Department of Psychology – Columbia University
Neuroscience of Imagination
GU4465 – Spring 2025 - 4 points
Class Meets: Monday 2.10 – 4PM   **Room:** Schermerhorn 200C

Instructor: Alfredo Spagna, Ph.D. (email)   **Office Hours** (link)

Course Bulletin Description

Visual Mental Imagery (VMI) is perceptual processing in the absence of direct sensory input – a quintessentially human faculty. It is our "Mind's Eye" - the faculty we use to relive our memories, enjoy a novel, create a painting, or predict whether our car will fit in a parking spot. As William Blake famously stated: "The imagination is not a state: it is the human existence itself". In short, VMI simulates the content of perceptual experiences, perhaps by translating conceptual knowledge into a visual format. Nobody has yet provided a convincing theory as to how to explain the subjective nature of our mental lives in objective physical terms. In this seminar, we will get a detailed understanding of the underlying neural processes responsible for conscious processing and awareness - one of the hottest topics in contemporary neuroscience.

Discussion will be related of current issues in the scientific studies of mental imagery, particularly in the visual modality, including the search for the neural correlates of visual imagination, and the various kinds of impairments of VMI in clinical and non-clinical cases. **A crucial aspect of this seminar is to help students develop their ability to critically read and evaluate the latest published research in this field.**

Prerequisites

Open to Ph.D. students in the Psychology department and graduate students in other related departments, with instructor's permission. Open to advanced undergraduate students who have taken an introductory course in neuroscience or cognitive psychology (e.g., UN2430), with instructor's permission.

Full Description:

Close your eyes and think of Leonardo da Vinci's Mona Lisa. Is she looking at you? Is her hair curly? In voluntary Visual Mental Imagery (VMI) we use our mind's eye to visualize things that are not in our direct line of sight (or that do not exist at all: imagine Mona Lisa frowning at you). VMI is perceptual processing in the absence of direct sensory input - the capability we use when we relive our memories, enjoy a novel, create a painting, or predict whether our car will fit in a parking spot.

Individuals vary in the subjective vividness of their voluntary VMI. Some experience extremely vivid quasi-visual imagery (hyperphantasia); others have less vivid imagery; in a few, otherwise healthy individuals – around 4% of the general population – VMI is completely absent (aphantasia). After briefly reviewing the historical philosophical debate that dominated the study of visual conscious perception and imagination (weeks 1 and 2), this seminar will then focus on contemporary investigations of mental imagery, including major challenges and pitfalls. By the end of the seminar, students should have learned about major theories of VMI and contemporary neuroscientific methodologies that allows us to study this cognitive function. Specifically, the course will:

- Introduce theories, research, and experiments that provided the basis for most debates on consciousness perception, whether seen or imagined.
- Provide overview of structure and function of sense organs and discussion on the role of psychophysical and neurophysiological experiments in providing insights in our understanding of consciousness.

- introduce case studies from neuropsychological patients for discussion, with the goal of demonstrating how data from patients with specific types of brain damage provide important insights into the neural bases of normal cognitive functioning.
- Stream through a variety of cognitive functions which are important to achieve and maintain a "conscious imager" over time, from attention, to episodic memory, to semantic processing.
- Meld together the data from both the behavioral and neurobiological sources for each topic to show our current thinking on how VMI is instantiated in the brain, and how it is mapped onto specific brain networks and the nature of the calculations performed in the different nodes within these networks.

Learning Objectives:
By the end of the course, students are expected to demonstrate their knowledge of:
- The structure of the major sensory systems.
- The history and methods used in the science of mental imagery.
- Behaviorally based models and theories of mental imagery.
- The neurobiological bases of normal and abnormal conscious states.

Role in the Psychology curriculum
PSYC GU4465 is an advanced seminar, designed particularly for undergraduates who are majoring in Psychology or in Neuroscience and Behavior, for students participating in the Post-bac Psychology Program, and for Psychology Graduate Students. Students with a background in the computational sciences and philosophy are also welcome to apply. In covering the cognitive and neural bases of mental imagery, the course provides an integrated perspective on topics of current interest in the fields of psychology and cognitive neuroscience.

