ADVANCES IN VISUAL PERCEPTION, PSYC 526 Winter semester 2018

Professors: Dr. Kathy T. Mullen & Frederick A.A. Kingdom

COURSE DETAILS

Tuesday & Thursdays 1:00–2:30pm, Stewart Biology Bldg., Room S3/4, unless otherwise stated. The textbook is "Basic Vision", Revised Addition, by Robert Snowden, Peter Thompson, and Tom Troscianko, Oxford University Press (available from the McGill Bookstore), with additional articles as listed below (usually posted on myCourses). The PowerPoint presentations accompanying the lectures can be viewed on myCourses. Readings below may be substituted or altered as the course progresses. See also "**Course summary**".

Topic 1: Introduction to Course & Brief History of Vision (1 class). Prof. Fred Kingdom Tues. 9th January.

Welcome and Introduction to the course. The aims, content and method of assessment of the course will be described.

A brief history of vision. I describe some of the principal ideas about vision held by philosophers and scientists throughout history, beginning with the 'emanation theory' of vision held by Greek philosophers, the idea that eyes emitted rays of light. During the Renaissance the emanation theory was replaced by the idea that images were created inside the eye and transmitted to a 'sensorium' in the brain, which could "see" what was in them. Finally, this gave way in the 19th century to the modern idea that physiological structures within the nervous system analyze the content of the retinal image. Today we recognize that the form of these physiological structures determines much of the way in which we perceive the visual world.

Reading:

"Seeing", by Frisby and Stone, Ch. 1.

Wade, N. (1998) "Light and sight since antiquity", *Perception*, 27, 637-670.

Topic 2: Structure to Function 1, Prof. Kathy Mullen, Thurs. 11th & Tues. 16th January

Cornea to cortex. Over the next three weeks, I will examine the physiological basis of our vision. We will consider how much of our visual function can be explained by the available physiological data. I will first give an overview of the visual pathway from eye to brain. Then I will give a more detailed discussion of each stage, beginning with the role of the retina in vision. I will ask what information leaves the retina for processing by the brain, and what information is discarded. This reveals the first stages in building the neural representation of the image, and the first evidence for a segregation of function into parallel 'streams'.

Reading:

"Basic Vision", Snowden, Thompson & Troscianko (OUP) 2006. Pp32-65. (Not boxes 2.3, 2.4).

Start on two short reviews: 1. Merigan, W.H. & Maunsell, JHR (1993) "How parallel are the primate visual pathways? *Annual Reviews of Neuroscience*, 16, **pp369-377 only** – gives a **brief** overview related to the readings below. 2. A more **recent** review is: Callaway E.M. (2005) "Structure and Function of parallel pathways in the primate early visual system." *J. Physiol.* 566, **pp13-15 only**.

For Thursday's Discussion, we will compare:
Merigan, W.H. "M & P pathway specializations in the Macaque". In *From Pigments to Perception*, pp117-125 (1991).

Schiller, P et al. "Functions of the color-opponent and broadband channels of the visual system", *Nature, 343*, 68-70 (1990).

Discussion Topics: How do the properties of the M cell & P cell pathways of the primate retina and LGN differ? How have their properties been identified? Do these pathways contribute selectively to the specialized functions associated with different cortical regions? Do M and P cells influence vision at the behavioural level?

Course Add/Drop deadline Tuesday, 23rd January 2018.

Topic 3: Structure to Function II, Prof. Kathy Mullen, Thurs. 18th & Tues. 23rd January.

The primary visual cortex. The classical experiments of Hubel & Wiesel in the 1960s and 1970s gave us fundamental insights into how information is processed in the visual cortex. Their work will be discussed and how these ideas have since evolved. We will examine why Hubel & Wiesel's experiments suggested that there was a hierarchical analysis of visual information in the striate cortex. I will discuss the advantages and disadvantages of hierarchical and parallel modes of visual processing, and the evidence for each at the level of the striate cortex.

Reading:
"Basic Vision", Snowden, Thompson & Troscianko, Ch. 3 to page 86.

"Visual Perception: physiology, psychology and ecology". Bruce, Green and Georgeson. Chapter 3, **pp43-57**. (Psychology Press, New York). Similar to "Basic Vision" but has more information.

Continue with the two short reviews: 1. Merigan, W.H. & Maunsell, JHR (1993) "How parallel are the primate visual pathways? *Annual Reviews of Neuroscience*, 16, **pp384-392 only** – gives a **brief** overview related to the readings below. 2. A more **recent** review is: Callaway E.M. (2005) "Structure and Function of parallel pathways in the primate early visual system." *J. Physiol.* 566, **pp16-18 only**.

