Announcements

- Exam next Tuesday
  - I will email specific instructions about the book material
- Review session Monday at 6:15PM in Meliora 203
- Journal due **in class** next Thr
  - Write the word count on the paper
  - Little over the 1000 word limit is OK
    - Certainly don't go over 2000 words!!!
    - Simply writing more will not help, if the content isn't there

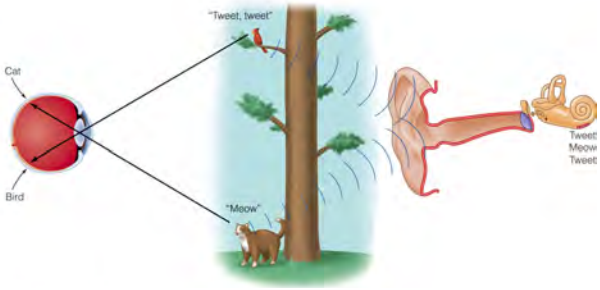
http://www.youtube.com/watch?v=IUDTIvagjJA

Hearing outline

- Localization of sounds
- Segmentation/grouping of sounds
- A few research examples
- Audition and vision

ALL IN CLASS DEMOS CAN BE SEEN HERE:
http://www.tutis.ca/Senses/L9Auditory/L9Auditory.swf

Auditory localization: The **WHERE** problem

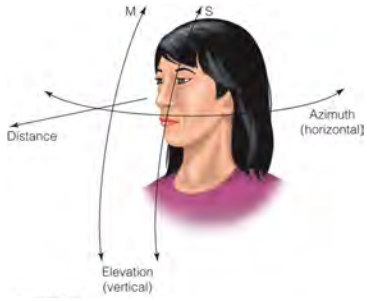


- Allows us to pinpoint a sound of interest
- Locate the position of another person
- Locate direction and distance of a moving sound source
- Allows us to quickly locate & attend to a speaker, esp. in multi-talker situations

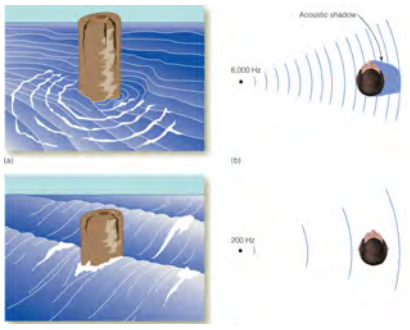
Auditory localization: The solutions

1. Interaural **Intensity** Difference, best for high frequency sounds
2. Interaural **Time** Difference, best for low frequency sounds
3. "Coloring" of the sound by your pinnas, best for vertical localization

Duplex theory of sound localization



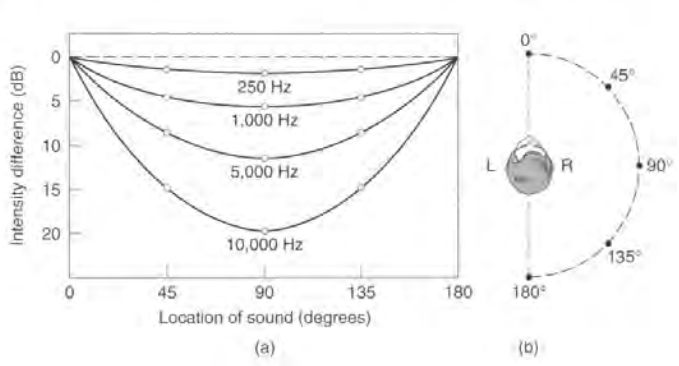
Auditory localization: Interaural Intensity Difference Best for high frequencies



About 20 dB at 10,000Hz, almost 0 at 200 Hz.

•Car base example

Auditory localization: Interaural Intensity Difference Its magnitude depends on sound frequency



About 20 dB at 10,000Hz, almost 0 at 200 Hz.

Auditory localization: Interaural Time Difference

The principle behind interaural time difference (ITD).
The tone directly in front of the listener, at A, reaches the left and the right ears at the same time. However, when the tone is off to the side, at B, it reaches the listener's right before it reaches the left ear.

Auditory localization: Interaural Time Difference

ITD is SMALL!

Interaural time difference for a sound located to your right?

