Timbre and harmonics

FizziQ activity · Middle school · 30 min

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Why do a flute, guitar and piano sound different on one note? Students compare spectra with FizziQ's analyzer on smartphone or tablet and link timbre to harmonics.

Learning objectives

- Compare the frequency spectra of different instruments playing the same note using FizziQ
- Identify the fundamental frequency and harmonics in each spectrum
- Observe how the number and relative amplitudes of harmonics differ between instruments
- Understand that timbre is determined by harmonic content, not fundamental frequency
- Compare a pure synthesized tone with real instrument tones to understand spectral richness

Instruments and sensors

Sound spectrum analyzer (FFT) · Synthesizer · Microphone

Materials

- Smartphone or tablet with FizziQ installed (spectrum analyzer and synthesizer)
- Sound library recordings of flute, guitar and piano playing the same note (built into FizziQ)
- Note: the protocol remains adaptable to any comparable spectral analysis tool.

Protocol

1. Open the app Synthesizer and generate a pure 880 Hz tone (A5). Open the Spectrum Analyzer and observe: there should be a single peak at 880 Hz.
2. Record or sketch this spectrum. This is the reference: a pure tone with no harmonics.
3. Load the flute recording playing A5 (880 Hz) from the Sound Library. Analyze its spectrum.
4. Count the number of visible harmonic peaks and note their relative amplitudes. The flute should show few harmonics (2-4 visible peaks).
5. Load the guitar recording playing the same note. Analyze its spectrum.
6. The guitar should show many more harmonics (6-10 visible peaks), with the amplitudes decreasing more gradually.
7. Load the piano recording playing the same note. Analyze its spectrum.
8. The piano typically shows a rich harmonic series with a distinctive amplitude pattern.
9. Create a comparison table: for each instrument, list the amplitude (relative to the fundamental) of harmonics 1 through 8.
10. Listen to all four sounds (pure tone, flute, guitar, piano) in sequence. Can you now connect the spectral differences with the perceived timbre differences?
11. Plot a bar chart of harmonic amplitudes for each instrument to visually compare their spectral signatures.
12. Discuss: what physical properties of each instrument (string, air column, hammer, bow) determine its harmonic pattern?

Expected results

The pure synthesizer tone should show a single peak at 880 Hz with no other frequency components. The flute typically shows 2-4 harmonics, with the fundamental dominant and upper harmonics rapidly decreasing in amplitude. The guitar shows 6-10 harmonics with a more gradual roll-off and possibly enhanced mid-range

harmonics. The piano shows a complex harmonic pattern that depends on the specific register and dynamic level. All instruments should share the same fundamental frequency (880 Hz ± 2 Hz) but differ dramatically in their harmonic content. Students should observe a clear correlation between the number and strength of harmonics and the perceived richness or brightness of the sound.

Questions

- Why does a flute sound hollow compared to a violin? What spectral feature explains this?
- What physical properties of a vibrating string determine which harmonics are strongest?
- How does the point where a guitar string is plucked affect the harmonic content?
- Why does a pure synthesized tone sound artificial compared to real instruments?
- What role does the temporal evolution (attack, sustain, decay) play in timbre perception beyond the spectrum?
- Could you identify an instrument from its spectrum alone, without hearing it?

Going further

- Compare the timbre of the same instrument playing at different dynamic levels (soft versus loud)
- Analyze how the spectrum of a guitar changes depending on whether the string is plucked near the bridge or near the neck
- Record and compare your voice singing a vowel with an instrument playing the same note
- Investigate how a mute changes the timbre of a brass instrument by comparing spectra with and without the mute
- Create a synthetic tone with FizziQ by adding harmonics one by one until it sounds like a real instrument