Frequency-Modulation Vowel Maps in Normal-Hearing and Hearing-Impaired Listeners

Santurette, Sébastien; Vatti, Marianna; Pontoppidan, Niels Henrik; Dau, Torsten

Publication date: 2013

Citation (APA):
INTRODUCTION
Sound emitted by most natural vibrating sources is not steady in pitch but contains frequency fluctuations over time during which the harmonicity of the frequency spectrum changes. This phenomenon is known as vibrato and is produced by vocal fold oscillation, which causes variations in the fundamental frequency (F0) of a singing voice. Such frequency fluctuations are perceived as a characteristic of vocal performance, and they are crucial for the perception of musicality and intonation quality. However, the perception of vibrato is not straightforward and can be influenced by various factors, such as the characteristics of the auditory system, the listener's musical training, and the specific context of the auditory environment.

RESEARCH QUESTIONS
- What is the nature of the vowel map in HI listeners along the FM-rate and FM-excitation dimensions?
- Is such a map affected by hearing impairment, and if so, along which dimensions?

METHODS
Stimulus configuration
- Harmonic complex tone with first 8 harmonics of vowel /oh/
- CFM applied by adding the same frequency shift M (cents) to all N components:

\[ \text{Harmonic complex tone with first 8 harmonics of vowel } /\text{oh}/ \]

- In the third segment, the added harmonics from the added harmonics.

- Three temporal segments with "old+new" conditions (Bregman and Ahmad, 1986) such that adding CFM leads to the fusion of all components into a singing voice.

Procedure
- Tracking of the "sweet spot" area for which a singing voice emerges in the third segment stimulus as a function of FM rate and FM excursion (Fig. 2).
- One FM parameter was kept constant while the other was adjusted in a 1-interval 2-ARC yes-no task with a 1-up 1-down paradigm.

RESULTS
- Effects of hearing impairment and musical experience
  - Broader sweet spot in HI listeners, shifting towards higher FM excursions and lower FM rates compared to NH listeners (Figs. 4, 5).
  - 2-way ANOVA on mean FM rates and square-root transformed mean FM excursions for each boundary, with hearing loss and musical experience as factors (Fig. 5).
  - Significant effect of musical experience for lower FM boundary excursions.
  - No correlation of mean FM-parameter thresholds with HF-HL or ERB for any boundary.
  - Correlation of threshold with LF-HL for lower FM boundary excursion only (p < 0.05).

- Large individual differences (Fig. 4) not explained by audibility or frequency selectivity at F0.

CONCLUSIONS
- In HI listeners, adding CFM to an unmodulated complex tone was sufficient to evoke the perception of vibrato for FM rates between 4 and 7.5 Hz and FM excursions between 17 and 83 cents on average.
- These values may provide some guidelines when constructing synthetic-sound stimuli for a realistic singing voice.
- Threshold was found to be the perception of a sung voice based on FM-rate and FM-excitation cues.
- Further work is needed to clarify the role of stimulus and FM-excitation or FM-rate and FM-excitation cues.
- Further work is needed to clarify the role of stimulus and FM-excitation or FM-rate and FM-excitation cues.

REFERENCES