SYSTEMS NEUROSCIENCE
Biology 461/561 CRN 20971/20985
Winter 2007
2:00 - 2:50 MWF 12 Pacific Hall

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The goal of systems neuroscience is to decipher the neuronal codes that produce behavior and perception. 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 pervasive 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 textbooks (e.g., Kandel & Schwartz – on reserve in UO Science Library) should be consulted to brush up on fundamental neuroscience concepts.

The course is taught from the primary literature (reading list below) 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. The review articles, listed at the top of each topic, are recommended (not required) to gain a simplified perspective. Your grade is based on three or four short problem sets (no more than four double-spaced pages) built around the Key Questions. Concise explanations and logical arguments are expected; vague or poorly-written answers indicate a lack of understanding and will count against you.

READING LIST

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?

McAlpine D, Jiang D, Palmer AR 2001 A neural code for low-frequency sound localization in mammals. *Nat Neurosci* 4:396-401.

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. Extreme phase sensitivity?

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 the two eyes: computation of retinal disparities and stereoscopic vision

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

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.

IV 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)

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.

Heiligenberg WF, Rose GJ 1986 Gating of sensory information: Joint computations of phase and amplitude data in the midbrain of the electric fish, *Eigenmannia*. *J. Comp. Physiol.* 159:311-324.

V Comparing neuronal responses and behavioral performance

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.

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.

Salzman CD, Britten KH, Newsome WT 1990 Cortical microstimulation influences perceptual judgements of motion direction. *Nature* 346:174-177.

KEY QUESTIONS

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 and 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'
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 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?
3. 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.

IV 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. 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?

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. What is the evidence that perception is based on the contributions of a relatively small number of specialized (for detecting visual motion) neurons?

Approximate Schedule

M	8-Jan	Course Introduction
W	10-Jan	Sound localization - General Principles
F	12-Jan	Sound localization - General Principles
M	15-Jan	No Class MLK Day
W	17-Jan	Sound localization
F	19-Jan	Sound localization
M	22-Jan	Sound localization
W	24-Jan	Sound localization
F	26-Jan	An alternative to the Jeffress Model?
M	29-Jan	An alternative to the Jeffress Model?
W	31-Jan	Bat echolocation
F	2-Feb	Bat echolocation
M	5-Feb	Bat echolocation
W	7-Feb	Bat echolocation
F	9-Feb	Bat echolocation
M	12-Feb	Bat echolocation
W	14-Feb	Guest lecture
F	16-Feb	Guest lecture electroreception
M	19-Feb	Jamming Avoidance Response
W	21-Feb	Jamming Avoidance Response
F	23-Feb	Jamming Avoidance Response
M	26-Feb	Jamming Avoidance Response
W	28-Feb	Stereovision Introduction to Vision
F	2-Mar	Stereovision
M	5-Mar	Stereovision
W	7-Mar	Stereovision
F	9-Mar	Stereovision
M	12-Mar	Comparing neuronal responses & behavior
W	14-Mar	Comparing neuronal responses & behavior
F	16-Mar	Course evaluation
	19-Mar	Finals wk