Systems Neuroscience: Syllabus

Course Materials: Research Papers listed below

(NO TEXTBOOK)

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Email .... *avinash@uoregon.edu*
CLASS TIME (106 CON) .... 10:00-11:20 M/W
OFFICE HOURS........ 11:30 to 12:30 (228B Huestis)
- Other days /times by appointment

Links:

- Canvas
- Course Data & Deadlines:
  - BI 461
  - BI 561
- UO Libraries
- Backup site for course document access (if Canvas is down)

I. Contents

NOTE: The electronic version of this document is available on blackboard as a PDF file, underlined phrases are functional hyperlinks.

II. Notice to Students with Disabilities

The University of Oregon is working to create inclusive learning environments. If there are aspects of the instruction or design of this course that result in barriers to your participation, please let me know as early as possible, in person or via email. You may also wish to contact Accessible Education Services in 164 Oregon Hall, by phone at (541) 346-1155 or uoaec@uoregon.edu. I welcome the chance to help you learn, and will work with you to help make it a good learning opportunity and experience.

III. Introduction

The goal of systems neuroscience is to decipher the neuronal codes that produce perception and behavior. We will examine four very different neural systems: binaural hearing, binocular vision, echolocation, and electroreception. Different though they may be, these systems have in common the fact that they all require the comparison of information received by different parts of the body (e.g., left eye vs right eye) or at different points in time (e.g., sonar-pulse and echo return). Our goal is to identify general principles of this comparative process and see how they are differentially implemented to achieve various perceptual and behavioral goals. In addition, there is a general question that lurks behind all of these topics: How does behavioral performance compare with the performance of individual neurons? This all-encompassing topic is explored in the last segment of the course.

You are expected to have a working knowledge of basic physics, neuroanatomy, and neurophysiology. Basic neuroscience or neurobiology textbooks should be consulted to brush up on fundamental neuroscience concepts. Textbooks for brushing up basic knowledge:

- Fred Delcomyn, Foundations of Neurobiology
- Gary Matthews, Neurobiology: Molecules, Cells, Systems
- Eric Kandel, Principles of Neural Science.łl'

The course is taught from the primary literature (reading list below; all papers available online) and has a lecture/discussion format. The lectures are designed to give you background information and an organizational framework of each of the four topics. You are expected have read the papers ahead of time. The "Key Questions" listed below will give you an idea of the aspects of each of the papers to which you should attend. You should attempt to answer these questions before we discuss them in class. During class, you will be called upon to provide details, interpretations, and criticisms regarding the papers. In this manner, I hope to help you to arrive at an overall picture of each topic.

Details about grading, assignments, deadlines etc. will always be available in the document "201501_BI461561_Syllabus.pdf" in the 'Files' section on Canvas course site. Some details, and a link to the full syllabus, are also available at the 'Syllabus' section of the Canvas course site.

IV. Reading

I. **Comparing the two ears: Computation of binaural time disparities and spatial hearing.**
Review: Takahashi TT. 1989. The neural coding of auditory space. *J. Exp. Biol.* **146**:307-322.
   A. Coding of monaural phase
      - Sullivan WE, Konishi M. 1984. Segregation of stimulus phase and intensity coding in the cochlear nucleus of the barn owl. *J. Neurosci.* **4**:1787-1799.
   B. Computation of binaural phase difference
      - Carr CE, Konishi M. 1990. A circuit for detection of interaural time differences in the brain stem of the barn owl. *J. Neurosci.* **10**:3227-3246.
   C. Computation of time difference from phase difference

- Wagner H, Takahashi TT, Konishi M. 1987. Representation of interaural time differences in the central nucleus of the barn owl's inferior colliculus. *J. Neurosci.* **10**:3106-3116.

D. An alternative to the Jeffress Model?

- (1) McAlpine D, Jiang D, Palmer AR. 2001. A neural code for low-frequency sound localization in mammals. *Nat Neurosci* **4**:396-401.
- (2) Brand A, Behrend O, Marquardt T, McAlpine D, Grothe B. 2002. Precise inhibition is essential for microsecond interaural time difference coding. *Nature* **417**:543-547

II. Comparing two points in time: Computation of target range in echolocating bats

Review: Simmons JA. 1989. A view of the world through the bat's ear: The formation of acoustic images in echolocation. *Cognition* **33**:155-199.

