Auditory Physiology
PSY 310
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Waves, waves, waves.

Organ of Corti

- Tectorial membrane
  - Sits on top
- Inner hair cells
- Outer hair cells
- The “microphone” for the brain
Hearing

- Perceptually, we hear sounds that differ in pitch and loudness
  - And several other qualities, as we'll discuss later
- What is the physiological response to these perceptual qualities?
- How are different aspects of sounds represented in the cochlea?
  - At least two possibilities
  - Different neurons code different properties of sound
  - Neural responses vary for different properties of sound

Frequency

- We can explore the responses to different frequencies of sound waves
  - Not the same thing as perceived pitch
- Georg von Bekesy (Nobel Prize in physiology and medicine in 1961)
  - Something similar also proposed by Helmholtz (1857)
- Place theory of hearing
  - The frequency of a sound is coded by the place on the organ of corti that responds to the sound best
**Cochlea**

- Pressure from the stapes pushes the fluid in the cochlea
- Causes membranes to vibrate

**Basilar membrane**

- The vibration differs, depending on the frequency of the sound
- Different places on the basilar membrane have the best vibration in response to sounds of different frequencies
- Like a traveling wave on a rope
Basilar membrane

- The differences are partly due to the mechanical structure of the basilar membrane
- Thickness of material and width of the membrane

Traveling wave

- Remember that there is constant push and pull by the stapes
- One can get a variety of interesting wave patterns
Traveling wave

- As the wave travels along, its amplitude changes

Displacement of basilar membrane

Maximum Displacement vs. position: envelope
Wave envelope

- The amplitude of the peak of the wave maps out the envelope of the wave

Frequency encoding

- The wave envelopes peak at different places for different frequencies of sounds
Frequency encoding

- So different frequencies give rise to peak responses at different places on the cochlea
- Neurons that respond to the hair cells at different places, represent different frequencies

Wave envelope shape

- The way waves travel and the properties of the basilar membrane makes the waves asymmetrical
Tuning curve

- Pick a place on the cochlea
- Measure the faintest sound that generates a small movement (dB)
- Vary the frequency of the sound
- The three curves are for three different cats (the numbers are dates)

Sound detection

- Pure tone sounds produce responses at different places in the cochlea

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Sound detection

- A sound that consists of more than one sine wave will produce separate responses at different places
  - Fourier analysis?

Suppose two sounds are presented together
- Target
- Noise
- The response on the basilar membrane is a mixture of the two sounds
- We can look at the discriminability of the tones and relate it to the properties of the cochlea
- Masking demonstration
  - Not all noise is created equal
  - Expect significant effect of noise only when its frequency range will interfere with detection of the tone (e.g., spread out the peak of the traveling wave)
Sound detection

- There are several ways to do this kind of experiment
- One way: present a target tone of a given amplitude and frequency (the number on the graph)
- Vary the frequency and amplitude of the mask
  - Adjust the amplitude to make the target tone not heard

A problem

- The cochlea is about 2.3 cm in length
- There are about 16,000 - 20,000 hair cells
- People resolve around 1,500 different pitches
  - E.g., the difference between 1000 Hz and 1003 Hz
- This would imply that different pitches are coded every 0.002 cm
- The wave envelope is not that precise
Tuning curves

- Here the animals (guinea pigs) are alive or dead
- The alive curve shows sharp tuning
- The dead curve shows broader tuning (less sensitivity)
- Something is different when the animal is alive that changes the properties of the basilar membrane

Organ of corti

- The outer hair cells apparently move (motile response) to change the way the basilar membrane vibrates
- This changes the peak of the wave envelope
Sharpening

- With the motile response, the location of the wave envelope is more precise.

Frequency tuning

- Not everything is determined by the place on the cochlea.
- Some neurons respond with bursts of activity at the same frequency as the stimulus:
  - Only for lower frequency stimuli
  - Neurons cannot change fast enough for high frequency sounds.

500 Hz stimulus:

Spikes:

2 msec

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Conclusions

- Waves on the basilar membrane are different for different sound frequencies
- Provides the basis for pitch perception
  - Different neurons respond to different frequencies
- Very complicated
- Lots of other neural processing that we have discussed

Next time

- Using sound to understand the environment
- Auditory localization