

## CN560: Neural and Computational Models of Speech Perception and Production / BE509: Quantitative Studies of the Auditory System

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**Lectures:** **Mondays, 1-3:50 p.m.**      **Discussion: To Be Determined**

### Schedule at a Glance *(subject to change)*

**9/14**      **Lecture 1: Acoustics to cochlea; Signal processing primer**  
*Homework 1: Some simple signals*

**9/21**      **Lecture 2: Cochlea; Auditory Nerve**  
*Homework 2: Auditory nerve responses*

**9/28**      **Lecture 3: Cochlear Nucleus**  
*Discussion 1: Neural specialization and neural computation*

**10/5**      **Lecture 4: Basic perceptual abilities; Signal detection**  
*Homework 3: Signal detection theory*

**10/13**      **Lecture 5: Superior Olive; Inferior Colliculus (NOTE TUES. DATE)**  
*Discussion 2: Beyond the Jeffress model of interaural time delay coding*

**10/19**      **Lecture 6: Spatial and binaural hearing**  
*Homework 4: Spatial computations and spatial perception*

**10/26**      **EXAM 1**

**11/2**      **Lecture 7: Pitch and timbre**  
*Discussion 3: Which acoustic features convey pitch and which convey meaning?*

**11/9**      **Lecture 8: Auditory scene analysis and source segregation**  
*Discussion 4: What are the neural correlates of source segregation?*

**11/16**      **Lecture 9: Auditory attention**  
*Discussion 5: Similarities between auditory and non-auditory attention*

**11/23**      **Lecture 10: Speech perception and production**  
*no discussion (Thanksgiving break)*

**11/30**      **Lecture 11: Auditory Cortex**  
*Discussion 6: How is information encoded in auditory cortex?*

**12/7**      **Lecture 12: Hearing loss and cochlear implants**  
*Discussion 7: Hearing loss and complex scenes*

**12/16**      **FINAL EXAM (1-3 pm)**

## Overview

CN560 / BE509 covers auditory perception, physiology, and modeling. Emphasis will be placed on relating known psychophysical and physiological results to models of perception and behavior. 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 codes. These codes will be compared with perception and performance, with an emphasis on relating how the auditory pathway processes sound and how this affects basic human abilities. In order to teach these topics effectively, the course will introduce and use some basic mathematical concepts from signal processing, probability, signal detection theory, and psychophysical methods.

## Class Meeting

Lectures will be held in room B03 at 677 Beacon Street on Mondays, 1:00 p.m. – 3:50 p.m. An additional discussion section will be held at a time to be determined (one hour per week). Discussions will center on articles and papers related to the lecture topics and will be lead by different students on designated weeks (see below).

## Prerequisites

Students must have working knowledge of algebra and calculus and basic familiarity with computers. Students not meeting these requirements must consult with the instructor prior to enrolling. Students should be aware that strong quantitative and analytic skills are necessary to perform well in this course, even though formal prerequisites are few. MATLAB will be used to introduce mathematical concepts.

## Course requirements

All students must complete **two exams** and **help lead a group discussion** in order to complete the course. The exams are meant to test your ability to think critically on the basis of what you have learned in class. In addition to these requirements, there will be short homework assignments. No provision will be made for “make-up” or missed exams, discussions, or homework.

## Homework

Homework will be assigned in class in weeks when there is no discussion (see below). When assigned, homework is due at the beginning of the next class, unless otherwise specified. Homework assignments are designed to familiarize you with techniques or material discusses in class, by analyzing acoustic signals, running computer simulations, and writing up results. Each homework assignment will be assigned a grade ranging from 0 to 10. Homeworks may be handwritten (as long as your handwriting is legible). No homework will be accepted late.

Students may discuss homework problems and assist each other in learning the material. However, the homework turned in must reflect the work of the individual student. In other words, it is acceptable to discuss approaches to problems; it is not acceptable to write up answers together, and each student is expected to complete each assignment on his or her own. Any evidence of inappropriate sharing of work will lead to disciplinary action.

