Maximum Acceptable Vibrato Excursion as a Function of Vibrato Rate in Musicians and Non-musicians

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This study was concerned with the way in which the maximum acceptable vibrato excursion varies as a function of vibrato rate in normal-hearing (NH) musicians and non-musicians.

## Background and aim of the study

Sound produced by the human voice is rich in frequency variations which convey important cues for speech intelligibility, sound segregation and the valence of sound sources [1,2]. This study focused on the frequency variations that occur in the vocal vibrato of human singing voices. Vocal vibrato is physically described as coherent fluctuations imposed on the harmonics of sounds produced by the human voice. It is mainly characterized by two parameters: vibrato excursion and vibrato rate [3].

These parameters have been found to exhibit an interaction both in physical recordings of singers' voices [4] and in listeners' preference ratings [5].

## Methods

### Stimulus configuration

- **Harmonic complex tone with first 7 harmonics of vowel /oh/.
- **Coherent fluctuations applied by adding the same frequency shift (cents) to all components:
  \[
  \text{cent} = \frac{m \cdot f_0}{10000} \quad \text{for} \quad m = 1, 2, 3, \ldots \text{and} \quad f_0 = 440 \text{Hz}.
  \]
- **Shimmer and jitter added for better simulation of natural vocal vibrato.
- **Three temporal segments: "old vowel/decay," "new vowel/attack," and vibrato. Adding coherent fluctuations leads to the fusion of all components into a singing voice.

### Procedure

- **One-interval, two-alternative, forced-choice "null/tau" task.
- **The 50% point of the psychometric function was derived by means of a 1-up-1-down algorithm.
- **Six reference values of vibrato rate: 3, 4, 5, 6, 7, and 8 Hz.
- **The starting value for the excursion was 200 cents.

For each presentation of the stimulus, the listeners were requested to give a "null/tau" reply to the question "Can this sound be linked to a singing voice?"

### Spectrogram of the basic stimulus, showing its three temporal segments.

- **Two alternatives: at 440 Hz, 2) at eight harmonics of the "sawtooth," and 3) fluctuations (vibrato) imposed on the vowel. In the last segment, the doubling of the excursion for every harmonic can be seen (lower frequency axis). The colors indicate the normalized magnitudes of the frequency components in dB.

### Comparison with physical recordings

- **Figure 3: Spectrogram of the basic stimulus, showing its three temporal segments.
- **Figure 4: Vocal Excursion as a Function of Centre for Applied Hearing Research.
- **Figure 5: Vocal Excursion as a Function of.
- **Figure 6: Vocal Excursion as a Function of.

### Discussion

- **Comparison with physical recordings:
  - The grey area indicates the measurements from a number of soprano voices presented in [2]. A range of about 100 cents can be observed at 5.5 Hz between the maximum and minimum excursion produced by singers.
  - Thresholds exhibit a peak as a function of rate, but at a rate which did not always correspond to the 5.5-Hz peak of the recordings.
  - There may be a listener-dependent rate range (5-7 Hz) within which larger vibrato excursions are favoured.

### Conclusion

- **No significant effect of musical experience or rate was found. However, the individual thresholds were found to vary across rate, indicating that most listeners' perceptions is not solely defined by the amount of vibrato excursion.
- **Large across-subject variability was observed, which may be explained by the large spread of vibrato excursion found in physical recordings and thus the differences in musical preference of the listeners.

- **Most of the listeners' thresholds exhibited a peak at medium vibrato rates. These rates did not consistently correspond to the 5.5-Hz peak measured in recordings, but suggested that there is a listener-dependent rate for which larger excursions are favored.
- **Further work will investigate modifications in real recordings and also whether the objective is more objective measures for quantifying the sensitivity to frequency changes. This would be relevant when studying auditory deficits experienced by elderly as well as hearing-impaired listeners.

## Results

- **Thresholds were found to range from 20 to 180 cents for the musi-
- **The starting value for the excursion was 200 cents.
- **For each presentation of the stimulus, the listeners were requested to give a "null/tau" reply to the question "Can this sound be linked to a singing voice?"
- **Six measures, step sizes of 14 and 4 cents.
- **Thresholds exhibit a peak as a function of rate, but at a rate which did not always correspond to the 5.5-Hz peak of the recordings.

- **The 50% point of the psychometric function was derived by means of a 1-up-1-down algorithm.
- **Six reference values of vibrato rate: 3, 4, 5, 6, 7, and 8 Hz.

## References


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