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

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FREQUENCY-MODULATION VOWEL MAPS IN NORMAL-HEARING AND HEARING-IMPAIRED LISTENERS

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INTRODUCTION
Sound emitted by most natural vibrating sources is not steady in pitch but contains frequency fluctuations over time during which the harmony of the frequency components is typically preserved, as for instance in the vibrato of human singing voices (e.g., McAdams, 1984; Maher and Beauchamp, 1990). This coherent frequency modulation (CFM) has been shown to enhance the subjective fusion of the sound's frequency components (Sundberg, 1994), with implications for the ability of listeners to recognize and segregate vowel sounds (e.g., McAdams, 1984; McAdams, 1984; Maher and Beauchamp, 1990). There is compelling evidence that sensorineural hearing impairment is in, addition to a loss of sensitivity, often accompanied by a deterioration of frequency discrimination and of the ability to detect frequency changes over time, as reflected by elevated frequency-modulation discrimination limens (FMDLs), with implications for the ability of listeners to perceive a sung vowel based on the addition of CFM to a steady tone, compared to a group of normal-hearing (NH) listeners. This was achieved by obtaining "vowel maps" in the two groups as a function of the two primary acoustic parameters of vocal vibrato: FM rate and FM excursion.

RESEARCH QUESTIONS
- What is the extent of the vowel map in NH listeners along the FM-rate and FM-excursion 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: $A_n \cos(2\pi f t + \varphi_n) + \Delta A \cos(2\pi f t + \varphi_n + \Delta \varphi) = \sum_{n=1}^{N} A_n \cos(2\pi f t + \varphi_n) + \Delta A \cos(2\pi f t + \varphi_n + \Delta \varphi) = \sum_{n=1}^{N} A_n \cos(2\pi f t + \varphi_n)$ (k: harmonic number; fM: FM rate; AM: harmonic amplitude; fV: harmonic frequency)
- Simmer and Jäger added for better simulation of natural vocal vibrato
- Three temporal segments with "old+new heuristic" (Bregman and Ahad, 1996) such that adding CFM leads to the fusion of all components into a singing voice [Fig. 1]

Procedure
- Tracking of the "sweet spot" area for which a singing voice emerges in the third stimulus segment as a function of FM rate and FM excursion [Fig. 2]
- One CFM parameter was kept constant while the other was adjusted in a 1-interval, 2-AFC yes-no task with a 1-up/1-down paradigm
- Thresholds were approached from outside the sweet spot (unnatural vibrato) at FM rates of (3, 4, 5, 6, 7, 8) Hz and FM excursions of [21, 35, 49, 63, 77, 91] cents
- 6 reversals, step sizes of [5.0, 15.4] Hz (FM rate) and [14.0, 16.0] cents (FM excursion)
- 3 repetitions per subject for each of the 24 conditions

RESULTS
- Mean and standard error threshold data are given for each condition
- Significant effect of musical training on peak excursions
- Highly significant difference in sweet-spot area between NH and HI listeners
- Significant effect of musical experience on FM-rate threshold for HI listeners
- Correlation of mean thresholds with LF-HL for lower FM excursion boundary only
- Potential explanations for individual differences in the sweet-spot area

CONCLUSIONS
- In NH listeners, adding CFM to an unmodulated complex tone was sufficient to enhance the perception of a sung vowel 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 which a realistic sung vibra is desired
- Further work is needed to clarify the role of deficits in detection or discrimination of CFM parameters, e.g., frequency selectivity and the ability to follow the rate of frequency changes, for the perception of vocal vibrato and vowel quality in HI listeners

REFERENCES