## Exams

The two exams will be of equal weight in determining your final grade. The second exam, given in lieu of a final exam, primarily will cover material from the last set of lectures, but may require you to assimilate knowledge from earlier material as well

Exams are closed book; however, ***you may bring a single page of hand-written notes to each exam.***

## Weekly Discussion

Most weeks, in lieu of homework assignments, students will participate in a group discussion of readings that are related to (but go beyond) the basic material covered in the main lecture for the week. Each student must be part of a team that leads the class during a discussion of the readings one week. Each of the readings assigned for discussion (marked by asterisks in the weekly reading list, below) relate to a theme, although they can be quite diverse in their content.

### *Expectations for discussion lead team*

The discussion lead team is expected to lead and moderate discussion of the papers. It is the responsibility of the discussion lead team to prepare sufficient discussion material to fill available time and to encourage participation from other students, provoking and promoting discussion. The team should come with prepared discussion questions, be ready to point out important themes in the readings, explain and explore how the readings are (or are not) inter-related, etc. The lead team members must turn in a short (three to four sentence) summary of the papers and a list of questions (four or more) for discussion prior to the start of the discussion.

The formal oral presentation of the discussion lead team should be only 5-10 minutes long (i.e., long enough to mention the main issues raised in the readings). This means you ***should not summarize all of the results, but rather highlight the big questions raised and what they mean.*** Following this brief summary (***not more than six slides of prepared material, TOTAL***), the team should open the floor for discussion by calling on the class to ask their own questions and/or posing a question and calling on the rest of the class for input. Members of the discussion lead team will be graded on their understanding of the basic issues raised in the material and their preparedness in leading the discussion. While it is likely that the grades of all students on a discussion team will be highly correlated, each of the students on the team will receive a separate grade.

### *Expectations for remainder of class*

Students are expected to attend all discussion sections. Each student must submit two questions (one about each of the main papers) that they think are interesting points for discussion, to be turned in at the start of the discussion meeting (***i.e., prior to the class discussion***). These questions will be graded on a scale of 1-10, with the grade reflecting the depth of insight into the readings that they reflect. Students should have read all of the relevant material and be prepared to engage in active discussion with the lead team, including bringing up questions for discussion.

At the end of the discussion, non-lead-team students will be asked to turn in a short evaluation / critique of the presentations and assign grades to the presenters. This feedback

will be given (anonymously) to the presenters and will contribute to the discussion leaders' grades. In addition, I will read the evaluations in order to assess the evaluators participation / understanding on the part of the non-lead-team class members.

### *Grades*

Grades from leading the discussion will be influenced by peer grades as well as the instructor's opinion. Grades for participating in the discussion will be based on the questions turned in prior to discussion and the participation during the discussion time. These two grades will be averaged to determine the overall grade for class discussion.

### *Discussion Section Meeting Times*

The weekly date and time for discussion section meetings will be determined democratically during the first class meeting (September 14), depending on the schedule constraints of the enrolled students.

### *Assignment of Discussion Teams*

*Discussion teams will be assigned the first week of class. Students should do their best to self-organize into groups of 2-3 students. These groups should submit a list of the team members along with a list of **at least three dates** that their team could lead the discussion, ordered by preference. This list must be sent to the instructor **by 5 p.m. on September 17**.* The instructor will assign student teams to lead discussions using an ad hoc method (trying to make everyone happy, but failing miserably in some instances). The solution to this imperfect matching problem may include asking for volunteers for dates that no team picks, combining or splitting teams to even out coverage, or any other approach that the instructor deems reasonable. Whining is likely to have an adverse effect on your discussion grade.