The seminar fulfills the following degree requirements:
- For Psychology Graduate Students, PSYC GU4465 will apply toward the "two seriously graded seminars" requirement of the Master's degree.
- For the Psychology major or concentration in the College and in G. S., and for the Psychology Post-bac certificate, PSYC GU4465 will meet the Group II (Perception and Cognition) distribution requirement.
- For the Neuroscience and Behavior joint major, PSYC GU4465 will fulfill the 5th Psychology requirement: "one advanced psychology seminar from a list approved by the Psychology Department advisor to the program."
- For the Psychology post-bac certificate, PSYC GU4465 will fulfill the 7th (advanced seminar) requirement
- For the science requirements of the College and GS, PSYC GU4465 is numbered among the group of courses (3200s, 4200s, 3400s, 4400s) that are not designed for non-science majors but that do fulfill one term of the requirement. Graduate students, and students who are majoring in Psychology or in Neuroscience and Behavior, will have priority over students who wish to take the course for the science requirement.

Readings:
There is no textbook required for this course
Readings will comprise scientific articles from peer - reviewed journals, literature reviews, and commentaries in the fields of neuroimaging. The readings listed in the Schedule below are provisional but illustrative of the types of articles we will be reading and discussing. All readings will be posted in PDF form on CourseWorks.

Course Requirements:
1. **Class preparation and participation (20%):**
The assigned readings are designed to expand your knowledge on the latest advancement in the field of neuroscience of human imagination and to hone your critical thinking skills. The topics discussed during the course are complex, leaving plenty of space to discuss and debate. Strong preparation and participation will enable us to have high-level, thought-provoking discussion.
Effective class preparation and participation could include:

• Asking insightful or clarifying questions.
• Connecting the reading to other reading we've done in the course or reading you've done on your own, drawing parallels and/or contrasts among findings.
• Actively listening to fellow classmates and responding to their ideas.
• Offering thoughtful critiques of the research methodology and providing suggestions for how it might be improved.
• Bringing in outside sources – potentially from the news media or other sources – that shed light on neuroscience findings or that illustrate ways in which these findings are interpreted and applied.

2. Weekly Responses (30%):
The Sunday before each class period you will be asked to <u>submit a short (one-paragraph) reading response</u> (i.e., summary of the article + reflections on each of the weekly readings) to CourseWorks by 10:00pm. Goals of these reading responses are to help you keep current on course topics and to help me understand where students may have had difficulty with the readings and which topics students were most intrigued by and, therefore, which areas may warrant more focus during class time. Each summary+ reflection should be no more than a short paragraph, either discussing something interesting you found in the reading or asking substantive questions about concepts in the reading you found challenging. These assignments will be graded on a two-point scale with 0 = not submitted / incomplete; 1 = completed but superficial / lacking / late; 2 = completed on time and discusses all the material properly.

Careful reading enables thoughtful discussion. It is important to engage with the material during the instructor's introduction as well as during class discussions. <u>Your active participation will contribute to your final grade</u>. Some of the topics discussed in the course could be harder to digest, please do reach out to the instructor if something is unclear. If you feel that regularly contributing to class discussions is difficult for you, you should raise this issue with me as soon as possible. In such cases, we will work out a way for you to participate thoughtfully through your reading responses.

3. **Presentation and Leading section (30%):** Everyone is required to give two 30-minute slide presentations on a papers assigned for that week. Presentations should be at least a few weeks apart from each other. <u>Use this shared google sheet to (self) sign up for a presentation.</u> Follow this structure when building your presentation:

   1. Introduce the authors and journal where the article is published.
   2. Briefly introduce the topic and create an outline of the topics you'll be discussing;
   3. Describe the main concepts introduced, methods and results (if not a review);
   4. Highlight strengths or weaknesses of the study design;
   5. Give your thoughts on the meaning and importance of the findings.
   6. To make sure that your presentation is clear and effective, all students must:
   7. <u>Complete a handout and email that to the instructor</u> at least one week before the date of your presentation. I will provide feedback in advance of your actual presentations. A penalty of 5 points will be applied if the student does not submit the handout ahead of time.
   8. <u>Schedule a time to meet with me during office hours</u> at least one week before the date of your presentation. A penalty of 5 points will be applied if the student does not schedule a meeting.

