

Fundamental Principles of Vision (AS.080.355)

Room: Maryland 309

Fall 2019

Time & Place: Tuesday & Thursday
10:30 – 11:45
Maryland 211

Course Directors: Charles Connor
338 Krieger Hall
6-8648
connor@jhu.edu

Kristina Nielsen
338 Krieger Hall
6-5833
Kristina.nielsen@jhu.edu

Office hours: Wednesday/Friday 1-3

Course Description

Even though we rarely acknowledge it as such, vision is our superpower. It is so central to how we (or at least most of us) interact with the world, and it comes to us with such ease, that we underappreciate its complexity. To this date, there are no computer vision programs that can parallel the performance of the human visual system. Vision is also the topic that both of us actively research, and are passionately interested in. Lastly, the neural underpinnings of vision are amongst the most thoroughly studied. As such, vision provides a very useful framework for learning about general principles of Neuroscience.

The goal of this class is to teach you the Neuroscience of vision, with topics ranging from a general overview of the visual system to highlighting ongoing research studies. We will also talk about state-of-the art computer vision efforts as a comparison. The class is designed to not only provide you with the relevant background knowledge, but also to teach you how to critically evaluate current research papers. As such, the class will be split into ‘classical’ lectures, in which we provide an overview over a particular topic, and discussion classes. Discussion classes will serve to discuss one or two original research papers in depth. Our intention is for the discussion classes to feel like a real journal club or lab meeting, with a very active discussion amongst all of the participants.

To achieve the latter will require rigorous work by everybody. All of the reading for the discussion classes will be primary material, which might (at least initially) be challenging. However, if we all do our job right, you should be well able to easily read the primary literature by the end of the class. Nonetheless, be prepared to work hard, and set aside time for the reading. This is a small and very advanced seminar, and participation in the discussions will be a central part of it (including your grade). Talking (or not talking) about things you haven’t read will not go unnoticed (and make us annoyed), and will be reflected in your grade. Attendance at every session is **required**.

Undergraduate Requirements & Grading

1. Participation and weekly discussion board post (40% total)

Participation will be a big factor in determining your grade. Participation means: useful contributions to class discussions and required weekly discussion board posts. Each week, every student is **required** to make a post to a discussion board that will be set up on Blackboard. **Your post must appear by Wednesday, 7pm** (i.e. the evening before the second class per week, which will be the class focused on discussing primary material). You're also **required** to read your fellow students' posts before class, so that we can have an informed conversation during class. These posts should be brief (~1 paragraph, or about 50 words, although you are free to write more if you want to), and should raise a question about that week's reading. These are not meant to be polished pieces of writing, but they shouldn't be overly informal either. For example, the following would be fine: "XXX designed their study to test the hypothesis that YYY. However, their analysis/study design fails to account for ZZZ." We will not assign grades to posts, but instead will take the general quality of your effort into account in deciding participation grades at the end of the term. If we find your posts insufficient early on, we'll let you know and pass on advice on how to improve them.

2. One review (30% total)

Another large portion of your grade will be determined by a longer and more substantive review of a scientific paper, related to ones we read during the class. The review should be about 1,500 to 2,000 words. We provide a list of suggested papers to review below, but you can also ask us for other suggestions. The review should address the following 3 questions:

- a. *Framework and hypotheses*: Describe the scientific background that the paper builds on, and state the hypothesis/hypotheses that the paper aims to test.
- b. *Methods and results*: Describe the key methodological design of the paper, and the central results.
- c. *Discussion and significance*: Discuss the main findings of the paper. Are there any issues with the methods including the analyses and/or results? Did they authors achieve a test of their hypothesis? Do the results prove or disprove it? Also discuss the significance of the findings. Will these results still be discussed in 5 years in the broader neuroscience community, and why?

Due dates for the review: November 5, at midnight.

3. Summary essay (30% total)

The final part of your grade comes from an essay that is to be written at the end of the class. We will provide the topic and length of the essay two weeks before it is due, but generally speaking, the essay prompt will ask you to summarize and reflect on general topics taught and papers discussed during the class.

Due date for the summary essay: December 17, at midnight.

4. Overall grading breakdown

40% participation (including board posts)

30% review

30% summary essay

Webpage

There will be a Blackboard page for this course. The syllabus and other course material (slides, hand-outs, reading material) will be posted there. The discussion board for posts is also there. To get to the course Blackboard page, go to <http://blackboard.jhu.edu>.