For Wednesdays Discussion, please read: Yao & Li "Clustered organization of neurons with similar extra-receptive field properties in the primary visual cortex" *Neuron, 35,* 547-553 (2002).

Graduates only: Seeing, Ch.10 on cortical maps.

Discussion Topics: How has our understanding of visual processing been advanced by the use of single cell recording techniques, developed by Hubel and Wiesel? What have we found out about the organization of the visual cortex (V1 & V2)? What is meant by 'parallel' versus 'hierarchical' organization of the visual system, and what are the advantages and disadvantages of each? What type of processing best describes: the retina, LGN, striate cortex, extra striate cortex?

Topic 4: Structure to Function III, Prof. Kathy Mullen, Thurs. 25th and Tues. 30th January

Multiple cortical areas and parallel processing. Many different visual areas in the primate cortex have now been discovered. These findings have led to the suggestion that the first visual areas (V1 & V2) act to 'parcel up' the visual information according to relevant attributes, like color, motion or depth, and distribute these to the different visual areas for parallel analysis in extra striate cortex. It is thought that the different visual areas can be grouped into two 'streams', one concerned with providing information about the shape, form and color in the image (the 'what' pathway) and the other concerned with where objects are located or moving in the visual field (the 'where' pathway'). I will discuss evidence for this division in primates.

Reading:
"Basic Vision", Complete Ch. 3 from p86 to end, and Ch. 11 to page 331.

Visual Perception: physiology, psychology and ecology. Bruce, Green and Georgeson. Chapter 3, pp57-74. (Psychology Press, New York)

Reading for Thursday's discussion TBA.

Discussion topic: Compare and contrast the functional roles of ventral areas V4 and medial area MT (V5) in primate vision. How may the specific visual function be defined experimentally?

Topics 5: Seeing patterns, Prof. Fred Kingdom, Thurs. 1st & Tues. 6th February

Seeing Patterns. How do we detect simple features in our visual world such as edges and contours? We can see objects because they have a contrast with their background, so a good way to start is to try to understand how we detect contrast. A basic measure of our ability to detect contrast is the Contrast Sensitivity Function, or CSF, which measures the visibility of special patterns called gratings. In examining the CSF we will consider measures of luminance, contrast, visual angle, spatial frequency and resolution. We will look at the use of eye charts, and examine how contrast sensitivity declines with age. The CSF is believed to be underpinned by neural mechanisms, or "channels", which are selectively sensitive to a narrow range of spatial scales. These channels constitute the first stage in the visual analysis of all objects. We will see how studies of visual adaptation have provided evidence for these channels.

Reading:
"Basic Vision", Ch. 4, and pp.365-373.

Topic 6: Seeing Features & Objects, Prof. Fred Kingdom, Thurs. 8th & Tues. 13th February

Seeing features and objects. What happened to the outputs of the early visual channels described in the previous lecture? We examine some recent ideas about how information in the channels might be used by the visual system for recognizing elementary features of objects such as edges. We then consider how these local features might be 'grouped' to help us recognize whole patterns. Finally, we examine the importance of 'prior knowledge' in object recognition.

Reading
"Seeing", by Frisby & Stone, Ch.5, Ch. 7, Ch. 8.

DEADLINE for handing in first essay: Sunday 11th February (midnight).

NO LECTURE: Thurs. 15th February

MID-TERM EXAMINATION: Tues. 20th February

Topic 7: Color Vision, Prof. Kathy Mullen, Thurs. 22nd & Tues. 27th February

What is a sense? I will begin with a general discussion about the complexities involved in the understanding of the special senses. This week and next I will discuss two of the specialized functions of our vision: color vision and light/dark adaptation. As well as understanding these senses, I will use them to illustrate some general principles of sensory processing.

Primate color vision. Color is a perception that's created within our visual system. I will begin by discussing what aspect of the physical world our color vision informs us about. Next, I will discuss how we are able to see color, describing the basic mechanisms of our color vision and how these account for some of the observations on color that have puzzled scientists and artists throughout the ages. These problems include: why we are unable to see color in the dark, and why we accept a mix of three colored lights or paints to match other colors. Of all the mammals, Old World monkeys have the best color vision, and so lastly, I will consider the question "why have color vision?", and discuss what the perception of color contributes to our vision.

Reading
"Basic Vision", Snowden, Thompson & Troscianko. Ch. 5.

Mollon. "Tho' she kneel'd in that place where they grew.." The uses and origins of primate color vision. *J. Experimental Biology,* 146, (1989).