Each presentation will be graded out of 50 points, following this grading scheme:
   a. 10 points: What question is this paper trying to answer? This will require reading some of the papers cited in this paper's introduction, to help provide context.
   b. 10 points: For papers reporting a new experiment, what is the experimental method? For review or theory papers, what are the details of the theory or theories being proposed?
   c. 10 points: What evidence is given in support of the hypothesis or theory?
   d. 10 points: Propose questions for discussion. Are there potential weakness or limitations to the conclusions of the paper? Do these results connect to topics from other sessions of the class or from other classes you've taken? Do these findings have implications for how writing or filmmaking can be made more effective?

e. 10 points: Clarity of slides, presentation, and class engagement. Slides should consist primarily of figures, images, and diagrams with only small amounts of text. You should engage your classmates by posing questions throughout your presentation and answering their questions about the paper (when possible).

As the goal is for you to become more skilled in presenting research findings and leading discussions, in calculating grades, the second presentation will be weighted more heavily than the first (see grading scheme).

2. **Research manuscript (20%):** The culmination of this course is the creation of a novel research proposal relating to the material of the class. Good writing is good thinking, and a primary goal of this assignment is to help students enhance writing and critical thinking skills by deepening their understanding of a course-related topic of their choice. The research manuscript assignment is composed of the 4 main steps of the scientific writing process:
   a. Topic Proposal (max 1 page). 10 points
   b. Submission (7-9 pages). 50 points

   ==**STEP 1: Choose your Topic**==: Early in the course students will be asked to identify a topic related to the class and submit the proposal on the Courseworks Assignment Page. The instructor will promptly approve the topic or give some suggestions for changes if needed (e.g., if the topic chosen does not fit with the course's content). Good topic proposals define literature searches that a student is planning to conduct, explaining why that topic is relevant / important. **Deadline Week 7 – Monday March 10th at 10PM.**
   Structure your topic proposal as:
   - Title of the topic
   - Your name and last name and affiliation
   - A paragraph (about 150 words) describing the motivation for writing this proposal
   - A preliminary list of references that the student is planning on reading to write the assignment.

   ==**STEP 2: Submission**==: The final draft of the paper will be graded not only as a standalone paper but also in how it demonstrates improvement upon the earlier draft.
   - <u>Title page</u>
     a) Title of the topic
     b) Your name and last name and affiliation
   - <u>The Submission itself (maximum 7-9 pages, double-spaced; one inch margins)</u>
     c) Clearly identify what is the topic you are working on
     d) Briefly summarize the state of the art of the literature and why the topic is important
     e) Identify the constructs / concepts you want to study and methods used
     f) Identify a scientific question that justify the need for your scientific investigation
     g) Critically discuss the relevant literature
     h) Discuss limitations of the relevant studies discussed/identify a gap in the literature
     i) Conclusions and future directions
   - <u>The list of references cited in the assignment (not included in the page limit)</u>.

   Each manuscript will be graded out of 50 points, following this grading scheme:
   - 10 points: Is the topic clearly identified, relevant to the course content, and thoroughly discussed? Why did you choose to write about this?
   - 10 points: Are multiple references (more than 10, at least 5 not from the reading list) included in the manuscript? What was the potential advancement in the literature that you are thinking about?
   - 10 points: Did the student identify challenges to study the theory / method / topic selected, and how to solve them? What is the main take home message you want to convey?
   - 10 points: Did the student propose some adaption to one or more aspects of the method used, or a revision of the theory? What are potential future research ideas?