A. Phase Sensitivity

- Simmons JA. 1979. Perception of echo phase information in bat sonar. *Science* **204**:1336

B. Phase sensitivity & Hyperacuity

- Simmons JA, Ferragamo M, Moss CF, Stevenson SB, Altes RA. 1990. Discrimination of jittered sonar echoes by the echolocating bat, Eptesicus fuscus: The shape of target images in echolocation. *J Comp Physiol* **167**:589-616.

III. Comparing body surfaces: Jamming avoidance response in weakly electric fishes

Review: Heiligenberg WF. 1991. Neural Nets and Electric Fish. MIT: Cambridge. (UO Sci. Lib. QP447.5 .H45 1991)

A. Carr CE, Heiligenberg WF, Rose GJ. 1986. A time-comparison circuit in the electric fish midbrain. I. Behavior and physiology. *J. Neurosci.* **6**:107-119.

IV. Comparing the two eyes: computation of retinal disparities and stereoscopic vision

A. Barlow HB, Blakemore C, Pettigrew JD. 1967. The neural mechanisms of binocular depth discrimination. *J. Physiol.* **193**:327-342.

B. Trotter Y, Celebrini S, Stricanne B, Thorpe S, Imbert M. 1992. Modulation of neural stereoscopic processing in primate area V1 by viewing distance. *Science* **257**:1279-1281.

C. Cumming BG, Parker AJ. 2000. Local disparity not perceived depth is signaled by binocular neurons in cortical area V1 of the macaque. *J. Neurosci.* **20**:4758–4767

V. Comparing neuronal responses and behavioral performance

A. Somatosensory Thresholds

- Johansson RS, Vallbo AB. 1979. Detection of tactile stimuli. Thresholds of afferent units related to psychophysical thresholds in the human hand. *J Physiol* **279**:405-422

B. Visual Motion

Review: Newsome WT Shadlen MN, Zohary E, Britten KH, Movshon JA. 1996. Visual motion: Linking neuronal activity to psychophysical performance. In The Cognitive Neurosciences, Gazzaniga MS (Ed), MIT Press, Cambridge. pp 401-414.

- (1) Britten KH, Shadlen MN, Newsome WT, Movshon JA 1992 The analysis of visual motion: A comparison of neuronal and psychophysical performance. *J. Neurosci.* **12**: 4745-4765.
- (2) Salzman CD, Britten KH, Newsome WT 1990 Cortical microstimulation influences perceptual judgements of motion direction. *Nature* **346**:174-177.

V. Key Questions

SYSTEMS NEUROSCIENCE: ENCODING, SIGNAL PROCESSING, AND BEHAVIOR

I Comparing the two ears: Computation of binaural time disparities and spatial hearing

1. Explain the concept of phase locking. Explain the construction of period histograms and the concepts of vector strength and mean phase angle. What happens to the mean phase angle if you change the stimulus frequency and what does such an experiment tell us?
2. Explain the delay-line and coincidence detector model of binaural phase computation. How does this mechanism give rise to phase-ambiguity?
3. How is phase-ambiguity solved theoretically and how does the owl's auditory system implement this solution?
4. Compare and contrast the manner in which the barn owl and small mammals (e.g., guinea pigs, gerbils) represent auditory space. Include a description of the place-code strategy and the rate code strategy.
5. Why is the dependence of best ITD on neuronal best frequency an important part of McAlpine group's argument on how small-headed mammals use their ITD-sensitive neurons

II Comparing two points in time: Computation of target range in echolocating bats

1. Application of cross-correlation principles: Imagine that you are a molecular biologist. You are faced with the following sequence of nucleotides, N(s): 5'GATCATTGAGTATTACGTTAGCAGCTAGGCCCATTGAGTAGTTTAAGCCGAT3'. You want to know whether the following probe sequence, P(s), is complementary to any part or parts of N(s) and where the complementary region(s) might be. P(s): 3'GTAACTCATC5'
    a. Write a set of specific instructions of the type that you might give to a computer to solve this problem. Remember, Watson-Crick pairing means G/C bind and A/T bind. (i.e., GxC=1; AxT=1; all other products = 0)
2. Simmons and colleagues (1990, *J. Comp. Physiol.* 167:589-616) taught bats to discriminate between jittering and stationary targets, and plotted the number of errors the bats made as a function of the size of the jitter. Their paper shows that the bats have problems distinguishing between jittering and non-jittering targets at a jitter of around 30 microseconds. Why is the bat making errors at this jitter and

how do the authors interpret this result? Why is it so controversial?