***This assignment, of leading a class discussion, is an important component of the course. In order to be effective at leading a discussion, plan on spending a significant amount of time reading and re-reading the assigned material, engaging in background research, and discussing the material within the group. For instance, I expect that most students will need to look up and read additional references beyond the primary material in order to be effective at leading the discussion. This is a part of the assignment and you should factor in this expectation when planning your discussion.***

## **Grading scale and policy**

Final grades will be set as:

- 10% Homework
- 30% Class Discussion see above
- 30% Exam 1 covering lectures 1-6
- 30% Exam 2 covering lectures 7-12

Students must complete all three exams and run a discussion to pass the course. Grades of I (incomplete) will not be given except by prior agreement the instructor. Grades will be judged on a curve (i.e., relative to performance of other students in the course), with the mean grade roughly equal to an A-/B+.

### Policy on incomplete grades

In the event that you are unable to complete the course requirements, **you must contact me no later than November 23** to discuss the possibility of taking an “I” (incomplete) grade in the course. If I have not received a formal, written request (e-mail is adequate; however, do not assume it has been received until you receive an acknowledgment), 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 be 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. **If you take an incomplete in the course, you will not be guaranteed an “A” in the course, even if you do a good job on all the missing assignments.**

When requesting an “I” grade, you must clearly indicate your understanding of (1) 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

Hard copies of the lecture notes for the first week will be made available in class. However, it is the student’s responsibility to download and print out lecture notes for subsequent lectures from the course web site. All supplementary readings for the course that are not in one of these texts will be made available for copying upon your request. Please do not use the CNS department photocopier to make copies of these readings. The BU Bookstore sells the required and recommended textbooks; the CNS library also has copies of most of these texts.

#### Required book:

Moore, B. C. J. (2003). *An Introduction to the Psychology of Hearing (5e)*. New York: Academic Press.

#### Supplemental books (DO NOT PURCHASE THESE—FOR REFERENCE ONLY!)

Dallos, Peter, Popper, Arthur N. and Fay, Richard R. (1998). *The Cochlea*. New York: Springer-Verlag.

Hawkins, Harold L., McMullen, Teresa A., Popper, Arthur N., and Fay, Richard R. (1996). *Auditory Computation*. New York: Springer-Verlag.

Hardcastle, William J. and Laver, John (1997). *The Handbook of Phonetic Sciences*. Oxford: Blackwell Publishers.

Moore, B. C. J. (1997). *Hearing*. New York: Academic Press.

Stevens, Kenneth N. (1998). *Acoustic Phonetics*. Cambridge: MIT Press.

### Policy on the use of email

An email alias called cn560 (notice that the cn is lowercase!) will be set up in order to broadcast information pertinent to the course. It is your responsibility to ensure that your email address is correctly registered and that you are receiving all cn560 notices. On the first day of class, a signup sheet will be passed around to get your email address. If you miss this signup, you should email your address to the instructor ([shinn@cns.bu.edu](mailto:shinn@cns.bu.edu)).

Email is a great way to keep in touch with your fellow students. Note that mail sent to this alias **will not be forwarded to the instructors or the teaching fellow**. If you wish to include copies of your message to the instructors or TF, be sure to include them on the "cc:" line (email addresses are given on page one of this syllabus). Although the use of email is encouraged for contacting either the instructor or the TF, it is always a good idea to double-check that your mail was received, especially if the message is important and/or you do not receive a reply within a day (excluding weekends). Also, try to avoid sending lengthy or sensitive messages by email, as this means of communication often fails to convey subtleties apparent in face-to-face or even voice communications and can lead to misunderstandings.

### **Policy on attendance**

Students are expected to attend lectures, discussions, and exams. In the case of an emergency or other extreme circumstances, it is the students 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 discussions will adversely affect your grade.

### **Policy on collaboration**

As discussed above (see Homework section), all students may discuss homework assignments, but are expected to turn in assignments that reflect their own work. No collaboration is permitted on exams (see CAS Academic Conduct Code). Any case of suspected academic misconduct will be referred to the dean's office. Any work deemed by the dean to be plagiarized will be assigned a failing grade.

### **The web**

The official web site for CN560 is <http://www.cns.bu.edu/~shinn/CN560>. The site is password protected (**user name: CN560; password: students**)

This site will have links to the syllabus, reading list, the weekly discussion assignments, and the discussion summaries. Note that the material on this webpage is intended for class use only.

