S. (1995). Cellular basis of working memory. *Neuron*, *14*(3), 477–485. <https://doi.org/10.1016/0896-6273(95)90304-6>

**Seminar 3. Working memory:** population dynamics (oscillations, network connectivity)

1. Miller, E. K., Lundqvist, M., & Bastos, A. M. (2018). Working Memory 2.0. *Neuron*, *100*(2), 463–475. <https://doi.org/10.1016/j.neuron.2018.09.023>
2. Riddle, J., Scimeca, J. M., Cellier, D., Dhanani, S., & D'Esposito, M. (2020). Causal Evidence for a Role of Theta and Alpha Oscillations in the Control of Working Memory. *Current biology : CB*, *30*(9), 1748–1754.e4. <https://doi.org/10.1016/j.cub.2020.02.065>

**Seminar 4. Working memory and the visual cortex**

1. Rademaker, R. L., Chunharas, C., & Serences, J. T. (2019). Coexisting representations of sensory and mnemonic information in human visual cortex. *Nature neuroscience*, *22*(8), 1336–1344. <https://doi.org/10.1038/s41593-019-0428-x>
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>

**Seminar 5. Working memory and the parietal cortex**

1. Kiyonaga, A., Powers, J. P., Chiu, Y. C., & Egner, T. (2021). Hemisphere-specific Parietal Contributions to the Interplay between Working Memory and Attention. *Journal of cognitive neuroscience*, *33*(8), 1428–1441. <https://doi.org/10.1162/jocn_a_01740>
2. Koenigs, M., Barbey, A. K., Postle, B. R., & Grafman, J. (2009). Superior parietal cortex is critical for the manipulation of information in working memory. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *29*(47), 14980–14986. <https://doi.org/10.1523/JNEUROSCI.3706-09.2009>

**Seminar 6. Working memory and the hippocampus**

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. Kamiński, J., Sullivan, S., Chung, J. M., Ross, I. B., Mamelak, A. N., & Rutishauser, U. (2017). Persistently active neurons in human medial frontal and medial temporal lobe support working memory. *Nature neuroscience*, *20*(4), 590–601. <https://doi.org/10.1038/nn.4509>

**Seminar 7. Working memory and 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. Miller, J. A., Tambini, A., Kiyonaga, A., & D'Esposito, M. (2022). Long-term learning transforms prefrontal cortex representations during working memory. *Neuron*, *110*(22), 3805–3819.e6. <https://doi.org/10.1016/j.neuron.2022.09.019>

**Seminar 8. 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>
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>

**Seminar 9. Working memory and children**

1. Crone, E. A., Wendelken, C., Donohue, S., van Leijenhorst, L., & Bunge, S. A. (2006). Neurocognitive development of the ability to manipulate information in working memory. *Proceedings of the National Academy of Sciences of the United States of America*, *103*(24), 9315–9320. <https://doi.org/10.1073/pnas.0510088103>
2. Perlman, S. B., Huppert, T. J., & Luna, B. (2016). Functional Near-Infrared Spectroscopy Evidence for Development of Prefrontal Engagement in Working Memory in Early Through Middle Childhood. *Cerebral cortex (New York, N.Y. : 1991)*, *26*(6), 2790–2799. <https://doi.org/10.1093/cercor/bhv139>

**Seminar 10. Working memory and aging**

1. Evangelista, N. D., O'Shea, A., Kraft, J. N., Hausman, H. K., Boutzoukas, E. M., Nissim, N. R., Albizu, A., Hardcastle, C., Van Etten, E. J., Bharadwaj, P. K., Smith, S. G., Song, H., Hishaw, G. A., DeKosky, S., Wu, S., Porges, E., Alexander, G. E., Marsiske, M., Cohen, R., & Woods, A. J. (2021). Independent Contributions of Dorsolateral Prefrontal Structure and Function to Working Memory in Healthy Older Adults. *Cerebral cortex (New York, N.Y. : 1991)*, *31*(3), 1732–1743. <https://doi.org/10.1093/cercor/bhaa322>
2. Tagliabue, C. F., Varesio, G., & Mazza, V. (2022). Inter- and Intra-Hemispheric Age-Related Remodeling in Visuo-Spatial Working Memory. *Frontiers in aging neuroscience*, *13*, 807907. <https://doi.org/10.3389/fnagi.2021.807907>