3. Explain the control that argues in favor of the involvement of phase.

III Comparing body surfaces: Jamming avoidance response in weakly electric fishes

1. How did Heiligenberg and colleagues demonstrate that the weakly electric fish, *Eigenmannia*, performed the JAR without benefit of an efference copy (a copy of its own EOD)?
2. 2. What physical cues does the fish need to determine whether its EOD frequency is higher or lower than a neighboring fish? What does it mean that the fish "reads" the sense of rotation in the phase/amplitude plane (Lissajous figure)?
3. Explain the methods by which Carr, Heiligenberg, and Rose (1986 *J. Neurosci.* 6:107-119) determined the minimal detectable time differences between two patches of the body surface. How did this compare to neuronal performance?
4. How are the cues represented in the nervous system and how are they combined to produce the neurons that can tell the difference in frequency between a fish's own EOD and that of it neighbor?

IV Comparing the two eyes: computation of retinal disparities and stereoscopic vision

1. What is the equivalent of ITD in stereopsis, and how does this parameter encode depth?
2. Derive the relationship between binocular disparity and the distance off of the horopter. What happens to this relationship if the location of the horopter is changed?

What is the difference in the response of cells that are selective for relative and absolute disparities? To which of these disparities are cells in the primate V1 tuned (Trotter et al., 1992)? Explain the results that lead you to your conclusion.

V Comparing neuronal responses and behavioral performance

1. What is the basic idea behind signal detection theory and how does it alter our basic ideas about perceptual thresholds? What does the quantity *d*' represent?
2. How did Johannson and Vallbo measure behavioral (psychophysical) and neuronal detection thresholds?
3. In other systems, sensory neurons may perform at, above, or below behavioral thresholds. What do Johansson and Vallbo conclude about the relationship between behavioral performance and neuronal sensitivity of human somatosensory receptors?
4. List some factors which, in your mind, would enhance the validity of comparing neuronal responses to behavioral responses.
5. Detail one example where behavioral thresholds are seemingly determined by the performance of single neurons, and one example where single neurons are unable to explain behavioral performance. What would you describe as the advantages and disadvantages of either process?
6. What is the evidence that perception is based on the contributions of a relatively small number of specialized (for detecting visual motion) neurons?

VI. Where can you find the Research Articles listed?

All papers listed are available online, and can be accessed via the hyperlinks at the end of each citation. Most can be found by searching at the main UO library search engine: just type the entire title. However, please remember that the Library's subscription to journals *can only be accessed* while you are *on the UO campus*, or are *connected to the university* via VPN. Off campus access is detailed here.

VII. Lecture Schedule

*Subject to change, depending on lecture pace and student feedback

Day	Date	Lecture	Section
M	28-Sep	1	I. Introduction
W	30-Sep	2	I. Binaural Hearing
M	5-Oct	3	I. Binaural Hearing
W	7-Oct	4	I. Binaural Hearing
M	12-Oct	5	I. Binaural Hearing
W	14-Oct	6	II. Echolocation
M	19-Oct	7	II. Echolocation
W	21-Oct	8	II. Echolocation
M	26-Oct	9	II. Echolocation
W	28-Oct	10	MID-TERM
M	2-Nov	11	III. E-fish Jamming Avoidance Response
W	4-Nov	12	III. E-fish Jamming Avoidance Response
M	9-Nov	13	III. E-fish Jamming Avoidance Response
W	11-Nov	14	III. E-fish Jamming Avoidance Response
M	16-Nov	15	IV. Depth Perception
W	18-Nov	16	IV. Depth Perception
M	23-Nov	17	IV. Depth Perception
W	25-Nov	18	V. Neurons vs Behavior
M	30-Nov	19	V. Neurons vs Behavior
W	2-Dec	20	V. Neurons vs Behavior
W	9-Dec		FINAL