Waves, waves, waves.

Auditory Physiology
PSY 310
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Lecture 30

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

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

Another view of a traveling wave.

As the wave travels along, its amplitude changes.

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

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 make 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 cells (the numbers are dates).

**Sound detection**

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

**Sound detection**

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

**Sound detection**

- 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

An issue

- 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

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PSY 310: Sensory and Perceptual Processes
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