- 10 points: Does the writing convey a student's learning? After the course, does the student have a deeper understanding about the topic? The grade submitted will be the same for the entire team. **Deadline for Final Submission Monday May 5th at 10.00PM.**

Letter Grade Assignment

A+: 100%	B+: 87-89.9%	C+: 77-79.9%	D: 60-60.9%
A: 95-99%	B: 83-86.9%	C: 73-76.9%	F: 0-59/9%
A-: 90-94.9	B-: 80-82.9%	C-: 70-72.9%	

Late Submissions Policy: a penalty worth of 50% of an assignment's grade will be applied to late submission (i.e., presentations, reading responses, components of the writing assignment).

Note: to avoid the penalty for late submission try to work on the assignments ahead of time. It is often the case that Canvas glitches happen during the process of submitting an assignment. The best way to avoid incurring the late submission penalty is giving yourself enough time *before* the actual deadline. In other words, submitting an assignment at 9:59PM is a risky decision and we recommend you avoid doing that or you might incur in the late submission policy.

Unreadable file submission: a penalty worth of 100% of an assignment's grade will be applied to unreadable file submissions. 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.

Note: 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. It is very rare that Canvas glitches are responsible for this type of issue.

Schedule

The calendar below details topics, readings, and assignments for each class period. It may be subject to changes to reflect interests of students. Students are responsible to be prepared to discuss the assigned readings for each class period. Typically, each class period will begin with a short lecture providing the background in neuroscience necessary to better explore the issue of the day, conducted by the Instructor. The majority of class time will be devoted to student presentations and student-led discussions (detailed in Course Requirements).

Week 1: Monday, January 27th
- **Introduction to the Seminar:** review of Syllabus and overview of the topics

Week 2: Monday, February 3rd: Introduction to Cognitive Neuroscience of Conscious Perception
- **History & Review:** Bassett Haggard Farah Poldrack et al 2020 - Reflections on the past two decades of neuroscience. *NatNeuro Viewpoints*
- **Original Research:** Pins D, Ffytche D (2003) The neural correlates of conscious vision. Cereb Cortex 13(5):461–474
- **Method:** Juavinett 2021 - The next generation of neuroscientists needs to learn how to code, and we need new ways to teach them. *Neuron*

Week 3: Monday, February 10th: The Classical Model of VMI - part I
- **History & Review:** Pearson, J., Naselaris, T., Holmes, E. A. & Kosslyn, S. M. Mental Imagery: Functional Mechanisms and Clinical Applications. *Trends in Cognitive Sciences* **19**, 590-602, (2015).
- **Original Research:** Dijkstra, N., Bosch, S. E. & van Gerven, M. A. Vividness of Visual Imagery Depends on the Neural Overlap with Perception in Visual Areas. *J Neurosci* **37**, 1367-1373, (2017).
- **Method:** Bandettini, P. A. (2012). Twenty years of functional MRI: the science and the stories. *Neuroimage*, *62*(2), 575-588

Week 4: Monday, February 17th: The Classical Model of VMI - part II
- **History & Review:** Pearson, J. The human imagination: the cognitive neuroscience of visual mental imagery. Nat. Rev. Neurosci. 20, 624-634, (2019).

- **Original Research:** Dijkstra, N., Mostert, P., Lange, F. P. D., Bosch, S., & van Gerven, M. A. (2018). Differential temporal dynamics during visual imagery and perception. Elife, 7, e33904.
- **Method:** Baillet, S. (2017). Magnetoencephalography for brain electrophysiology and imaging. Nature neuroscience, 20(3), 327.

