COGS 101A: Sensation and Perception

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Department of Cognitive Science

UCSD

Lecture 15:

Auditory Localization

Course Information

- Class web page: http://cogsci.ucsd.edu/ desa/101a/index.html
- Professor: Virginia de Sa
  - ⋆ I'm usually in Chemistry Research Building (CRB) 214 (also office in CSB 164)
  - ⋆ Office Hours: Monday 5-6pm
  - ⋆ email: desa at ucsd
  - ⋆ Research: Perception and Learning in Humans and Machines

For your Assistance

TAS:

- Jelena Jovanovic OH: Wed 2-3pm CSB 225
- Katherine DeLong OH: Thurs noon-1pm CSB 131

IAS:

- Jennifer Becker OH: Fri 10-11am CSB 114
- Lydia Wood OH: Mon 12-1pm CSB 114

Course Goals

- To appreciate the difficulty of sensory perception
- To learn about sensory perception at several levels of analysis
- To see similarities across the sensory modalities
- To become more attuned to multi-sensory interactions

Grading Information

- 25% each for 2 midterms
- 32% comprehensive final
- 3% each for 6 lab reports - due at the end of the lab
- Bonus for participating in a psych or cogsci experiment AND writing a paragraph description of the study (just a few sentences) Deadline to sign up for experiments on Experimetrix has passed
- New lenient midterm policy: If you do better on the final than your worst midterm, we'll downweight that midterm to 10% (and upweight the final); If you do better on the final than your best midterm, we'll downweight that midterm to 15%. There will be no downweighting of the final. We will also drop your lowest lab grade IF you complete all labs

You are responsible for knowing the lecture material and the assigned readings. Read the readings before class and ask questions in class.

Academic Dishonesty

The University policy is linked off the course web page.

You will all have to sign a form before each test

For this class:

- Labs are done in small groups but writeups must be in your own words
- There is no collaboration on midterms and final exam

Midterm 2

Congratulations! Generally grades are very high.