**Seminar 11. Working memory and Parkinson’s disease**

1. 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>
2. Simioni, A. C., Dagher, A., & Fellows, L. K. (2017). Effects of levodopa on corticostriatal circuits supporting working memory in Parkinson's disease. *Cortex; a journal devoted to the study of the nervous system and behavior*, *93*, 193–205. <https://doi.org/10.1016/j.cortex.2017.05.021>

**Seminar 12. Working memory and Schizophrenia**

1. Hahn, B., Robinson, B. M., Leonard, C. J., Luck, S. J., & Gold, J. M. (2018). Posterior Parietal Cortex Dysfunction Is Central to Working Memory Storage and Broad Cognitive Deficits in Schizophrenia. *The Journal of neuroscience : the official journal of the Society for Neuroscience*, *38*(39), 8378–8387. <https://doi.org/10.1523/JNEUROSCI.0913-18.2018>
2. Perlstein, W. M., Carter, C. S., Noll, D. C., & Cohen, J. D. (2001). Relation of prefrontal cortex dysfunction to working memory and symptoms in schizophrenia. *The American journal of psychiatry*, *158*(7), 1105–1113. <https://doi.org/10.1176/appi.ajp.158.7.1105>

**Seminar 13. Working memory and ADHD**

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. Mukherjee, P., Hartanto, T., Iosif, A. M., Dixon, J. F., Hinshaw, S. P., Pakyurek, M., van den Bos, W., Guyer, A. E., McClure, S. M., Schweitzer, J. B., & Fassbender, C. (2021). Neural basis of working memory in ADHD: Load versus complexity. *NeuroImage. Clinical*, *30*, 102662. <https://doi.org/10.1016/j.nicl.2021.102662>

**Seminar 14. Course Wrap Up and Poster Presentations**

1. Nikolaidis, A., Voss, M. W., Lee, H., Vo, L. T., & Kramer, A. F. (2014). Parietal plasticity after training with a complex video game is associated with individual differences in improvements in an untrained working memory task. *Frontiers in human neuroscience*, *8*, 169. <https://doi.org/10.3389/fnhum.2014.00169>
2. Vivas, A. B., Ypsilanti, A., Ladas, A. I., Kounti, F., Tsolaki, M., & Estévez, A. F. (2018). Enhancement of Visuospatial Working Memory by the Differential Outcomes Procedure in Mild Cognitive Impairment and Alzheimer's Disease. *Frontiers in aging neuroscience*, *10*, 364. <https://doi.org/10.3389/fnagi.2018.00364>

**Course Grade:**

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

* **In-class participation and preparation 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%)

**Seminar Attendance:**

Attendance and active participation are a critical component of your grade. I will monitor attendance in 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 Participation:**

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.

**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.

**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.

**Readings:**

The course readings will 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 two days 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 be 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

**Late Assignments:**

Any assignment that is turned in late will have a 25% deduction in points for each day that they are turned in late, meaning an assignment turned in more than 4 days late will not earn any points. If there are extenuating circumstances (illness, death in the family, etc.) please notify me. I will of course be flexible if extenuating circumstances arise but I cannot make accommodations if I don't know what's going on.

**Zoom class link:**

If you need to join class via Zoom because of illness please use the link below. 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.

<https://columbiauniversity.zoom.us/my/sarah.demoya>

**Electronics Policy:**

It is strongly encouraged that you take hand-written notes. If you need to use a device (for example, to access one of the readings), 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.

**Academic Dishonesty:**

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 (SCCS).

**Disability Services:**

If you require additional assistance with assignments or exams, please check in with the Office of Disability Services. More information is available at:

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

**COVID-19:**

We will comply will all University-mandated COVID-19 policies.