Spectrum of sung vowels

FizziQ activity · Middle school · 30 min

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Sing vowels into the FizziQ spectrum analyzer and compare their harmonic peaks: formants show how mouth cavities filter the voice. Smartphone app, middle school.

Learning objectives

- Analyze the frequency spectra of different sung vowels using FizziQ
- Identify formant frequencies as bands of enhanced harmonic amplitude
- Compare the spectral signatures of vowels like 'i', 'e', 'a', 'o', 'u'
- Understand that the vocal cords produce the harmonics while the mouth cavities shape the formant pattern
- Connect acoustic physics with articulatory phonetics and speech science

Instruments and sensors

Sound spectrum analyzer (FFT) · Microphone

Materials

- Smartphone or tablet with the FizziQ app (Spectrum Analyzer / FFT tool)
- A quiet environment for voice recordings
- Note: the protocol remains adaptable to any comparable spectral analysis tool.

Protocol

1. Open the app and select the Spectrum Analyzer (FFT) tool.
2. In a quiet environment, sing the vowel 'a' (as in 'father') at a comfortable, steady pitch. Hold the note for at least 3 seconds.
3. Observe the spectrum. You should see a series of harmonic peaks with certain frequency regions showing higher amplitudes (formants).
4. Record the frequencies of the two or three strongest spectral regions (formant frequencies).
5. Now sing the vowel 'i' (as in 'see') at the same pitch. Observe how the spectral envelope changes dramatically.
6. Record the formant frequencies for 'i'. Note that the formants are spaced differently from 'a'.
7. Repeat for vowels 'e' (as in 'say'), 'o' (as in 'go'), and 'u' (as in 'you').
8. Create a comparison table with the first two formant frequencies (F1 and F2) for each vowel.
9. Note the pattern: for 'i', F2 is very high (>2000 Hz); for 'u' and 'o', F2 is low (<1000 Hz); for 'a', F1 is high (>700 Hz).
10. Sing the same vowel at different pitches and verify that the formant frequencies remain approximately the same (they depend on mouth shape, not vocal cord frequency).
11. Try whispering the vowels (no vocal cord vibration) and observe that the formant structure is still visible as broad noise bands.
12. Discuss: how does the shape of the mouth cavity determine the formant frequencies for each vowel?

Expected results

Each vowel should show a distinct formant pattern. Typical formant frequencies for an adult male voice are: 'i' (F1 ≈ 270 Hz, F2 ≈ 2300 Hz), 'e' (F1 ≈ 400 Hz, F2 ≈ 2000 Hz), 'a' (F1 ≈ 730 Hz, F2 ≈ 1100 Hz), 'o' (F1 ≈ 570 Hz, F2 ≈ 840 Hz), 'u' (F1 ≈ 300 Hz, F2 ≈ 870 Hz). Female voices show higher formant frequencies (shifted up by about 15-20%). The key observation is that while the individual harmonics shift when singing at different pitches, the formant envelope (the spectral regions that are enhanced) remains approximately constant for each vowel, proving that formants depend on mouth shape rather than vocal cord frequency.

Questions

- Why do the formant frequencies remain the same when you sing the same vowel at different pitches?
- What physical property of the mouth cavity determines the first formant frequency?
- How do the vocal cords produce harmonics? Why are there many harmonics rather than a single frequency?
- Why does whispering still allow vowels to be distinguished even without vocal cord vibration?
- How does speech recognition technology use formant analysis to identify spoken vowels?
- Why do different languages have different numbers of vowel sounds?

Going further

- Compare the formant patterns of vowels spoken by male and female voices and quantify the frequency shift
- Analyze the vowels of a foreign language and compare with your native language
- Investigate how nasal vowels differ from oral vowels in their spectral signature
- Record the same vowel with different mouth openings (wide versus narrow) and observe how F1 changes
- Use the analysis to build a simple vowel recognition system based on F1 and F2 values