Shepard auditory illusion

FizziQ activity · High school · 30 min

Scan to open in FizziQ

High school students decode the Shepard tone with FizziQ's spectrum analyzer and frequency meter on a smartphone, revealing octave-spaced sinusoids behind the rise.

Learning objectives

- Listen to and experience the Shepard tone illusion of endlessly rising pitch
- Use spectral analysis to identify the multiple frequency components of the Shepard tone
- Observe that the components are spaced exactly one octave apart
- Understand the amplitude modulation that creates the illusion of infinite ascent
- Connect the acoustic analysis to the principles of auditory perception and psychoacoustics

Instruments and sensors

Sound spectrum analyzer · Frequency meter · Microphone

Materials

- Smartphone with the FizziQ application
- 'Shepard' recording from the FizziQ sound library
- Headphones (recommended) for better perception
- FizziQ experiment notebook to record spectral data
- Note: the protocol remains adaptable to any comparable spectral analysis tool.

Protocol

1. Open FizziQ and load the 'Shepard' recording from the sound library. Put on headphones for the best perceptual experience.
2. Listen to the recording without looking at any analysis tools. Note your impression: does the sound appear to rise continuously in pitch?
3. Now open the Spectrum Analyzer (FFT) in FizziQ and replay the recording.
4. Observe the spectrum. You should see several peaks at different frequencies, not just one.
5. Identify the frequencies of the peaks. Verify that they are separated by approximately octave intervals (each is roughly double the previous one).
6. Watch how the peaks evolve over time as the tone appears to rise. Note that high-frequency peaks fade out while new low-frequency peaks fade in.
7. Use the Frequency Meter to track the apparent fundamental frequency over time. Does it truly increase indefinitely?
8. Pause the recording at several moments and record the frequencies and amplitudes of all visible spectral peaks.
9. Create a table showing the evolution of each frequency component over time.
10. Verify that each component rises in frequency while its amplitude follows a bell-shaped envelope: growing from silence, reaching maximum intensity, then fading out.
11. Sketch or describe the amplitude envelope shape that makes the illusion work.
12. Discuss: why does the brain perceive a continuous rise when the spectrum is actually recycling frequencies?

Expected results

The spectrum should reveal 4-8 simultaneous sine wave components spaced one octave apart (frequency ratios of 2:1). At any given moment, the middle components are loudest while the highest and lowest are near silence. As time progresses, all components shift upward in frequency, but when a high component reaches the upper amplitude cutoff, a new low component emerges from silence at the bottom. The frequency meter may show a steadily increasing value (tracking the dominant component) or may jump unpredictably as different components alternately dominate. The key observation is that despite the impression of infinite ascent, the frequency range of the entire signal remains bounded within approximately 2-3 octaves.

Questions

- Why does the brain perceive a single rising tone rather than multiple separate frequencies?
- What role does the amplitude envelope play in creating the illusion?
- How is the Shepard tone similar to the visual illusion of the Penrose staircase?
- Could you create a descending Shepard tone? What would need to change?
- How has the Shepard tone been used in film and music to create emotional effects?
- What does this illusion tell us about how the auditory system processes pitch?

Going further

- Create your own Shepard tone using FizziQ's synthesizer by superimposing several sine waves at octave intervals
- Compare the Shepard tone with a simple rising sine wave and analyze how the brain interprets each differently
- Investigate the Shepard-Risset glissando (continuous version) versus the discrete Shepard scale
- Test whether the illusion is equally strong for all listeners by surveying classmates
- Explore other auditory illusions available online and analyze their spectral structure with FizziQ