BE509: Perception and Quantitative Physiology of the Auditory System

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Mondays, 2:30 – 4:15 pm		Wednesdays, 2:30 – 4:15 pm	
1/22	Why things sound the way they do	**1/24**	Why things sound the way they do
1/29	The ear	**1/31**	The ear *(project groups & topic requests due)*
2/5	Subcortical coding	**2/7**	Subcortical coding
2/12*	**EFR lab**	**2/14***	**EFR lab**
2/20 ***(Tues)***	Periodicity and pitch perception *(EFR lab writeup due)*	**2/21**	Periodicity and pitch perception
2/26	Hearing speech	**2/28**	Hearing speech *(project reading list due)*
3/5	**spring break (no class)**	3/7	**spring break (no class)**
3/12	Neural basis of sound localization	**3/14**	Neural basis of sound localization
3/19	Auditory scene analysis	**3/21**	Auditory scene analysis
3/26	Attention	**3/28**	Attention
4/2	Prosthetics	**4/4**	Prosthetics *(project presentation outline due)*
4/9*	**Cortical EEG lab**	**4/11**	**Cortical EEG lab**
4/16	**Patriot's day (no class)**	**4/18**	Development, Learning, & Plasticity *(Cortical EEG lab writeup due)*
4/23*	Cortical processing *(project draft slides due)*	**4/25**	Cortical processing
4/30	Final presentations	**5/2**	Final presentations

Overview

BE509 / NE560 covers auditory neuroscience from different perspectives, including perception, physiology, and modeling. We will examine how sound is transduced and transmitted through the auditory pathway, following the auditory signal as it is transformed from acoustic energy to neural code, then considering different stages of processing extract different aspects of sound and meaning. Emphasis is on understanding how the computations along the auditory pathway affect basic human abilities. The course will introduce and use basic mathematical concepts from signal processing, probability, signal detection theory, and psychophysical methods.

Class Meetings

Lectures will be held on Mondays and Wednesdays, 2:30-4:15 pm. Laboratory demos will be held during regular class hours in small groups in the Auditory Neuroscience Laboratory on the 9th floor of Kilachand Center.

Prerequisites

Students should be aware that strong quantitative and analytic skills are necessary to perform well in this course, even though formal prerequisites are few. Students must have working knowledge of algebra, calculus, probability theory, and Fourier analysis. Students not meeting these requirements must consult with the instructor prior to enrolling.

Required book:

Schnupp, Nelken, and King (2012). *Auditory Neuroscience.* Cambridge: MIT Press.
Also see the **associated web site:** http://auditoryneuroscience.com/

Course requirements

There will be **weekly quizzes** on the first day of class of each week (typically on Mondays). Each quiz will cover the material from the previous week. In addition, each student must complete **two labs and a final presentation**. No provision will be made to “make-up” missed quizzes, labs, final presentations. There will be no mid-term or final exams.

Weekly quizzes

The first 10-15 minutes of the first class of each week, there will be a multiple-choice / brief answer quiz on the material covered in the previous week. This quiz will be closed book, but students can consult a single index card (standard size 3”x5”) of notes. Anyone who is not present for the quiz will receive a zero (no exceptions). The lowest 2 (of a planned 10) quiz grades will be automatically dropped and the remaining grades averaged to determine the final weekly quiz grade.

Laboratories

Two laboratories are planned, each utilizing a different technique. Students will be assigned to a laboratory group consisting of 4-5 students. Each group will be assigned to attend one of the four demo sessions, to be held across two class periods, each of which will last about 40 min. Each student must attend their assigned laboratory session to get full credit for the laboratory, unless there is a medical or other documented emergency. Following the lab demonstrations, each group will be given a data set to analyze and write up. This work should be done cooperatively, with a single lab report turned in for each group (maximum four pages). Individual grades will be determined as described below. Individual grades for each lab will be determined by modulating the instructor grade by the estimated individual contributions to the group (see below).

Final presentations

Each student must participate in a final project that culminates in oral presentations to the class on the final two meeting days of the semester. Each group must be 4-5 students. Each group must select a topic, either from the suggestions in the appended handout, or of their own choosing (in consultation with the instructor). Groups are responsible for researching this topic on their own throughout the semester, developing a reading list covering the topic, creating an outline of the final presentation, and then presenting their material to the class (see handout for due dates for each). Grading of the final presentations will be determined by the instructor grade, the average peer grade assigned by classmates, and individual contributions to the group (see below). There will not be any final written report.