Mean 80%

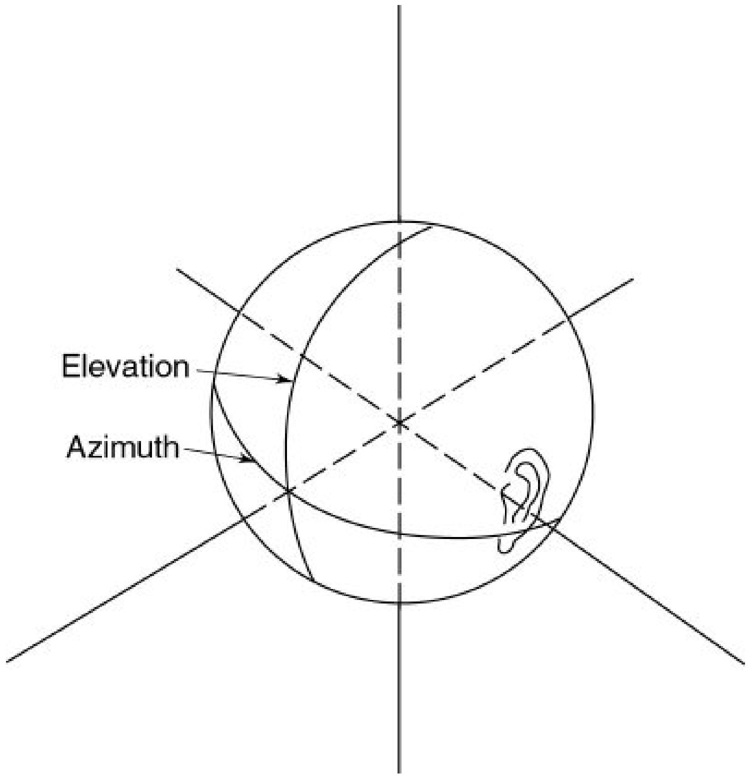
Low 46%

High 100%

Sound localization

Tutis Vilis' notes on sound localization

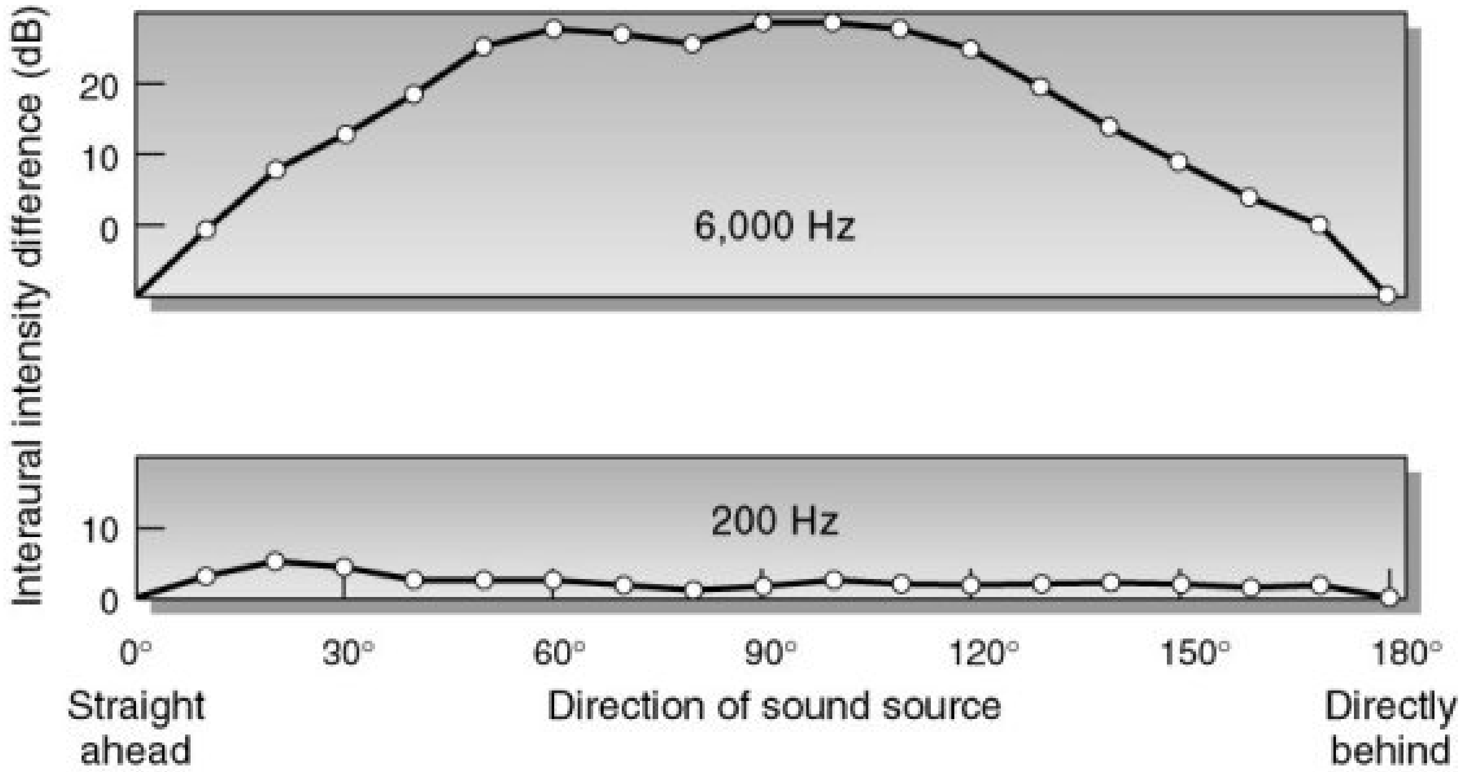
Azimuth and **elevation**



http://www.acs.appstate.edu/ kms/classes/psy3203/SoundLocalize/directions.jpg

Interaural intensity difference (IID) of Interaural level difference (ILD)

caused by shadow of the head



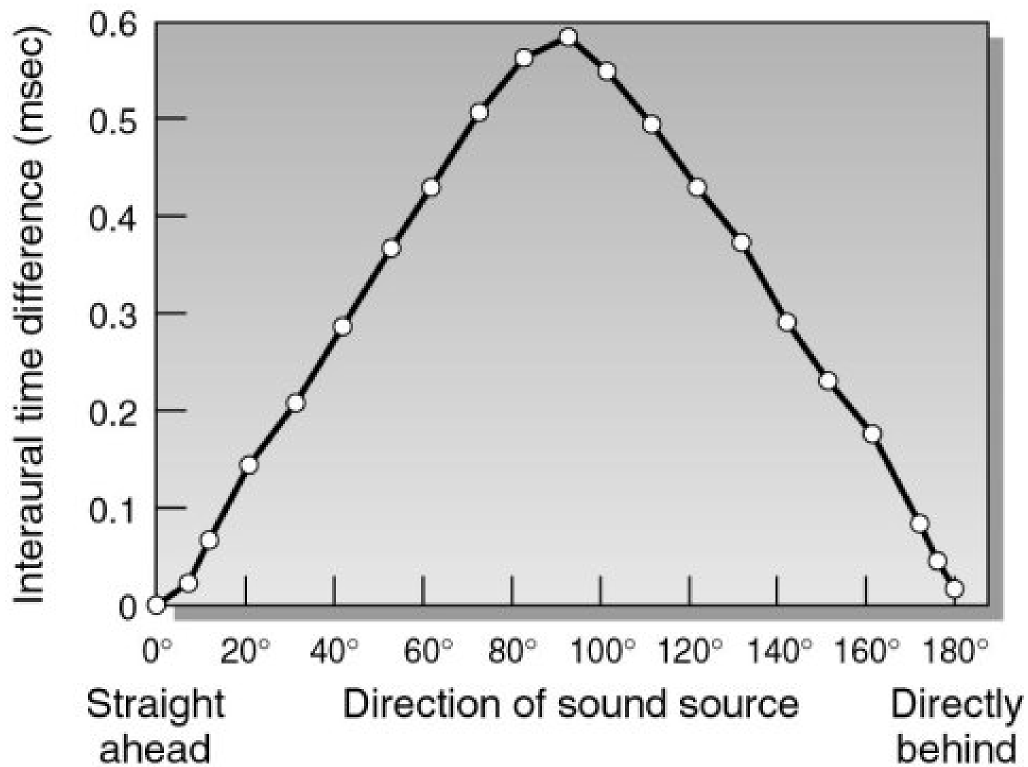
http://www.acs.appstate.edu/ kms/classes/psy3203/SoundLocalize/intensity.jpg

IID

works best for high frequencies (most shadowed by the head) (just like low frequencies get through your neighbors wall better, they get around/through the head better)

Interaural Time Difference (ITD)

