Picture Memory and Change Blindness

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What do you actually see?

Dan Simon experiment: In the midst...
Hearing: Physiology and Psychoacoustics

- The Function of Hearing
- What Is Sound?
- Basic Structure of the Mammalian Auditory System
- Basic Operating Characteristics of the Auditory System
- Intensity and Loudness
- Hearing Loss

Hearing is a specialized form of mechanoreception

- Hearing is the detection and analysis of vibrations transmitted to the ear as pressure waves in a medium such as air.

- Hearing allows us to localize, identify, and analyze sources of vibrations that originate at points far from or bodies.
Acoustics of Sound

• What is sound?
  – Physically
    • sound is a form of dynamic pressure disturbance transmitted in a medium that has mass and elasticity
  – Auditorally
    • sound is the sensation of the dynamic pressure disturbance in the auditory system (ear)
Basic qualities of sound waves

- **Amplitude**: Magnitude of displacement of a sound pressure wave
- **Intensity**: Amount of sound energy falling on a unit area
- **Frequency**: For sound, the number of times per second that a pattern of pressure change repeats
- **Loudness**: The psychological aspect of sound related to perceived intensity or magnitude

Sound waves are (literally) waves

The sinusoidal vibration of the speaker diaphragm results in a sinusoidal change in the air pressure, as shown in the figure.
Properties of a sine wave

- Frequency: Cycles per second, or Hertz (Hz).
- Amplitude: decibels (dB)

\[ T = \frac{1}{f} \] (frequency)

\[ C = \lambda \times f \] (speed of sound 340 m/sec)

(wavelength in meters) (frequency in cycles per second)

Equal loudness contours (red) (from ISO 226:2003 revision)
Original ISO standard shown (blue) for 40-phon
Human hearing uses a limited range of electromagnetic energy: From about 20 to 20,000 Hz.
The information that reaches the ear does not separate sounds from different sources.

- When sounds originate from multiple sources, the individual waveforms combine so that a single complex waveform reaches the ear.
Spreading of sound from an omnidirectional source

- The pattern of condensation and rarefaction is propagated away from the vibrating source much like ripples in water.
- Sound intensity progressively decreases with distance from the source.

Sound is modified by objects in the environment

- Reflection (echoes) from objects of different sizes
- Transmission
- Absorption
Characterizing simple and complex sounds

- The frequency composition of a sound is called its *spectrum*.

- A *pure tone* contains only one frequency (sine wave).

- Frequencies in a sound that are integer multiples of some *fundamental frequency* are called *harmonics*.

Complex Sounds
How do we analyze complex waveforms?

- **Simple sounds**
  - Sine waves are simple harmonic motion; pure tone
- **Complex sounds**
  - Need Fourier analysis and Fourier synthesis

**Fourier Analysis and Synthesis**

- **Fourier transformation**
  - Allows a complex sound wave to be decomposed into constituent sinusoidal frequencies, each an integer multiple of the original’s (fundamental) frequency
  - Fundamental frequency (or first harmonic) determines the pitch of a complex sound
Harmonics:
Fourier components of a complex tone are multiples of the fundamental frequency

- Two pure tones whose frequencies are multiples of each other blend into one in our perception, producing a single tone at the fundamental (the lower) frequency (e.g., a 400 Hz tone and a 500 Hz tone would have a fundamental of 100 Hz)
Harmonics: Components of Complex Sound
Harmonics (contd.)

- Musical instruments hardly ever produce pure tones.
  - Instead, when you pluck a string on a guitar, it will produce a vibration at some fundamental frequency as well as several multiples (called harmonics).

- Our perception of timbre is related to the harmonic composition of a tone.

- This is also the basis of *a capella* singing.