Assignments to groups

Groups for laboratories and final presentations must consist of 4-5 students, with at most 10 groups for the entire class (based on time and resources available for demoing labs and holding final presentations). Students can request to be assigned to the same group; all such requests will be honored to the extent possible; however, additional students may be assigned to a group, or other adjustments made, in order to accommodate everyone.

Grading of group work

Each group will receive a letter grade for laboratories and final presentations; however, individual grades will also depend on the contributions of each person to the group effort. Specifically, each group participant must allocate points to members of the group to reflect the contributions of that member. Each group member will be given 100 points that they can assign amongst the group members (excluding themselves). Points must be allocated in "chunks" of 5 point multiples. Thus, if you are on a five-member team where you think everyone contributed equally, you would allocate 25 points to each of the other members. However, if 3 of the 4 others contributed a great deal and one member contributed very little, you might allocate the points 30, 30, 30, and 10. A more typical assignment might be 30, 25, 20, and 20. The final individual grade a team member receives will have a base grade that is the assigned grade for the group effort, modulated by the average point allocation that they received across all group members. Specifically, to compute the "delta" in the score for a group of N students. subtract 100/(N-1) from the average score given to a group member, multiplied by 2. The individual grade assigned will be equal to the raw group score (out of 100) plus this delta.

Grading scale and policy

Final grades will be determined by a weighted average of the following grades:

40%	Weekly quizzes (5% each)
40%	Laboratories (20% each)
20%	Final presentations

Final grades will be judged on a curve (i.e., relative to performance of other students in the course), with the mean grade set at roughly a B-/C+.

Policy on incomplete grades

Grades of I (incomplete) will not be given except by prior agreement the instructor. In the even that you are unable to complete the course requirements, **you must contact me no later than April 11** to discuss the possibility of taking an incomplete in the course. If I have not received a formal, written request, your final course grade will be based on the work available to me. If an "I" is granted, any work turned in late to complete the course will marked down by one letter grade. Furthermore, since you will have extra time to complete the work, grading will be stricter than with regular assignments.

When requesting an "I" grade, you must clearly indicate (1) your understanding of what work remains to be completed, and (2) a firm timetable for completion of this work. An "I" will be granted *only* if the timetable is acceptable. In general, the "I" grade will be turned into a final grade by the final date on the accepted timetable, based on all work received up to that date.

Lecture notes and readings

It is the student's responsibility to download lecture notes from the course web site. The course covers an unusual collection of anatomical, physiological, behavioral, and computational material. Some topics will be addressed in more detail in the lectures than in the textbook. Supplemental readings for the course will be put on the course web site for download. Most students find it critical to be able to take notes on the slides that are provided to remember what is relevant about each topic.

Policy on attendance

Students are expected to attend class lectures, lab demonstrations, and final presentations. In the case of a medical emergency or other extreme circumstances, it is the student's responsibility to ***contact another student***, determine what material / announcements they missed, and take appropriate action to catch up, as necessary. It is not the instructor's responsibility to provide make-up materials to the student. Note also that missing laboratory demos / quizzes will directly affect the corresponding laboratory / quiz grade.

Policy on collaboration

As discussed above, much of the work for the class will be done in groups; in general, cooperation is encouraged. The exception to this rule are the weekly quizzes, which should reflect each student's understanding (see CAS Academic Conduct Code).

The web

A blackboard site is being set up through BU's Information Technology services for BE509. From the site, you will be able to access the syllabus, assigned readings, and lecture notes. Note that the material on this webpage is intended for class use only.

Weekly Lectures and Readings

For each week, any required readings are listed; any supplemental material (not required) is so marked. All readings will be available for download from the class website.

1/22-1/24 Why things sound the way they do

As we will see in the coming weeks, the inner ear (cochlea) analyzes acoustic inputs by breaking them down into frequency content as a function of time. This is the heart of Fourier analysis. Moreover, to model how an input acoustic signal is altered from its source of origin to its entry into the ear, from the entry of the outer ear into the inner ear, or even from the inner ear to the firing rate of the auditory nerve, one can use linear-system theory.

Schnupp, Nelken, & King: Chapter 1.

Shatkay A (1995). The Fourier Transform: A Primer, Technical Report CS-95-37, Department of Computer Science, Brown University, 1995.

1/29-1/31 The ear

We discuss how movement of the basilar membrane, the organ of hearing in the inner ear (cochlea) transforms mechanical energy into neural firing patterns. We examine the anatomical and mechanical processes governing the operation of the cochlea. The function of inner and *outer hair cells is described along with the crucial idea of the critical band. We discuss the firing patterns of neurons in the auditory nerve, which transduces all acoustic information to the central nervous system. We cover how the auditory nerve firing patterns relates to the movement of the cochlea and how it depends on the sound reaching the ears.*

Schnupp, Nelken, & King: Chapter 2.