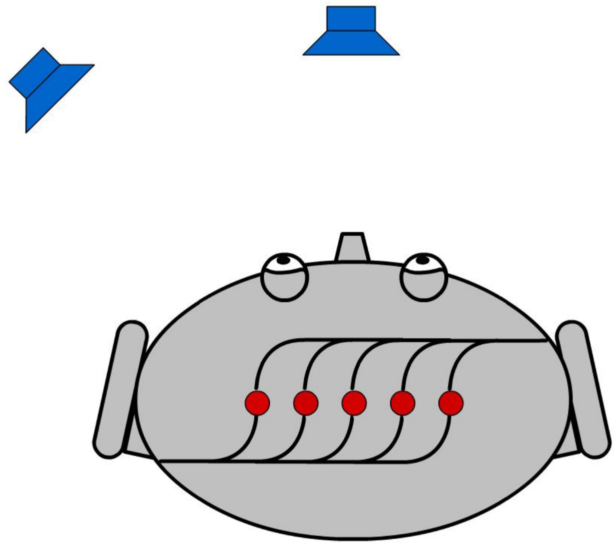
Detects phase differences between signals to the two ears (best for low frequencies as high frequencies are too ambiguous)



http://www.acs.appstate.edu/ kms/classes/psy3203/SoundLocalize/time.jpg

Go to Interaural time difference and Interaural loudness difference on textbook CD

Auditory Localization

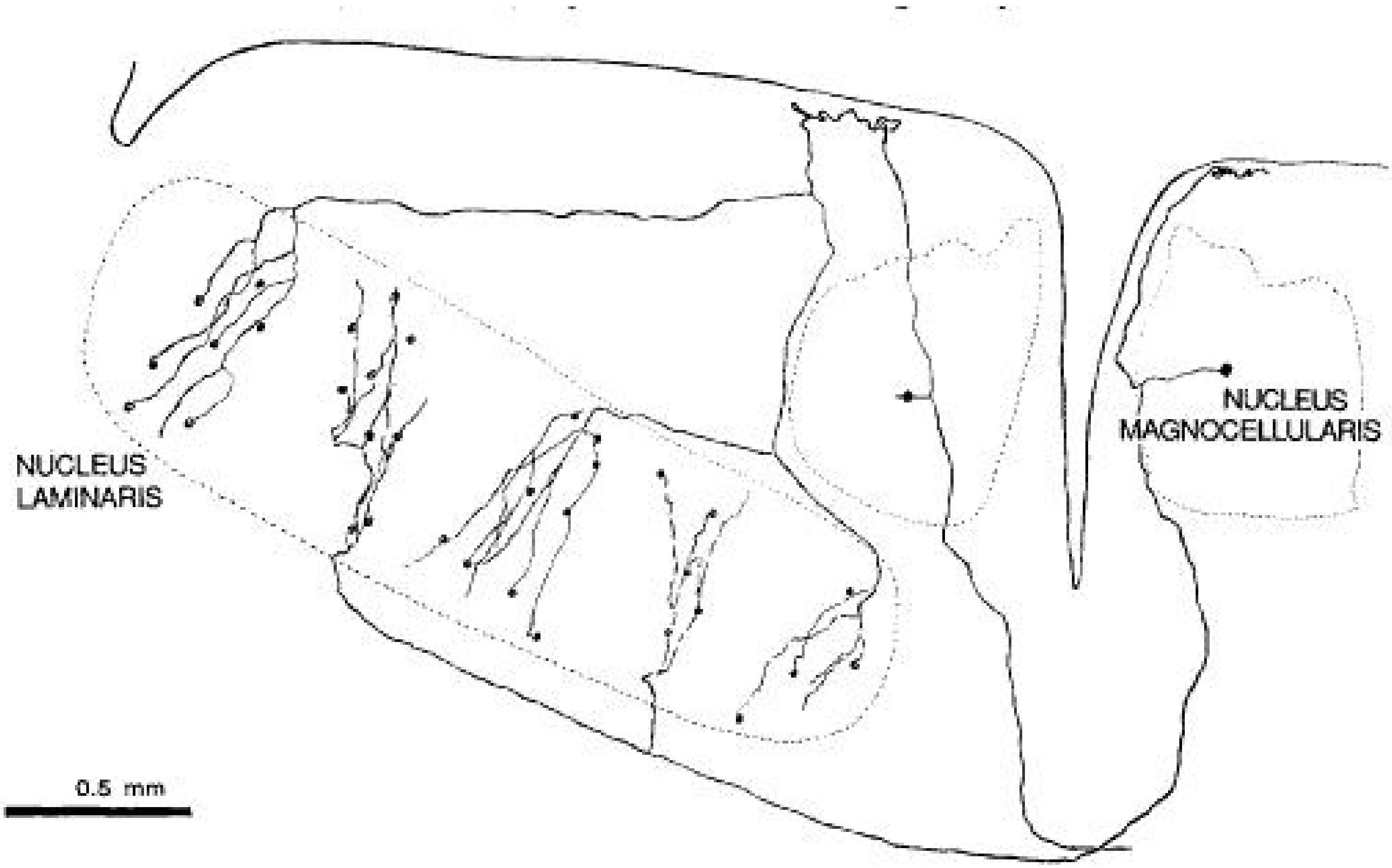


Jeffress demo

http://www.mbfys.kun.nl/mbfys/education/medical/webteach/cochlea/jeffress_webfile

In 1948 Jeffress created a model of sound localization based on interaural time difference involving delay lines

Barn owl circuitry



Catherine Carr and Masakazu Konishi found a similar circuit in the Nucleus Laminaris of the owl (equivalent in mammals is called the Medial superior olive)

Judging elevation

The head and pinnae result in amplification and depression of different frequencies coming from different directions. The particular pattern differs from person to person. The difference between the spectrum of the sound source and that entering the ear canal is called the **directional transfer function**.