Discussion Topic: Why do we have color vision? Find examples of visual tasks that color vision performs well at and ones that color vision is poor at.

STUDY WEEK: 4th – 10th March 2018

Topic 8: Light & Dark Adaptation, Prof. Kathy Mullen, Thurs. 1st rd & Tues. 13th March

Light and dark adaptation. I will address the question of how we are able to see over such a wide range of light intensities. We can see on a moonlit night and on a sunny beach, yet these ambient light levels are a hundred million times different from each other. However, neurons in the brain have only a restricted operating range since they can fire only over a maximum range of 1-500 impulses per second. We will discuss the possible solutions to the problem of how we can have good contrast (grey level) discrimination without sacrificing the range of ambient light levels we can use. Much of the understanding of this problem has come from human behavioral work, with more recent contributions from physiological studies.

Reading:
Lecture notes and PPT presentation
"Basic Vision", Snowden, Thompson & Troscianko. p62 Box 2.4.
Seeing Ch. 16, pp374-377, pp381-388.

Jacobsen & Gilchrist, "The ratio principle holds over a million-to-one range of illumination", *Perception & Psychophysics*, 43, (1988).

Adelson. "Perceptual organization and the judgement of brightness", *Science,* 262, 2042-2044, (1993).

Discussion Topic: What is 'the ratio principle' of vision and Weber's Law based on your reading of the Jacobsen & Gilchrist article? What are 'top-down' influences on lightness and brightness perception, based on your reading of the Adelson article?

Topic 9: Imaging Methods in Vision, Prof. Kathy Mullen, Thurs. 15th & Tues. 20th March

Imaging Methods in Vision. What determines the categorization of sensation into different modalities and submodalities? What would be the result of connecting the hair cells in your ear to the optic nerve: seeing sound or hearing light? In this lecture, I will discuss some of the new approaches to the understanding of the different human brain areas, based on the imaging techniques of PET and fMRI. I will discuss the limitations of these techniques and what they have revealed about vision so far. The reading focusses on recent evidence revealed by the fMRI approach for cortical plasticity in the adult human brain.

Reading:
"Basic Vision", Snowden, Thompson & Troscianko. Ch.12 to page 364.

Saenz, M. et al, "Visual motion area MT /V5 responds to auditory motion in human sight-recovery subjects", *Journal of Neuroscience*, 28, 5141-5148, (2008).

Topic 10: Motion perception, Prof. Kingdom, Thurs. 22nd & Tues. 27th March

Motion Perception (Tues). Seeing movement is one of the most important aspects of vision. We examine the various biological functions of motion perception. A simple physiological model for movement detection is presented. We discuss the phenomenon of apparent movement, the correspondence problem in complex moving stimuli and the aperture problem in motion perception.

Vision Laboratory Practical (Thurs). This will be a practical in which students carry out a psychophysical experiment measuring the perception of movement in random-dot-patterns.

Reading:
Basic Vision, Ch. 6.

DEADLINE for handing in second essay is Monday 2nd April

Topic 11: Depth Perception, Prof. Fred Kingdom, Thurs. 29th March and Tues. 3rd April

Depth Perception. Perceiving the relative distances of objects is fundamental to vision and there are many ways in which we do it. First there are a number of monocular cues to depth, for example motion parallax and texture gradients. Second there are binocular cues, the best understood being stereopsis. Stereopsis exploits the fact that the two eyes view the world from a slightly different angle. We examine stereopsis in detail.

Reading:
Basic Vision, Ch. 7.
"Seeing" by Frisby & Stone, Ch. 18

Topic 12: Modular Basic of Vision, Prof Fred Kingdom, Thurs. 5th and Tues. 10th April

The modular basis of vision: Here we bring together many of the ideas already discussed in the course and consider the extent to which the visual system is divided into separate pathways or 'modules'. A module processes a particular attribute of the visual scene, for example motion, color or depth. In discussing the modular basis of visual perception, we will introduce color vision and distinguish between scalar (e.g. hue, saturation and brightness) and structural (e.g. shape) information in the visual world. We also discuss how much "cross-talk" there is between different modules, for example the extent to which motion and depth perception are "color blind". Whatever the degree of modularity, many different scene attributes (motion, shading, texture) provide information about the structure of objects, and we examine a number of these.

Reading:
Mullen & Boulton "Absence of smooth motion perception in color vision", *Vision Research*, 32, (1992).

Kingdom “Colour brings relief to human vision”, *Nature Neuroscience*, 6, (2003). (Supplied by instructor).

IN CLASS REVISION SESSION: Thurs. 12th April

McGill CLASSES END: April 16th

FINAL EXAM: Date to be announced