Project groups & topic requests due 1/31.

2/5-2/7 Subcortical coding

Response properties of the cochlear nucleus (an obligatory pathway for all auditory input) will be presented. Functional implications for the diversity of cell types and cell responses will be discussed and analyzed. Neural circuit models of the different cell types (taking into account both anatomical and physiological results) will be presented.

Oertel D, Bal R, Gardner SM, Smith PH, and Joris PX (2000). "Detection of synchrony in the activity of auditory nerve fibers by octopus cells of the mammalian cochlear nucleus," Proc Natl Acad Sci, 97, 11773-11779.

2/12-2/14 Envelope-following response lab

In this lab, you will learn how electroencephalography can be used to measure subcortical auditory responses.

2/20-2/21 Periodicity and pitch perception

This week, we look at the perception of pitch and timbre. We start by discussing periodic signals, then explore pitch perception for signals that are not strictly periodic. Having considered basic perception of pitch, we then look at models of pitch perception, focusing particularly on rate and place codes.

Schnupp, Nelken, & King: Chapter 3.

Gockel, H. E., Carlyon, R. P., Mehta, A., and Plack, C. J. (**2011**). "The Frequency Following Response (FFR) May Reflect Pitch-Bearing Information But is Not a Direct Representation of Pitch," JARO, **12**, 767–782. doi:10.1007/s10162-011-0284-1

EFR lab write-up due 2/20

2/26-2/28 Hearing speech

We'll discuss the "source-filter" theory of speech acoustics and how basic speech sounds are perceived.

Schnupp, Nelken, & King: Chapter 4.

Project reading list due 2/28.

3/12-3/14 Neural basis of sound localization

We will discuss the perception of spatial information and the importance of hearing with two ears, covering basic perceptual phenomena in binaural and spatial hearing. We will discuss physiology the Superior Olivary Complex in relation to spatial hearing. We will look at the original "Jeffress model" of binaural interaction and relate this to responses of Medial Superior Olive (MSO) cells.

Schnupp, Nelken, & King: Chapter 5.

3/19-3/21 Auditory scene analysis

Because we live in a world full of multiple, competing sounds, what we hear is usually contains gaps of time / frequency in which portions of the sound sources present in the environment cannot be heard due to masking by other sources. The process of segregation addresses how we bind information across time and frequency to estimate the content of auditory objects in the environment. Basic rules governing this process of auditory scene analysis are described and demonstrated.

Schnupp, Nelken, & King: Chapter 6.

3/26-3/28 Attention

We cannot possibly process everything that we hear. In the visual domain, a lot of work has addressed the specific cortical mechanisms involved in regulating this competition for resources through directing attention to a source of interest. Until recently, vision researchers have conducted most of the work examining how attention affects performance in the auditory domain. Now, as a field, auditory researchers have become interested in how attention affects performance in psychoacoustic tasks and adjusts how neurons respond to stimuli based on what is behaviorally important.

Shinn-Cunningham BG (2008). "Object-based auditory and visual attention," Trends Cogn Sci, 12, 182-186.

4/2-4/4 Prosthetics

One of the most important research topics in hearing is hearing loss. Hearing loss is a natural consequence of aging, but is also caused by noise exposure. We will discuss the effects of hearing loss and the reasons it is so difficult to find effective treatments for patients with hearing loss. The most successful neural prosthesis is the cochlear implant. Cochlear implants use microphones to pick up sound, then process the sound and use the resulting signals to directly stimulate the auditory nerve. We will discuss how cochlear implants work and the ways *in which sound is transformed by current cochlear implants. Ph.D. candidate Ross Maddox guest lectures.*

Schnupp, Nelken, & King: Chapter 8.

Heinz MG (2010). "Computational modeling of sensorineural hearing loss," in Computational Models of the Auditory System, R Meddis, EA Lopez-Poveda, AN Popper and RR Fay, Springer Verlag, 177-202.

Project presentation outline due 4/4.

4/9-4/11 Cortical EEG lab

This laboratory will include a demonstration of cortical EEG measurements, and analysis of cortical responses.

4/18 Development, Learning, & Plasticity

Interpreting what sound means depends upon experience at multiple levels, from development, to learning, to plasticity based on recent experience. We will discuss some key examples of how experience shapes perception of sound.

Schnupp, Nelken, & King: Chapter 7.

Lab write-up due 4/18

4/23-4/25 Cortical processing

Auditory processing depends on entire networks in the brain, not just on processing in sensory auditory cortical regions. This lecture discusses how different aspects of auditory processing depend on other brain regions, and how these regions work together.