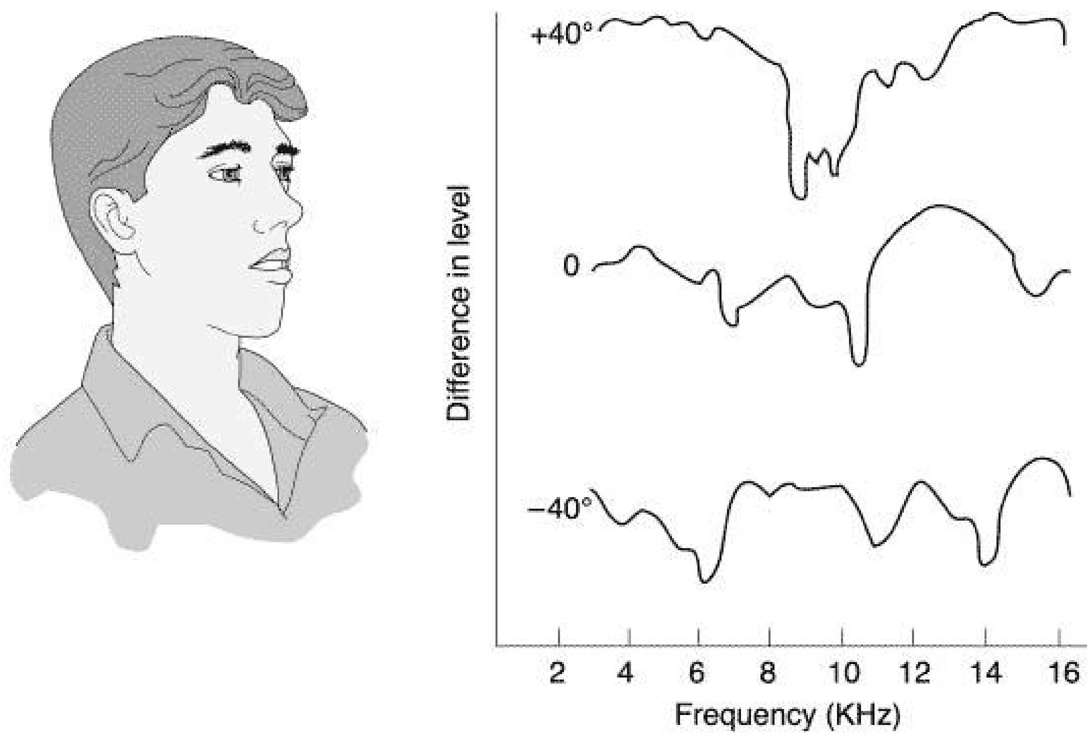


Figure 11.9 from your textbook

You can reshape someones pinna with modeling clay and their sound localization ability gets much worse.

Judging Distance

For sounds more distant than arm's length, we tend to underestimate the distance

Cues include

- sound level - the sound decreases by 6dB when the distance to a sound source is doubled (in an open environment with no echoes)
- frequency - sounds that are farther away are more muffled (lose the high frequencies) (c.f. atmostpheric perspective)
- movement parallax - sounds that are closer move faster when we move (c.f. motion parallax)
- reflection - at farther distances the ratio of indirect (reflected) sound to direct sound is higher

Go to Sound level as a cue to distance on book cd

Dealing with Reflections

Sound localization is complicated by reflections (which direct sound from other directions) (see Figure 11.10 in your text)

To simplify, most research has been done with two speakers

When the sounds to the two speakers are presented within 1 millisecond subjects hear one sound located between the two speakers (and closer to the first sound) **fusion**

When the sounds to the two speakers are presented 1-5msec apart, subjects hear one sound coming from the location where the the first speaker is. **precendence effect**

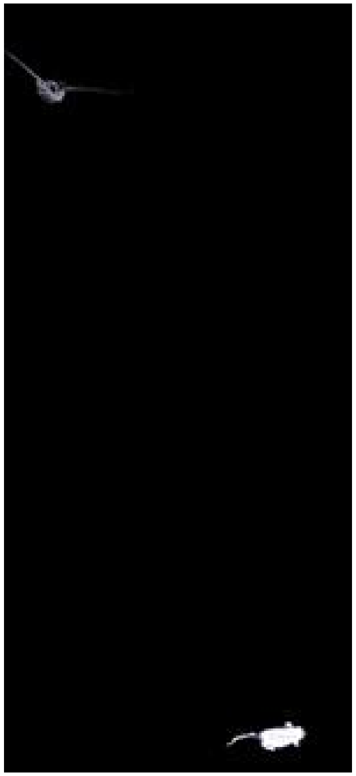
When the sounds to the two speakers are presented more than about 5 msec apart, subjects hear 2 sounds (from the locations of the two speakers). The time at which this switch occurs is called the **echo threshold**. It is longer if the sounds are longer or if the second sound is of lower magnitude (as would be more consistent with an echo).

Go to Echoes on CD

Physiology of Localization

- Auditory cortex is necessary for localization
  - ⋆ Jenkins and Merzenich showed that removal of a frequency band in auditory cortex degraded auditory localization for those frequencies
  - ⋆ Humans with damage to auditory cortex have trouble localizing sounds
- Interaural time difference detectors in auditory cortex
  - ⋆ respond best to a particular interaural time difference (e.g. 1 msec)
- Only a few neurons have been found that are selective to a specific area of space. Many more have a **virtual space field** that is quite large
- **panoramic neurons** have been found by Middlebrooks in non-primary auditory cortex (beyond A1). These neurons fire different temporal patterns for different directions of sounds.
- **neurons that signal sounds near the head** - Graziano et. al. have found neurons in non-primary auditory cortex that respond only to sounds near the head (e.g. within 30cm)

Barn Owl's topographic map of space



movie of owl localizing sound on-line movie
http://www.hhmi.org:80/senses/c210.html

