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 salience of sound sources [1]. 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. These parameters have been found to exhibit an interaction both in physical recordings of singers’ voices [2] and in listener’s preference ratings [3].

Methods

Stimulus configuration

- Harmonic complex tone with first six harmonics of vowel /o/.
- Coherent fluctuations applied by adding the same frequency shift (cents) to all components:
  \[
  \text{vibration rate (Hz)} = \frac{1}{\text{duration (s)}} \times \sum_{k=2}^{6} \frac{\text{amplitude}_k}{\text{fundamental}_k} \times \sin(k \times \text{frequency})
  \]
  \(k\) harmonic number, \(\text{amplitude}_k\) harmonic amplitude, \(\text{fundamental}_k\) fundamental frequency of the vowel /o/.

- Shimmer and jitter added for better simulation of natural vocal vibrato.

- Three temporal segments:
  - "Old mode/vibrato" and vibrato.
  - Adding coherent fluctuations leads to the fusion of all components into a singing voice.

Presentation level

- Stimuli presented digitally at a moderate sound level.
- Component levels in Hz with the fundamental component (4000 Hz) set at 70 dB SPL.

Results

- The thresholds were found to range from 20 to 180 cents for the musicians, while this range was from 33 to 130 cents for the non-musicians.
- In all subjects, the adaptive procedure converged to a threshold for vibrato rates of 4-7 Hz. However, 2 musicians and 4 non-musicians obtained thresholds for the 3-Hz rate, and 5 musicians and 4 non-musicians for the 0.6-Hz rate, the other listeners never judging the vibrato for appropriate for these rates.
- A two-way ANOVA showed no significant effect of musical education or vibrato rate on the thresholds.
- From the individual thresholds, it can be seen that even though all four listeners exhibited a peak in preferred excursion at the medium vibrato rates (5.7-11 Hz).

Discussion

Comparison with physical recordings

- The grey axes indicate the measurements from a number of soprano voices presented in [4]. A range of about 100 cents can be observed at 5.5 Hz between the minimum and maximum 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 favored.

Potential explanations for the non-significant effect of vibrato rate

- Thresholds at rates of 3 and 0.6 Hz were derived for only part of the listeners, consistent with the fact that very low and very high values of vibrato excursion are shown in the literature not to be preferred by listeners [5].

- Additionally, the individual excursion maxima were located at different rates for the different listeners (5-7 Hz).

Conclusion

- No significant effect of musical experience or rates 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 might be explained by the large spread of vibrato excursion found in physical recordings and that 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 on real recordings and also ask for 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.

Research questions

1. Does the maximum acceptable excursion vary across vibrato rate?
2. If so, how does this interaction between vibrato rate and excursion compare with the musical and voice vibrato excursions produced by singers?
3. Does musical training affect the preference of the listeners?