Week 5: Monday, February 24th: Challenges to the classical model of VMI - part I
- **History & Review:** Bartolomeo, P., Hajhajate, D., Liu, J., & Spagna, A. (2020). Assessing the causal role of early visual areas in visual mental imagery. Nature Reviews Neuroscience, 21(9), 517-517.
- **Original Research:** Spagna, A., Hajhajate, D., Liu, J., & Bartolomeo, P. (2021). Visual mental imagery engages the left fusiform gyrus, but not the early visual cortex: A meta-analysis of neuroimaging evidence. Neurosci & Biobehavioral Reviews, 122, 201-217.
- **Method:** Fox, P. T., Lancaster, J. L., Laird, A. R., & Eickhoff, S. B. (2014). Meta-analysis in human neuroimaging: computational modeling of large-scale databases. Annual review of neuroscience, 37, 409-434.

Week 6: Monday, March 3rd: Challenges to the classical model of VMI - part II
- **History & Review:** Spagna, A. (2022). Visual mental imagery: Inside the mind's eyes. Handbook of Clinical Neurology, 187, 145-160.
- **Original Research:** Liu, J., & Bartolomeo, P. (2023). Probing the unimaginable: The impact of aphantasia on distinct domains of visual mental imagery and visual perception.
- **Method:** Edlow, B. L., Mareyam, A., Horn, A., Polimeni, J. R., Witzel, T., Tisdall, M. D., ... & Tirrell, L. S. (2019). 7 Tesla MRI of the ex vivo human brain at 100 micron resolution. *Scientific data*, *6*(1), 1-10.

Week 7: Monday, March 10th
- Discussion and Practice session over Topic Proposal Writing

Week 8: Monday, March 17th
- Spring Break

Week 9: Monday, March 24th Using Neuroimaging to study Imagination
- **History & Review:** Spagna, A., Heidenry, Z., Miselevich, M., Lambert, C., Eisenstadt, B. E., Tremblay, L., ... & Bartolomeo, P. (2024). Visual mental imagery: Evidence for a heterarchical neural architecture. Physics of Life Reviews, 48, 113-131.
- **Original Research:** Liu, J., Zhan, M., Hajhajate, D., Spagna, A., Dehaene, S., Cohen, L., & Bartolomeo, P. (2023). Ultra-high field fMRI of visual mental imagery in typical imagers and aphantasic individuals. bioRxiv, 2023-06.
- **Method:** Vu, A. T., Jamison, K., Glasser, M. F., Smith, S. M., Coalson, T., Moeller, S., ... & Yacoub, E. (2017). Tradeoffs in pushing the spatial resolution of fMRI for the 7T Human Connectome Project. Neuroimage, 154, 23.

Week 10: Monday, March 31st Auditory Mental Imagery and Intracerebral Recordings
- **History & Review:** Vaidya, A. R., Pujara, M. S., Petrides, M., Murray, E. A., & Fellows, L. K. (2019). Lesion studies in contemporary neuroscience. *Trends in Cognitive Sciences*, *23*(8), 653-671.
- **Original Research:** Martin, S., Mikutta, C., Leonard, M. K., Hungate, D., Koelsch, S., Shamma, S., ... & Pasley, B. N. (2018). Neural encoding of auditory features during music perception and imagery. Cerebral Cortex, 28(12), 4222-4233.
- **Method:** Parvizi, J., & Kastner, S. (2018). Human intracranial EEG: promises and limitations. *Nature neuroscience*, *21*(4), 474.

Week 11: Monday, April 7th White Matter bundles supporting VMI
- **History & Review:** Liu, J., Spagna, A., & Bartolomeo, P. (2022). Hemispheric asymmetries in visual mental imagery. Brain Structure and Function, 1-12.
- **Original Research:** Hajhajate, D., Kaufmann, B. C., Liu, J., Siuda-Krzywicka, K., & Bartolomeo, P. (2022). The connectional anatomy of visual mental imagery: evidence from a patient with left occipito-temporal damage. Brain Structure and Function, 227(9), 3075-3083.
- **Method:** Catani, M., & De Schotten, M. T. (2008). A diffusion tensor imaging tractography atlas for virtual in vivo dissections. cortex, 44(8), 1105-1132.