Barn owls are extremely good at sound localization

Barn Owl's topographic map of space

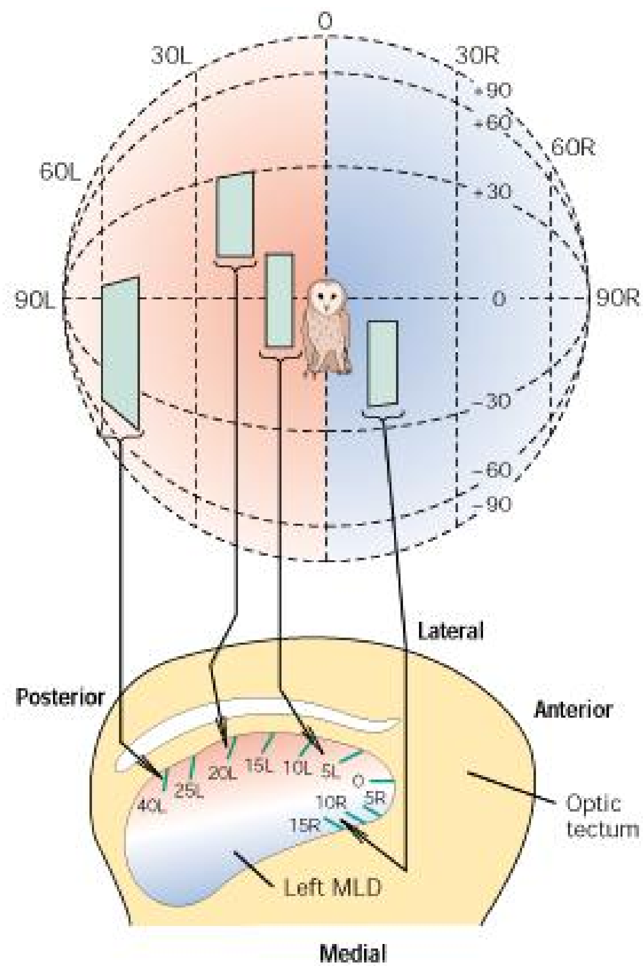
Neurons in the Nucleus mesencephalicus lateralis dorsalis (MLD) (analogue of the Inferior Colliculus) of the Barn owl respond to sounds originating from a small area of space (much smaller than has been found for cat, monkey and human).

Some of these neurons have excitatory centers and inhibitory surrounds

There is a map of location across the owl IC (adjacent neurons respond to nearby locations in space).

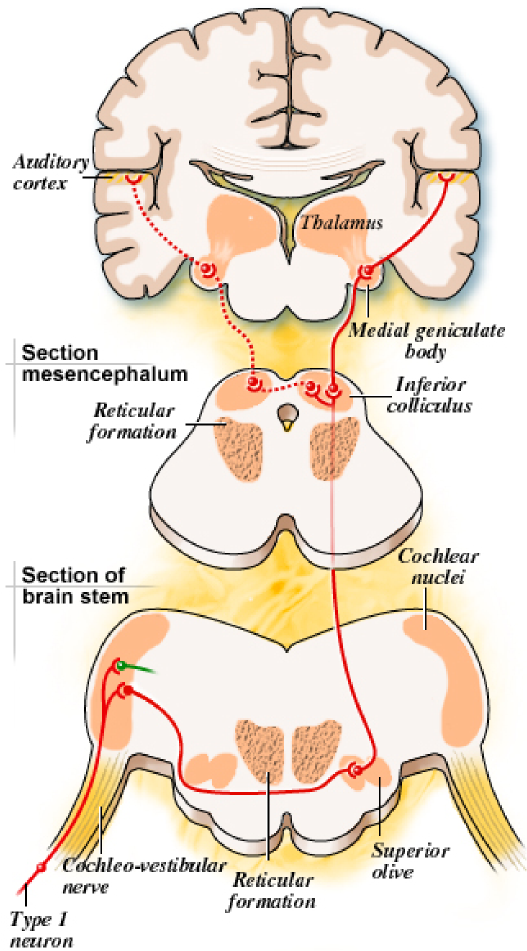
Plugging one ear eliminates the receptive fields in space. Partially plugging one ear shifts the receptive fields.

Barn Owl's topographic map of space



from Knudsen and Konish 1987 (at http://soma.npa.uiuc.edu/courses/bio303/Ch12.html)