Policy on Electronica

- **Laptop use is not allowed in class** (excepting accommodations). We would like you to focus on the material presented, without outside distractions. We want to make this class as active as possible, and you can't participate in the class if you're buried in your laptop. In addition, evidence has been building that students who take notes on their laptop tend to not learn material as well as those who take notes by hand. We will ask you to print out discussion papers so that you can annotate them and bring them to class.
- **Phones must remain out of sight with the ringer off.** This includes not texting, not emailing, not checking who texted, called etc. Again, we want you to be present in class so that you can effectively participate in the conversation.

Policy on Lateness

Late papers are assessed a one-third-grade penalty per day (an A will become an A-, an A- a B, etc). In extreme circumstances (e.g., death of a family member), a student may request, prior to the due date, an extension.

Reading Schedule

Date	Topic	Format	Paper
9/3	Introduction	Lecture	
9/5	From retina to V1	Lecture	
9/10	V1 tuning properties and organization	Lecture	
9/12	V1: Tuning and natural input statistics	Discussion	Olshausen & Field, Nature 381, 607-609 (1996)
9/17	From V1 to V4	Lecture	
9/19	V4: Tuning and natural input statistics	Discussion	Carlson et al, Current Biology 21 (4), 288 – 293 (2011)
9/24	3D configural coding: V4 and DNN	Lecture	
9/26	DNNs in vision research	Discussion	Ponce et al, Cell 177 (4), 999-1009 (2019)
10/1	IT: objects, faces and scenes	Lecture	
10/3	Face space coding	Discussion	Chang & Tsao, Cell 169 (6), 1013-1028 (2017)
10/8	Feedforward versus recursive processing	Lecture	
10/10	Prediction signals	Discussion	Schwiedrzik & Freiwald, Neuron 96 (1), 89-97 (2017)

10/15	Visual system beyond IT	Lecture	
10/17	Value processing	Discussion	Sasikumar et al, Current Biology 28 (4), 538-548 (2018)
10/22	<i>Free (prepare for review session)</i>	---	
10/24	Review session (to prepare for review papers)	---	
10/29	MT tuning properties and organization	Lecture	
10/31	Evolution of MT tuning properties	Discussion	Smith et al, Nature Neuroscience 8, 220-228 (2005)
11//5	Perceptual decision-making	Lecture	
11/7	Decisions and confidence	Discussion	Kiani & Shadlen, Science 324 (5928), 759-764 (2009)
11/12	Visual attention	Lecture	
11/14	Attentional control	Discussion	Moore & Armstrong, Nature 421, 370-373 (2003)
12/3	Conscious vision	Lecture	
12/5	Conscious vision	Discussion	Zuboff: The story of a brain

All papers will be available on Blackboard.

Paper suggestions for review

Vinje & Gallant: Sparse coding and decorrelation in primary visual cortex during natural vision. Science 287 (5456), 1273-1276 (2000).

Okazawa, Tajima & Komatsu. Image statistics underlying natural texture selectivity of neurons in macaque V4. PNAS 112 (4), E351-360 (2015).

Bashivan, Kar & DiCarlo. Neural population control via deep image synthesis. Science 364 (6439), eaav9436 (2019).

Srihasam, Vincent & Livingstone. Novel domain formation reveals proto-architecture in inferotemporal cortex. Nature Neuroscience (17), 1776-1783 (2014).

Issa, Cadieu & DiCarlo. Neural dynamics at successive stages of the ventral visual stream are consistent with hierarchical error signals. eLife 7:e42870 (2018).

Freedman, Riesenhuber, Poggio & Miller. A comparison of primate prefrontal and inferior temporal cortices during visual categorization. Journal of Neuroscience 23 (12), 5235-5246 (2003).

Pack, Gartland & Born. Integration of contour and terminator signals in visual area MT of alert macaque. Journal of Neuroscience 24 (13), 3268-3280 (2004).

Fetsch, Kiani, Newsome & Shadlen. Effects of cortical microstimulation on confidence in a perceptual decision. *Neuron* 83 (4), 797-804 (2014).

Briggs, Mangun & Usrey. Attention enhances synaptic efficacy and the signal-to-noise ratio in neural circuits. *Nature* 499, 476-480 (2013).