## **Weekly Lectures and Readings**

Readings for the main lecture are listed first, followed by supplemental material that is not required (marked by --). Readings to be covered by students in the weekly discussion section are marked by \*\* in the discussion section, along with any suggested supplemental reading.

### **Lecture 1 (9/14) Acoustic wave to cochlea; Signal processing primer**

*After a short introduction to the course and its structure, we start by examining the auditory system as a whole, looking at the basic pathways in order to understand how we sense and process sound. We discuss the physical attributes of sound and define some physical metrics of sound. In order to talk sensibly about sound stimuli and the processing that goes on in the auditory pathway, we introduce some basic linear system theory and Fourier analysis. We use*

*these ideas to examine how sound pressure waves are transformed as they impinge on the head and are transmitted to the inner ear.*

### **Readings**

Moore, Chapter 1, Sections 1-4.

### **Homework 1: Some simple signals**

## **Lecture 2 (9/21) Cochlea; Auditory Nerve**

*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 nearly all acoustic information to the central nervous system. We cover how the auditory nerve firing patterns depend on the sound reaching the ears.*

### **Readings**

Moore, Chapter 1, Sections 5-8.

Dallos, Popper, & Fay: Chapter 1.

### **Homework 2: Auditory nerve responses**

## **Lecture 3 (9/28) Cochlear Nucleus**

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

### **Readings:**

Yu JJ and ED Young (2000). "Linear and nonlinear pathways of spectral information transmission in the cochlear nucleus," Proc Natl Acad Sci, 97, 11780-11786.

### **Discussion 1: Neural specialization and neural computation**

What is the purpose of having the auditory nerve innervate so many separate areas of the cochlear nucleus? What basic properties of the input signals are being computed in the cochlear nucleus?

\*\*Young ED (1997) "Parallel processing in the nervous system: evidence from sensory maps," Proc Natl Acad Sci, 95, 933-934.

\*\*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.

\*\*Joris, P and PH Smith (2008) "The volley theory and the spherical cell puzzle,"  
Neuroscience, 154, 65-76.

## Lecture 4 (10/5) Basic perceptual abilities; Signal detection theory

*We will begin our foray in psychoacoustics by examining intensity / loudness perception. The philosophy behind psychophysical experiments is discussed. The second half of the lecture will discuss statistical decision theory (including ROC curves, the  $d'$  metric, response bias, etc.) used to quantify perception and experimental behavior.*

### Readings

Moore, Chapter 2 – 4.  
Durlach unpublished lecture notes.

### Homework 3: Signal detection theory

## Lecture 5 (10/13 – TUESDAY DATE) Superior Olive; Inferior Colliculus

*The physiology the Superior Olivary Complex is discussed in relation to spatial hearing. We will then look the original Jeffress model of binaural interaction as well as at a model of Medial Superior Olive (MSO) cells. Information from the superior olive passes through lemniscal pathways to the inferior colliculus, which also receives input from the cochlear nucleus. We will discuss how auditory information converges and is transformed as it passes from one level of the pathway to the next.*

### Readings

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

### Discussion 2: Beyond the Jeffress model of interaural time delay coding

Many people believe that in the original Jeffress model that interaural time delay is read out by simply identifying which neuron in an array is firing with the highest rate. However, Jeffress really was focused on describing a mechanism by which an individual neuron's rate could become sensitive to interaural time differences through a coincidence mechanism. Regardless, many people in the field now focus on refining our understanding of how neurons become ITD sensitive and how a population of such neurons encodes ITD. What does the evidence really say about the way the information is read out?

\*\*Thompson SK, K von Kriegstein, A Deane-Pratt, T Marquardt, R Deichmann, TD Griffiths, and D McAlpine (2006). "Representation of interaural time delay in the human auditory midbrain," Nat Neurosci, 9, 1096-1098.

\*\*Harper NS and D McAlpine (2004). "Optimal neural population coding of an auditory spatial cue." Nature, 430, 682-686.