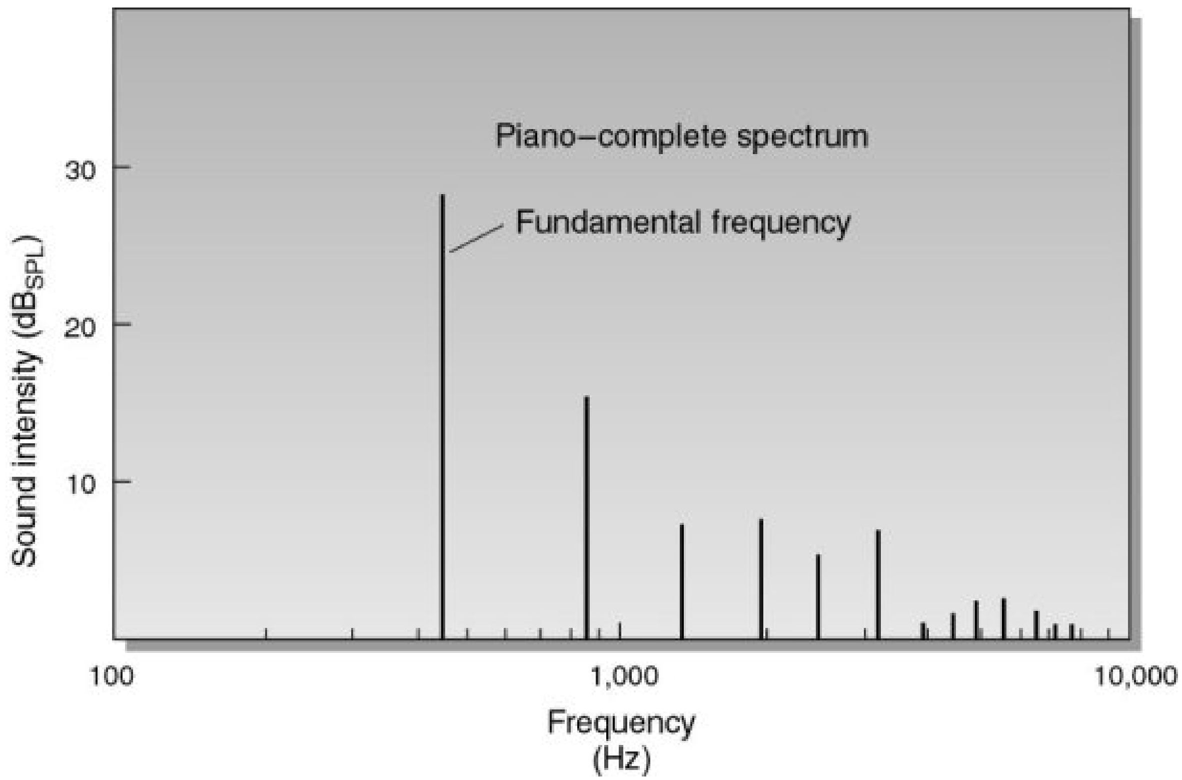
Reminder of the Auditory Pathway



Drawing by S. Blatrix from EDU website "Promenade around the cochlea" (www.cochlea.org) by R. Pujol et al., University Montpellier 1 and INSERM. Not to be reproduced without author permission (see the original website).

Timbre

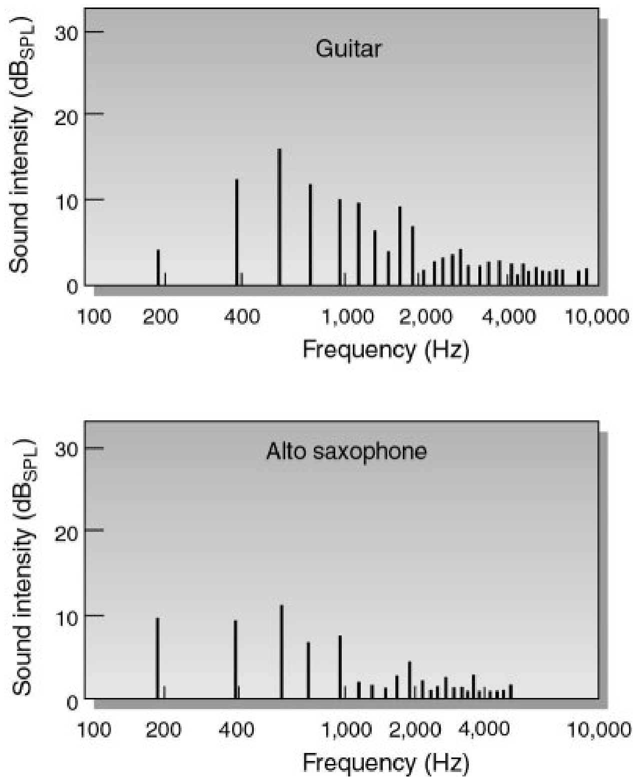
Musical instruments do not play pure tones



http://www.acs.appstate.edu/ kms/classes/psy3203/Music/PianoHarmonics.jpg

Timbre

Musical instruments do not play pure tones



http://www.acs.appstate.edu/ kms/classes/psy3203/Music/harmonics2.jpg

Reminder of the Missing Fundamental Effect

If you remove the fundamental frequency (but keep all the other harmonics the same), the pitch sounds the same! Pitch perceived this way is called **periodicity pitch** because you are using the period between harmonics as a cue to pitch.

You can also keep removing harmonics and the pitch stays the same.

Sound with energy at 800, 1200, 2000, and 2400 Hz will be perceived as

Reminder of the Missing Fundamental Effect

If you remove the fundamental frequency (but keep all the other harmonics the same), the pitch sounds the same! Pitch perceived this way is called **periodicity pitch** because you are using the period between harmonics as a cue to pitch.

You can also keep removing harmonics and the pitch stays the same.

Sound with energy at 800, 1200, 2000, and 2400 Hz will be perceived as a 400 Hz sound

Sound with energy at 1600 and 2400 Hz will be perceived as

Reminder of the Missing Fundamental Effect

If you remove the fundamental frequency (but keep all the other harmonics the same), the pitch sounds the same! Pitch perceived this way is called **periodicity pitch** because you are using the period between harmonics as a cue to pitch.

You can also keep removing harmonics and the pitch stays the same.

Sound with energy at 800, 1200, 2000, and 2400 Hz will be perceived as a 400 Hz sound

Sound with energy at 1600 and 2400 Hz will be perceived as an 800 Hz sound

missing fundamental demo

Pitch perception is thought to be computed cortically

Timbre

timbre refers to sound quality and reflects the characteristics that allow us to distinguish sounds that have the same pitch and loudness

A major factor in timbre is the relative strengths of the harmonics (see figures above)

Another major factor is the temporal envelope of the sound (the **attack** and **decay**) – how fast does it ramp up and down (respectively).