Speed of sound (air) 1130 ft/sec

Time to travel 1 foot = 0.00088 sec

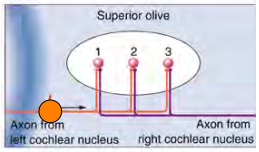
Distance between ears ~ 8" (0.66 ft)

ITD ~ 0.00058 sec

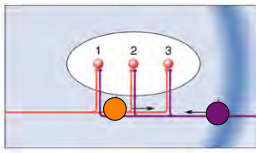
Auditory localization: Interaural Time Difference
Coincidence detection

Sound coming from the left side

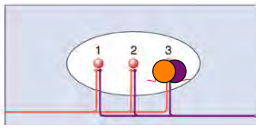
Sound from the left side initiates activity in the left cochlear nucleus; activity is then sent to the superior olive.



Very soon, the sound reaches the right ear, initiating activity in the right cochlear nucleus. Meanwhile, the first impulse has traveled farther along its axon.

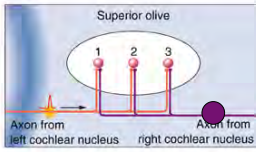


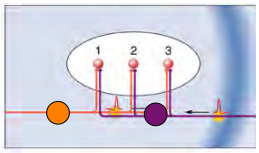
Both impulses reach olivary neuron 3 at the same time, and summation of synaptic potentials generates an action potential.

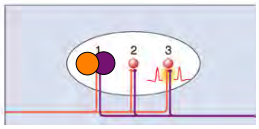


Auditory localization: Interaural Time Difference
Coincidence detection

Sound coming from the right side

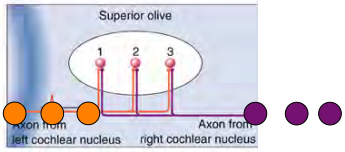


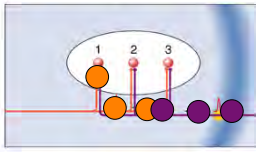


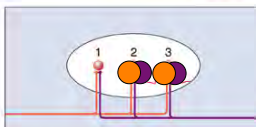


PS. Ignore these little axon potential icons - >

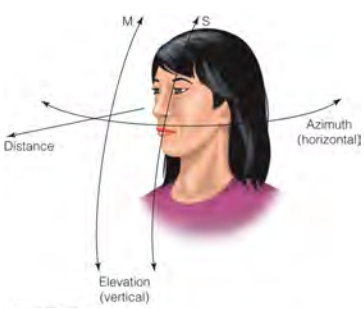
Auditory localization: Interaural Time Difference
Why not good for high frequencies?

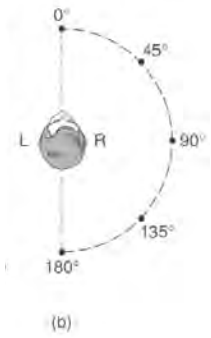






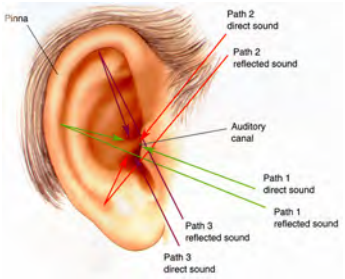
Auditory localization: How about elevation?



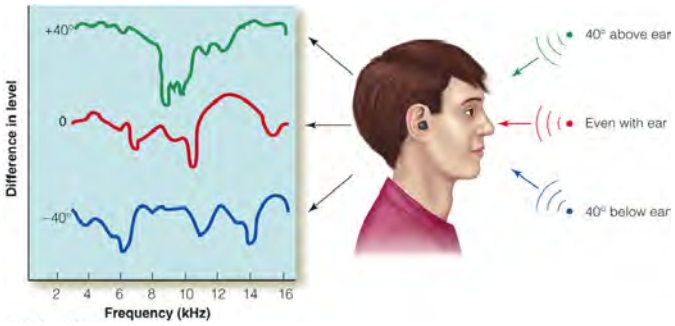


Auditory localization: How about elevation?

- elevation does not provide interaural differences, rather spectral cues
- the pinna acts like an acoustic antenna - its resonant cavities amplify some frequencies and attenuate other frequencies
- In other words, the pinna **filters** the sound, and this filtering depends on the sound direction



Auditory localization: How about elevation?