\*\*Porter KK, RR Metzger, and JM Groh (2007). "Visual- and saccade-related signals in the primate inferior colliculus," Proc Nat Acad Sci, 104, 17855-17860.

Suppl: Joris P and TCT Yin (2007). "A matter of time: internal delays in binaural processing," Trends Neurosci, 30, 70-78.

Suppl: Brand A, O Behrend, T Marquardt, D McAlpine, and B Grothe (2002). "Precise inhibition is essential for microsecond interaural time difference coding," Nature, 417, 543-547.

Suppl: Campbell RAA and AJ King (2004). "Auditory neuroscience: A time for coincidence?," Curr Biol, 14, R886-R888.

## Lecture 6 (10/19) Spatial and binaural hearing

*We move to the most exciting and important topic in hearin... oops. Despite Barb's bias, this week's lecture does cover one of the more prominent areas of hearing research: the perception of spatial information and the importance of hearing with two ears. We will discuss basic perceptual phenomena in binaural and spatial hearing, then examine models describing how the human brain extracts and processes spatial auditory cues.*

### Readings

Moore, Chapter 7.

Hawkins, McMullen, Popper, and Fay: Chapter 8.

Colburn HS and A Kulkarni (2006). "Models of sound localization."

## Homework 4: Spatial computations and spatial perception

## EXAM 1 (10/26)

## Lecture 7 (11/2) Pitch and timbre

*This week, we look at the perception of pitch and timbre. Possible neural mechanisms for encoding pitch and models of pitch perception are discussed (including temporal pattern and place of neural firings). The perception of sound timbre is then considered.*

### Readings

Moore, Chapters 5 & 6.

Hawkins, McMullen, Popper, and Fay: Chapter 6.

-- Hartmann, WM (1996). "Pitch, periodicity, and auditory organization," J Acoust Soc Am, 100, 3491-3502.

## Discussion 3: Which acoustic features convey pitch and which convey meaning?

Which features or cues in sound are really used to convey sound pitch? Which features are the dominant sources of information about speech meaning? How can we tell?

\*\*Oxenham AJ, JGW Bernstein, and H Penagos (2004). "Correct tonotopic representation is necessary for complex pitch perception," Proc. Nat. Acad. Sci., 101, 1421-1425.

- \*\*Smith ZM, B Delgutte, and AJ Oxenham (2002). "Chimaeric sounds reveal dichotomies in auditory perception," *Nature*, 416, 87-90.
- \*\*Shannon RV, F-G Zeng, V Kamath, J Wygonski, and M Ekelid (1995). "Speech recognition with primarily temporal cues," *Science*, 270, 303-304.
- Suppl: Shamma, S (2004). "Topographic organization is essential for pitch perception," *Proc Nat Acad Sci*, 101, 1114-1115.

## Lecture 8 (11/9) Auditory scene analysis and source segregation

*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. The concept of informational masking is described and discussed in relation to the hierarchy of processing in the auditory pathway. We also look at the clever tricks we employ to fill in missing, ambiguous bits.*

### Readings

- Darwin, CJ and RP Carlyon (1995). Auditory grouping. *Hearing*. BCJ Moore. San Diego, CA, Academic Press, 387-424.
- Carlyon RP (2004). "How the brain separates sounds," *Trends Cogn Sci*, 8, 465-71.
- Shamma, S (2008). "On the emergence and awareness of auditory objects," *PLoS Biology*, 6, 1141-1143.
- Suppl: Grossberg, S, KK Govindarajan, LL Wyse, and MA Cohen (2004). "ARTSTREAM: A neural network model of auditory scene analysis and source segregation," *Neural Networks*, 17, 511-536.
- Suppl: Verhey, JL, D Pressnitzer, and IM Winter (2003). The psychophysics and physiology of comodulation masking release," *Exp Brain Res*, 153, 405-417.

### Discussion 4: What are the neural correlates of source segregation?

What are the neural correlates of sound source segregation? Which aspects of auditory scene analysis do they represent?