Larson E and AKC Lee (2013). “The cortical dynamics underlying effective switching of auditory spatial attention,” Neuroimage, 64, 365-370.

Project draft slides due 4/23

4/30-5/2 Final Presentations

Final Presentations

Each student must participate in a final project that culminates in oral presentations to the class on the final two meeting days of the semester. Each group must be 4-5 students. Each group must select a topic, either from the suggestions provided here, or of their own choosing (in consultation with the instructor). Grading of the final presentations will be determined by the instructor grade, the average peer grade assigned by classmates, and individual contributions to the group. There will not be any final written report.

Most projects will consist of a simple literature review and final summary presentation. However, there is an option to do a data project, instead. This might consist of using existing computational models to simulate auditory nerve responses, analyzing existing data sets from EEG or fMRI experiments, or the like. Any student interested in pursuing a data project rather than a literature review is urged to consult with the Project TF, Justin Fleming (justintracyfleming@gmail.com), and/or the instructor, Barbara Shinn-Cunningham (shinn@bu.edu), before turning in their topic request.

Groups are responsible for researching this topic on their own throughout the semester, developing a reading list covering the topic, creating an outline of the final presentation, and then presenting their material to the class (see due dates below). Other than the final presentation, each of these elements will be graded on a pass/fail basis, with feedback provided by the instructor.

Grading

The raw group project grade will be determined by a weighted average of the following components:

5%	Reading list
5%	Presentation outline
5%	Draft slides
25%	Average peer grade
60%	Instructor grade

Final grades will be judged on a curve (i.e., relative to performance of other students in the course), with the mean grade set at roughly a B-/C+.

Each group will receive a letter grade for laboratories and final presentations; however, individual grades will also depend on the contributions of each person to the group effort. Specifically, each group participant must allocate points to members of the group to reflect the contributions of that member. Each group member will be given 100 points that they can assign amongst the group members (excluding themselves). Points must be allocated in “chunks” of 5 point multiples. Thus, if you are on a five-member team where you think everyone contributed equally, you would allocate 25 points to each of the other members. However, if 3 of the 4 others contributed a great deal and one member contributed very little, you might allocate the points 30, 30, 30, and 10. A more typical assignment might be 30, 25, 20, and 20. The final individual grade a team member receives will have a base grade that is the assigned grade for the group effort, modulated by the average point allocation that they received across all group members. Specifically, to compute the “delta” in the score for a group of N students. subtract 100/(N-1) from the average score given to a group member, multiplied by 2. The individual grade assigned will be equal to the raw group score (out of 100) plus this delta.

1/31 Project groups & topic requests due

Each student must turn in an ordered list of at least three topics that they are interested in for their final presentation. Students wishing to work together in a group should indicate the other students with whom they wish to work. Topics may be selected from among the suggestions at the end of this handout; alternatively, if there is a relevant topic of interest not on the list, this topic should be submitted with a one-sentence description. The instructor will determine final group and topic assignments, taking into account all requests and constraints.

2/28 Project reading list due

Each group must identify 4 or more key sources of material covering their assigned topic. The majority are expected to be peer-reviewed research articles. Each member of the team will be expected to read, discuss together, and understand the content of these readings.

4/4 Project presentation outline due

Each group must turn in a one-page outline of their final presentation.

4/23 Project draft slides due

A draft of the powerpoint (or similar) slides for the presentation must be submitted to bu509.bu@gmail.com.

4/30, 5/2 Final presentations

The final oral presentation will be 15 minutes long (this timing will be strictly enforced). The goal of the presentation is not to go through every aspect of the topic, but to define what the topic is about and to convey why the topic is interesting or what it tells us about auditory processing or perception. That said, after each presentation, there will be a five-minute question period. In order to field questions about the topic, the team members must understand details about the topic that go beyond the basics included in the main presentation—this is the expectation.

It is not necessary for each team member to present during the oral presentation, as long as each member contributes to the research and discussion of the material, and development of the presentation. As noted in the syllabus, the grade for each individual will be determined by the base score for the team, modulated by the mean assessment of contributions by the peer team members.

Topic suggestions

Middle-ear muscle reflex
Frontal eye fields
Superior colliculus
Absolute pitch
Harmonicity-dissonance
Microtonal scales
Comodulation masking release
Tinnitus

Ototoxic drugs
Auditory nerve and brainstem implants
Biosonar
Human echolocation
Birdsong learning
Flash-beep illusion
Ventriloquism effect
Sonification
Simulating auditory nerve responses*
fMRI data analysis*
EEG data analysis*

*data project ideas