Week 12: Monday, April 14th: <u>Multimodal mental Imagery and Causality Inference</u>
- **History & Review:** Nanay, B. (2018). Multimodal mental imagery. Cortex, 105, 125-134.
- **Original Research:** Thorudottir, S., Sigurdardottir, H. M., Rice, G. E., Kerry, S. J., Robotham, R. J., Leff, A. P., & Starrfelt, R. (2020). The architect who lost the ability to imagine: The cerebral basis of visual imagery. Brain Sciences, 10(2), 59.
- **Method:** Parkin, B. L., Ekhtiari, H., & Walsh, V. F. (2015). Non-invasive human brain stimulation in cognitive neuroscience: a primer. *Neuron*, *87*(5), 932-945.

Week 13: Monday, April 21st
- Discussion and Practice session Scientific Writing

Week 14: Monday, April 28th <u>Challenging the whole field: What are we talking about?</u>
- Buzsáki, G. (2020). The Brain–Cognitive Behavior Problem: A Retrospective. *eNeuro*, *7*(4).
- **Review:** Dijkstra, N., Kok, P., & Fleming, S. M. (2022). Perceptual reality monitoring: Neural mechanisms dissociating imagination from reality. Neuroscience & Biobehavioral Reviews, 135, 104557.

Week 15: Monday, May 5th <u>Class Discussion and catch up: what did we talk about?</u>
- no readings assigned
- update on the writing

Class policies: Important Information below – please read carefully!'

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. Be sure to be familiar with it, to be able to login to the website, and that you always have the readings with you (whether printed or electronic). If you have problems accessing the course website at any point during the semester, please let me know.

o <u>Special needs:</u> If you are a student with special needs and require any type of accommodation, please make an appointment with me before the first class to discuss your needs. You should also contact the office of Disability Services (https://health.columbia.edu/disability-services) before the first class to register for specific accommodations. If you have problems reading specific kinds of text (e.g., based on font or text size), please see me so I can make you exams (and a syllabus, and anything else you need) that you can more easily read.

o <u>Religious observances</u>: If you are going to miss class(es) due to religious holidays, you must notify me during the first week of class so that accommodations may be made.

o <u>Academic integrity:</u> As members of this academic community, we are responsible for maintaining the highest level of personal and academic integrity: "Each one of us bears the responsibility to participate in scholarly discourse and research in a manner characterized by intellectual honesty and scholarly integrity.… The exchange of ideas relies upon a mutual trust that sources, opinions, facts, and insights will be properly noted and carefully credited. In practical terms, this means that, as students, you must be responsible for the full citations of others' ideas in all of your research papers and projects… [and] you must always submit your own work and not that of another student, scholar, or internet agent" (from the [Columbia University Faculty Statement on Academic Integrity](http://www.college.columbia.edu/academics/academicintegrity)) http://www.college.columbia.edu/academics/academicintegrity .

o Cheating and plagiarism – whether intentional or inadvertent – is a serious violation of academic integrity. Plagiarism is the practice of claiming or implying original authorship of (or incorporating materials from) someone else's written or creative work, in whole or in part, without adequate acknowledgement. If you have any questions about what constitutes plagiarism and/or how to properly cite sources, please come to me. I am more than happy to help. Similarly, if you put yourself in a situation in which you think your best option might be to cut some corners, see me. If you feel like you are falling behind, don't understand the material, or are not confident about your ability to take tests, talk to me as soon as possible instead of taking measures that go against principles of academic integrity. <u>We are here to learn</u>, not to merely judge. It is a far better option to come talk to me than compromise your academic integrity and potentially put your academic standing in jeopardy.

o <u>Sexual Respect:</u> 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/

o <u>Attendance:</u> Coming to class is meaningless if class time is spent inappropriately. Chatting with friends, watching videos online, and browsing social media are not appropriate activities for the classroom. Also, remember to silence your cell phone before class. Generally, eliminate distractions as much as possible to respect your classmates, as well as increase your chance of staying focused and learning the material during class.

Changes to the Syllabus might happen during the course. The most recent version will <u>always</u> be posted on the Courseworks page.