There is a great example on the CD in your book Go to Timbre of a Piano Tone played backwards (and Effects of Harmonics on Timbre if time permits

Principles of Auditory Grouping

auditory stream segregation - the separation of auditory signals into separate perceptual streams

(compare with principles of visual grouping)

location- sounds created by one source come from one location or a slowly changing location

similarity of timbre- sounds that have the same timbre are often from the same source (auditory stream segregation of sounds with different timbres)

Principles of Auditory Grouping (cont'd)

similarity of pitch- sounds with the same frequency are often produced by the same source (auditory stream segregation of high and low sounds)

- **implied polyphony**-rapidly alternating high and low notes are perceived as two separate instruments go to Segregation of high notes in a Telleman Sonata

Principles of Auditory Grouping (similarity of pitch cont'd)

- **scale illusion** or **melodic chanelling**

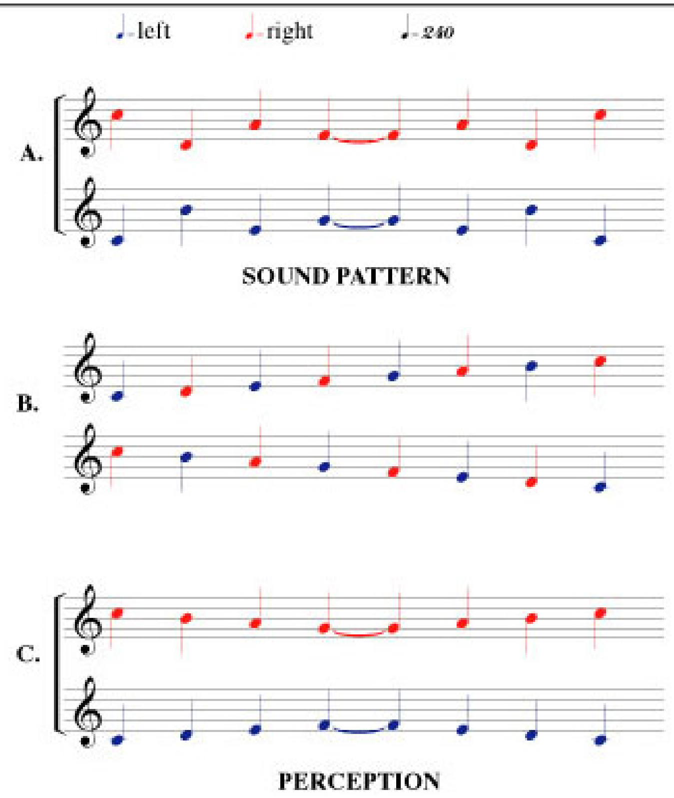


Figure 3. *The pattern that produces the scale illusion (A), and a way that it is often perceived (C). The notation in (B) shows how the pattern is composed of ascending and descending scales.*

http://psy.ucsd.edu/ ddeutsch/psychology/deutsch_research3.html Scale Illusion page

Principles of Auditory Grouping (similarity of pitch cont'd)

- Bregman and Rudnicky experiment -It is difficult to judge the order of two tones when there are distractor tones. But the distractor tones can be more easily ignored when they are part of another group (see Figure 11.25 in your textbook) go to Grouping by Similarity of Pitch

Principles of Auditory Grouping (cont'd)

temporal proximity sounds that occur close together in time tend to come from the same source

- go to Effect of Temporal proximity on Stream segregation and Grouping by Pitch and Temporal Closeness and Grouping of noise pitch and temporal closeness

onset and offset sounds that stop at start at different times tend to be produced by *different* sources

good continuation sounds that stay constant or change smoothly are often produced by the same source.

- Listeners hear a sound continuing behind noise go to Auditory Good Continuation and Auditory Good Continuation for Speech

Experience -

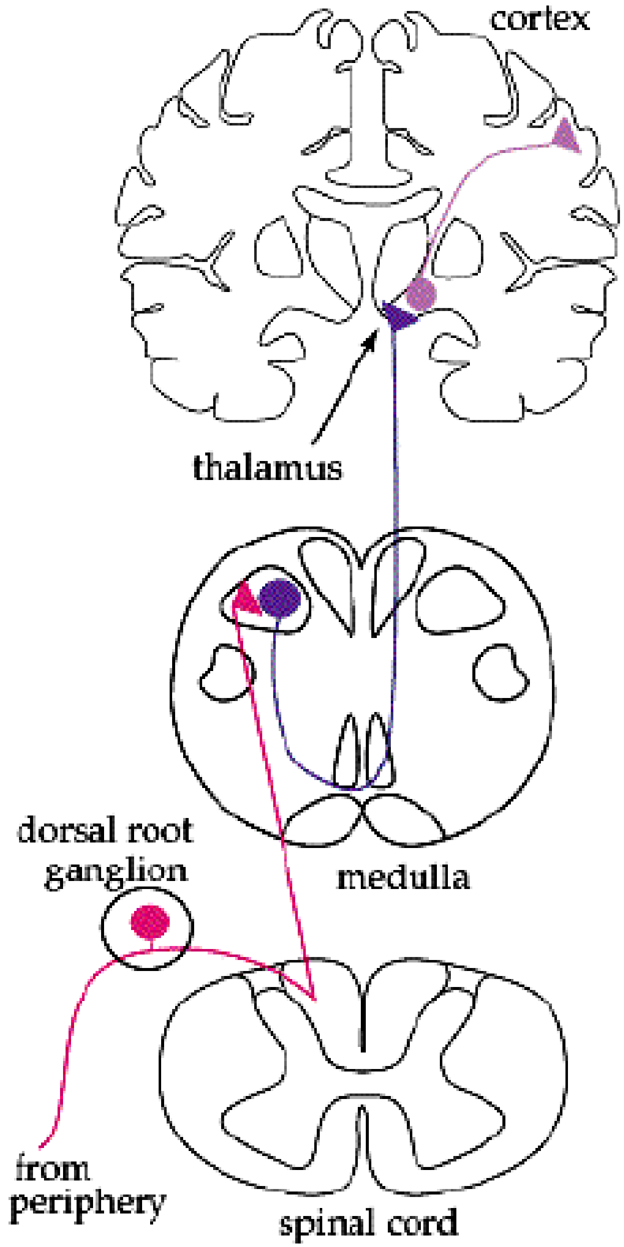
- Tend to group things that you have heard together in the past go to Effect of repetition on grouping by pitch