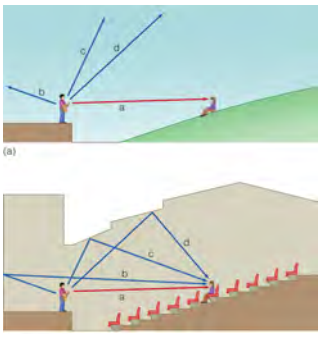


Head-related transfer functions (HTRFs) recorded by a small microphone inside the listener's right ear for sounds at three different locations.

These functions indicate how the frequencies of the sound source are affected by interactions of the sound with the head and the pinna. Notches indicate a decrease in level and peaks an increase.

More problems: Hearing Inside Rooms

- Direct sound - sound that reaches the listeners' ears straight from the source
- Indirect sound - sound that is reflected off of environmental surfaces and then to the listener
- When a listener is outside, most sound is direct; however inside a building, there is direct and indirect sound
- Poses a problem for sound localization



Reverberation

•Reverberations that occur in a room can **severely distort localization cues**.

•One strategy that listeners unconsciously employ to cope with this is to make their localization judgments instantly based on the **earliest arriving waves** in the onset of a sound.

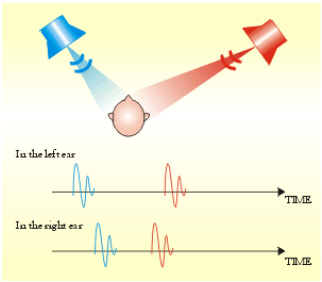
•This strategy is known as the **precedence effect**, because the earliest arriving sound wave (I.e., the direct sound with accurate localization information) is given precedence over the subsequent reflections and reverberation that convey inaccurate information.

•**Precedence effect** demonstration with two speakers reproducing the same sound.

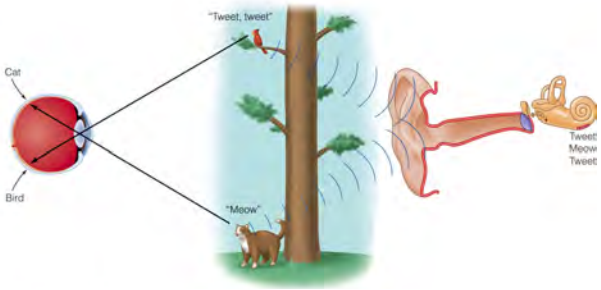
•The pulse from the left speaker leads in the left ear by a few hundred microseconds, suggesting that the source is on the left.

•The pulse from the right speaker leads in the right ear by a similar amount, which provides a contradictory localization cue.

•Because the listener is closer to the left speaker, the left pulse arrives sooner and wins the competition—the listener perceives just one single pulse coming from the left.



Auditory localization: The problem



- Even with all that - auditory localization is vastly **inferior** compared to vision

Hearing outline

- Localization of sounds
- Segmentation/grouping of sounds
- A few research examples
- Audition and vision

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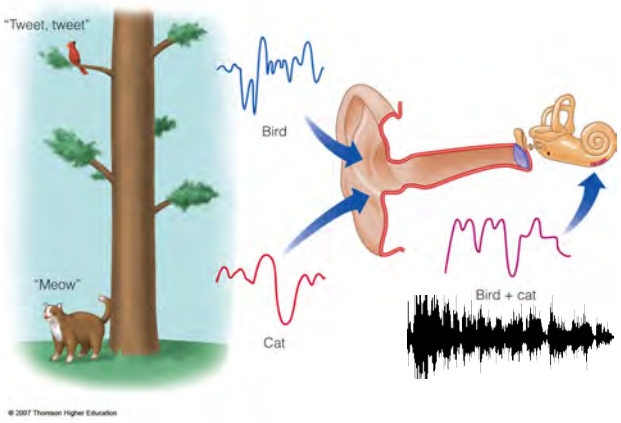
Auditory segmentation & grouping
The **WHAT** problem



Auditory segmentation & grouping
the "Cocktail Party Effect"

Segmentation based on **location**:
a single sound source tends to come from one location and to move continuously