- \*\*Winkler I, R Takegata, and E Sussman (2005). "Event-related brain potentials reveal multiple stages in the perceptual organization of sound," *Brain Res Cogn Brain Res*, 25, 291-299.
- \*\*Pressnitzer D, M Sayles, C Micheyl, and IM Winter (2008). "Perceptual organization of sound begins in the auditory periphery," *Curr Bio*, 18, 1124-1128.
- \*\*Gutschalk A, Micheyl C, Oxenham AJ (2008) Neural correlates of auditory perceptual awareness under informational masking. *PLoS Biol* 6(6): e138.
- Suppl: Gutschalk A, AJ Oxenham, C Micheyl, EC Wilson, and JR Melcher (2007), "Human cortical activity during streaming without spectral cues suggests a general neural substrate for auditory stream segregation," *J Neurosci*, 27, 13074-81.

Suppl: Micheyl C, B Tian, RP Carlyon, and JP Rauschecker (2005). "Perceptual organization of tone sequences in the auditory cortex of awake macaques," *Neuron*, 48, 139-48.

Suppl: Dewese MR and AM Zador (2005). "Neural gallops across auditory streams," *Neuron*, 48, 139-48.

## Lecture 9 (11/16) Auditory attention

*Because the world is complex and full of competing events, 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. The auditory neuroscience community has begun to recognize the relationship between attention, performance, and auditory scene analysis (auditory object formation). We will discuss the role of attention in auditory perception, and the relationship between attention and "informational masking" in audition.*

### Readings

Desimone, Desimone R and J Duncan (1995). "Neural mechanisms of selective visual attention," *Ann Rev Neurosci*, 18, 193-222.

Eramudugolla R, DR Irvine, KI McAnally, RL Martin, and JB Mattingley, (2005). "Directed attention eliminates 'change deafness' in complex auditory scenes," *Curr Biol*, 15, 1108-1113.

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

Suppl: Shomstein S and S Yantis (2006). "Parietal cortex mediates voluntary control of spatial and nonspatial auditory attention," *J Neurosci*, 26, 435-439.

### Discussion 5: Similarities between auditory and non-auditory attention

Up until recently, most work on attention has been in the visual domain, while most work in spatial hearing focused on how the brain computed where a sound was, ignoring its role in directing attention. What similarities / differences are there in the mechanisms of attention in the different sensory modalities? How does directing spatial attention impact behavior and perception?

\*\*Winkowski DE and EI Knudsen (2006). "Top-down gain control of the auditory space map by gaze control circuitry in the barn owl. *Nature*, 439, 336-9 (2006).

\*\*Best V, E Ozmeral, N Kopco, and BG Shinn-Cunningham (2008). "Object continuity enhances selective auditory attention," *Proc Nat Acad Sci*, 105, 13174-13178.

\*\*Ciaramitaro VM, GT Buracas and GM Boynton (2007). "Spatial and cross-modal attention alter responses to unattended sensory information in early visual and auditory human cortex," *J Neurophysiol*, 98, 2399-2413, 2007.

Suppl: Best V, EJ Ozmeral, and BG Shinn-Cunningham (2007). "Visually guided attention enhances target identification in a complex auditory scene," *Journal of the Association for Research in Otolaryngology*, 8(2), 294-304.

Suppl: Shinn-Cunningham B.G. (2005). "Influences of spatial cues on grouping and understanding sound," *Proc. Forum Acusticum*, Budapest, Hungary.

Suppl: Serences JT and S Yantis (2006). "Selective visual attention and perceptual coherence," *Trends Cogn Sci*, 10, 38-45.

## **Lecture 10 (11/23) Speech perception and production**

*The lecture begins with an overview of the anatomy of the vocal production system. The "source-filter" theory of speech acoustics is introduced, and the basic types of speech sounds are described and categorized, including different categories of vowels and consonants. The relationship between the spectro-temporal features of the different phonetic types are related to computational processes in the auditory pathway.*

### **Readings**

Moore: Chapter 9.