- When you know what to listen for you can hear it even when it has intervening noise notes or when the notes are transcribed to random octaves go to Perceiving a melody obscured by noise – This also illustrates grouping by frequency

Next Class

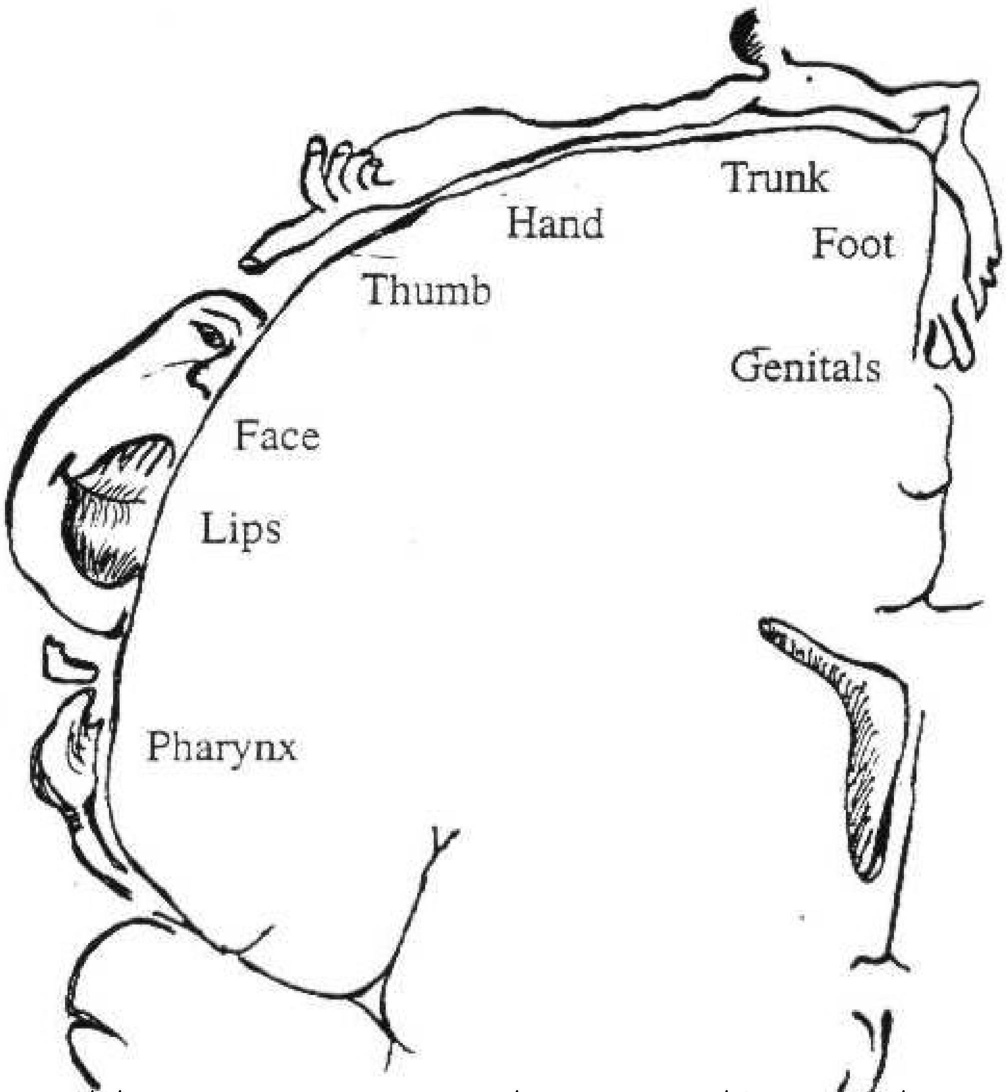
Somatosensory (touch) System and General Principles of sensory systems

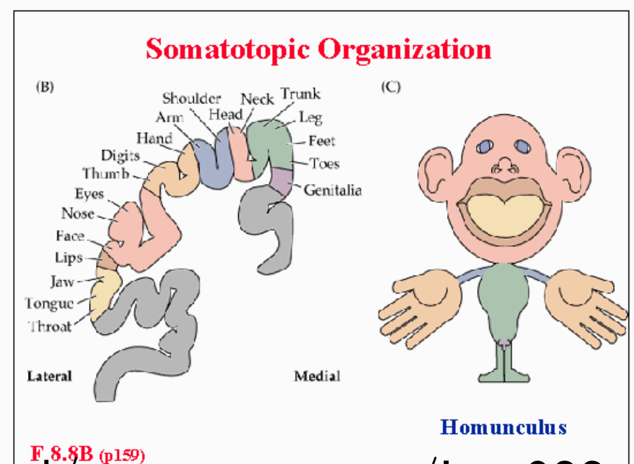
Somatosensory Pathway



http://thalamus.wustl.edu/course/bassens.html

Somatotopic Map





http://zeus.rutgers.edu/ ikovacs/SandP/fig5.jpg
http://aids.hallym.ac.kr/d/kns/tutor/medical/unified/somatosensory/img022.gif