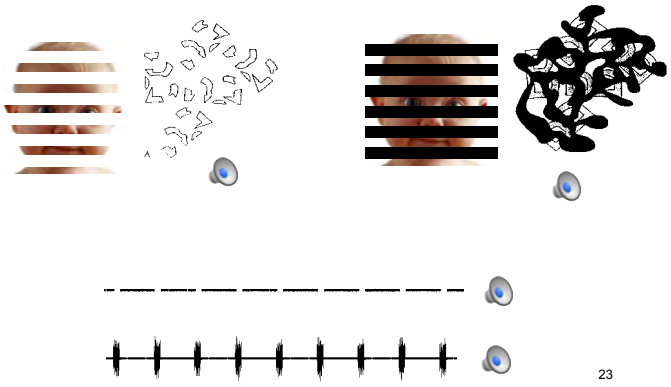
"same" "different"

Segmentation based on **timber & pitch:**
similar sounds are grouped together

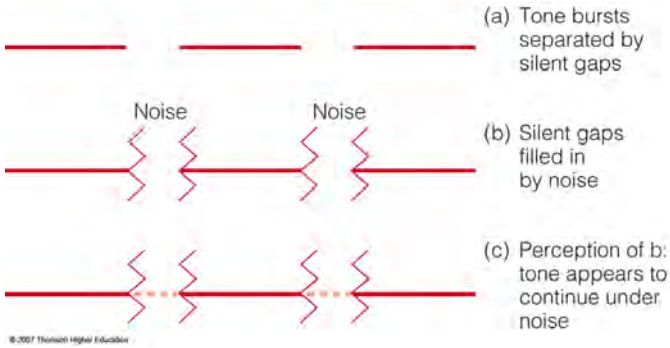
Auditory segmentation & grouping
location vs. pitch

- Experiment by Deutsch
  - Stimuli were two sequences (differing in pitch) alternating between the right and left ears
  - Listeners perceive two smooth sequences by grouping the sounds by similarity in pitch
  - This demonstrates the perceptual heuristic that sounds with the same frequency come from the same source, which is usually true in the environment

Auditory segmentation & grouping
filling in the gaps

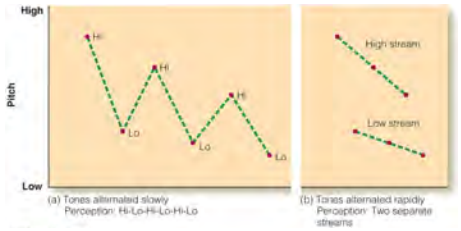


Auditory segmentation & grouping
filling in the gaps = good continuation



Auditory segmentation & grouping
temporal proximity

- Experiment by Bregman and Campbell
  - Stimuli were alternating high and low tones
  - When stimuli played **slowly**, the perception is hearing high and low tones alternating
  - When the stimuli are played **quickly**, the listener hears two streams; one high and one low



Auditory segmentation & grouping
effect of past experience

1 channel

2 channels

3 channels

4 channels

6 channels

8 channels

24 channels

song with 4 channels, then 8, 16, and 32 channels. Ends with the original song

Gershwin: Rhapsody in Blue

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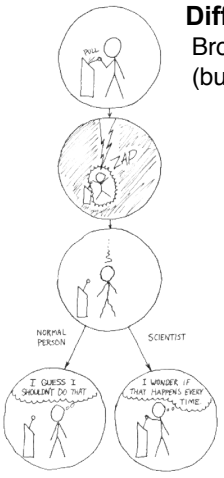
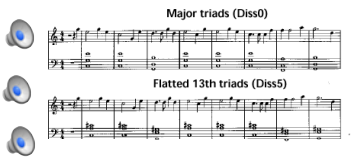
Different people hear different sounds

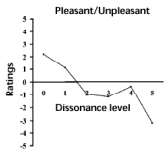
Wine grows on **v**ines
This **l**ed is **r**ed



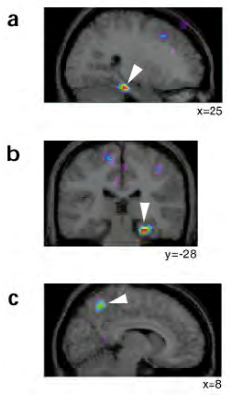
Difference between singing and talking
Broca's area is critical for speech production (but not for signing)

Musical Discordance
"Disturbs" the Brain





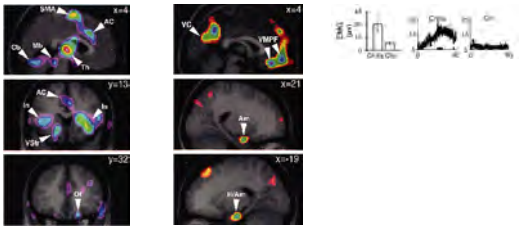
Emotional responses to pleasant and unpleasant music correlate with activity in paralimbic brain regions



Emotional Reactions to Music:
Do you ever get the chills?