Fujimura O and D Erickson (1997). "Acoustic phonetics," in *The Handbook of Phonetic Sciences* (Hardcastle and Laver, eds), Oxford: Blackwell Publishers, 65-115.

**NO DISCUSSION: Thanksgiving break**

## **Lecture 11 (11/30) Auditory Cortex**

*This lecture traces the auditory pathway through the midbrain to the cortex. We discuss evidence for specialized processing areas within cortex, including "what" and "where" pathways. Finally, we consider what acoustic features the cortex may be encoding, if any*

### **Readings**

Moore: Chapter 8.

Nelken, I, A Fishbach, L Las, N Ulanovsky, and D Farkas (2003). "Primary auditory cortex of cats: feature detection or something else?" *Biol Cybern*, 89, 397-406.

Ulanovsky, N, L Las, and I Nelken (2003). "Processing of low-probability sounds by cortical neurons." *Nat Neurosci*, 6, 391-8.

Read, HL, JA Winer, and CE Schreiner (2002). "Functional architecture of auditory cortex." *Cur Opin Neurobiol*, 12, 433-440.

### **Discussion 6: How is information encoded in the auditory cortex?**

Is the role of each neuron is fixed, such that each neuron encodes a particular feature of sound independent of task demands or past experience? It may be that the population of neurons in sensory auditory cortex encodes different elements of the input stimuli in different situations. What does the evidence suggest? Remporal structure in sound is what conveys meaning, to a great degree. How do these dynamics interact with intrinsic dynamics in brain

responses? What is the implication for how information is encoded in the auditory cortex (and in non-auditory cortex)? How is information encoded?

- \*\*Fritz J, S Shamma, M Elhilali, and D Klein. (2003). "Rapid task-related plasticity of spectrotemporal receptive fields in primary auditory cortex." *Nat Neurosci*, 6, 1216-23.
- \*\*Nelken I (2004). "Processing of complex stimuli and natural scenes in the auditory cortex." *Curr Opin Neurobiol*, 14, 474-80.
- \*\*Luo H and D Poeppel (2007). "Phase patterns of neuronal responses reliably discriminate speech in human auditory cortex," *Neuron*, 54, 1101-1010.
- Suppl: Tang J and N Suga (2008). "Modulation of auditory processing by cortico-cortical feed-forward and feedback projections," *Proc Nat Acad Sci*, 105, 7600-7605.

## Lecture 12 (12/7) Hearing loss and cochlear implants

*Assuming that we have not gotten side-tracked by discussions and need this lecture time to catch up, the final formal lecture will be devoted to hearing loss, hearing aids, cochlear implants, and the consequences of abnormal peripheral hearing.*

### Readings

- Moore: Chapter 10.
- Shinn-Cunningham B and V Best (2008). "Selective attention and hearing loss," *Trends in Amplification*, 12, 283-299.

### Discussion 7: Hearing loss and complex scenes

Listeners with impaired hearing often have inordinate trouble with communicating in settings with multiple sources. How is it that deficits in peripheral encoding so strongly affect high-level perception?

- \*\*Laback B and P Majdak (2008). "Binaural jitter improves interaural time-difference sensitivity of cochlear implantees at high pulse rates," *Proc Nat Acad Sci*, 105, 814-817.
- \*\*Rouger J, S Lagleyre, B Fraysse, S Deneve, O Deguine, and P Barone (2007). "Evidence that cochlear-implanted deaf patients are better multisensory integrators," *Proc Nat Acad Sci*, 104, 7295-7300.
- \*\*Lorenzi C, G Gilbert, H Carn, S Garnier, and BCJ Moore (2006). "Speech perception problems of the hearing impaired reflect inability to use temporal fine structure," *Proc Nat Acad Sci*, 103, 18866-18869.
- Suppl: Shannon RV (2007). "Understanding hearing through deafness," *Proc Nat Acad Sci*, 104, 6883-6884.

## FINAL EXAM (12/16—Wednesday 1-3 pm)