Emotional Reactions to Music:
Do you ever get the chills?

Example of "chilling" music

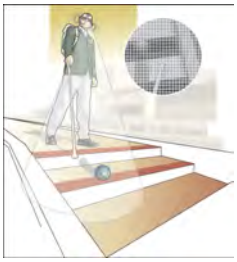


Cerebral blood flow variations were observed in brain regions thought to be involved in reward/motivation, emotion and arousal ….

These brain structures are known to be active in response to other euphoria-inducing stimuli such as food, sex and drugs of abuse.

This finding links music with biologically relevant, survival-related stimuli via their common recruitment of brain circuitry involved in pleasure and reward. (Blood and Zatorie, PNAS, 2001, vol. 98, 11818-11823)

Sensory substitution:
Turning sights into sounds



http://www.seeingwithsound.com/javoice.htm

- **vertical positions of points in a visual sound are represented by pitch.**
- **horizontal positions are represented by left-to-right scanning and corresponding stereo panning.**
- **brightness is represented by loudness.**
- **pixels become... voicels!**

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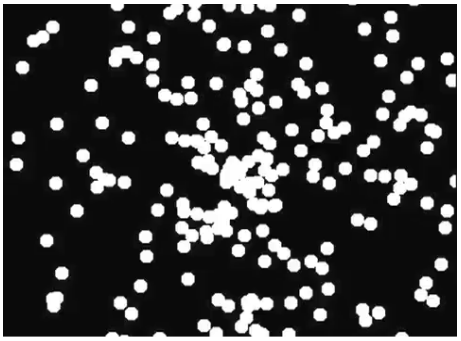
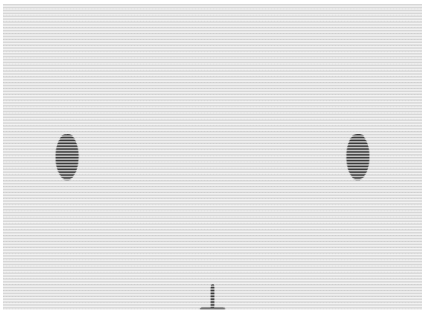
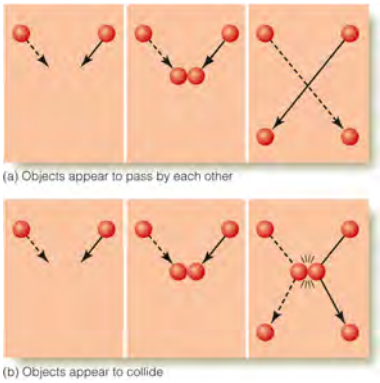
Auditory-Visual Interactions



Auditory-Visual Interactions



- Experiment by Sekuler et al.
  - –Balls moving without sound appeared to move past each other
  - –Balls with an added "click" appeared to collide



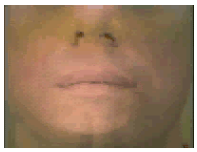
Two conditions in the Sekuler et al. (1999) experiment showing successive positions of two balls that were presented so they appeared to be moving.

(a) No sound condition: the two balls were perceived to pass each other and continue moving in a straight-line motion.

(b) Click added condition: observers were likely to see the balls as colliding.

Auditory-Visual Interactions

Vision can influence perception of auditory events (McGurk Effect demo)



Audition vs. Vision

Visual capture (the ventriloquist effect)

- an observer perceives the sound as coming from the seen location rather than the source for the sound

Conflict in space: Vision wins

Audition vs. Vision

http://www.cns.atr.jp/~kmtn/audiovisualRabbit/index.html

Conflict in time: Audition wins