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1pPP9 — Effects of harmonic roving on pitch discrimination

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Introduction

Performance in pitch discrimination tasks is limited by variability intrinsic to listeners which may arise from peripheral auditory coding limitations or more central noise sources. Perceptual limitations may be characterized by measuring an observer's change in performance when introducing external noise in the physical stimulus (Lu and Dosher, 2008). The present study used this approach to attempt to quantify the "internal noise" involved in pitch coding of harmonic complex tones by estimating the amount of harmonic roving required to impair pitch discrimination performance. It remains a matter of debate whether pitch perception of natural complex sounds mostly relies on either spectral excitation-based information or temporal periodicity information. Comparing the way internal noise affects the internal representations of such information to how it affects pitch discrimination performance may help clarify pitch coding mechanisms. As training on frequency discrimination tasks has been found to result in a reduction of internal noise (Jones *et al.*, 2013), it was also investigated whether the effect of harmonic roving varied with musical training.

Research questions:

- How much harmonic roving is necessary to impair pitch discrimination performance? (Experiment 1)
- Does musical training affect how performance varies with roving? (Experiments 1-2)
- Is the effect of roving the same in low vs. high spectral regions, where different pitch coding mechanisms and different types of internal noise limitations may occur (Oxenham and Micheyl, 2013)? (Experiments 2-3)

Methods

- Fundamental-frequency difference limens (F0DLs) with alternative forced-choice (AFC) task: "Choose the interval with the higher pitch."
- Bandpass-filtered resolved or unresolved complex tones embedded in threshold-equalizing noise with roving of components on an interval-by-interval basis

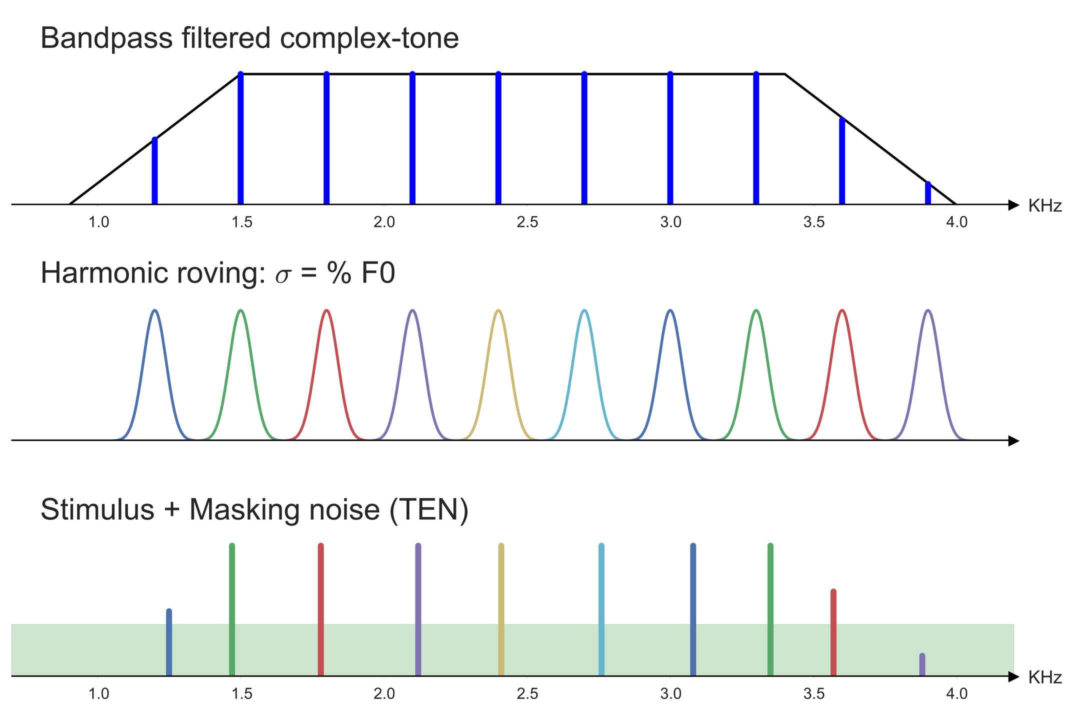

Fig.1 Simplified illustration of stimulus roving. The amount of roving is determined by the standard deviation of a Gaussian distribution centered on each harmonic frequency, varied between 0% and 16% of the tested F0 (*i.e.*, same standard deviation in Hz applied to all harmonics).

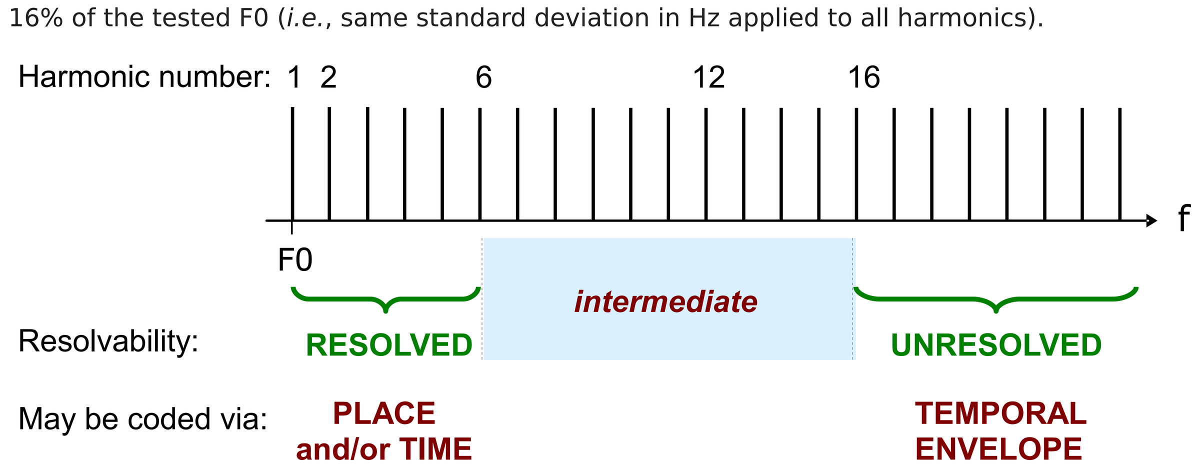

Fig.2 Harmonic resolvability and available cues for pitch extraction as a function of harmonic number.

1: Musicianship/Resolvability

Methods:

F0DLs as a function of harmonic roving:

- 13 normal-hearing listeners (7 musicians and 6 non-musicians)
- 3-AFC task, weighted up-down tracking rule (75%)
- Complex tones bandpass-filtered between 1.5 and 3.5 kHz
- Resolved condition: F0=300 Hz (audible harmonics 5-13)
- Unresolved condition: F0=75 Hz (audible harmonics 17-55)

Results:

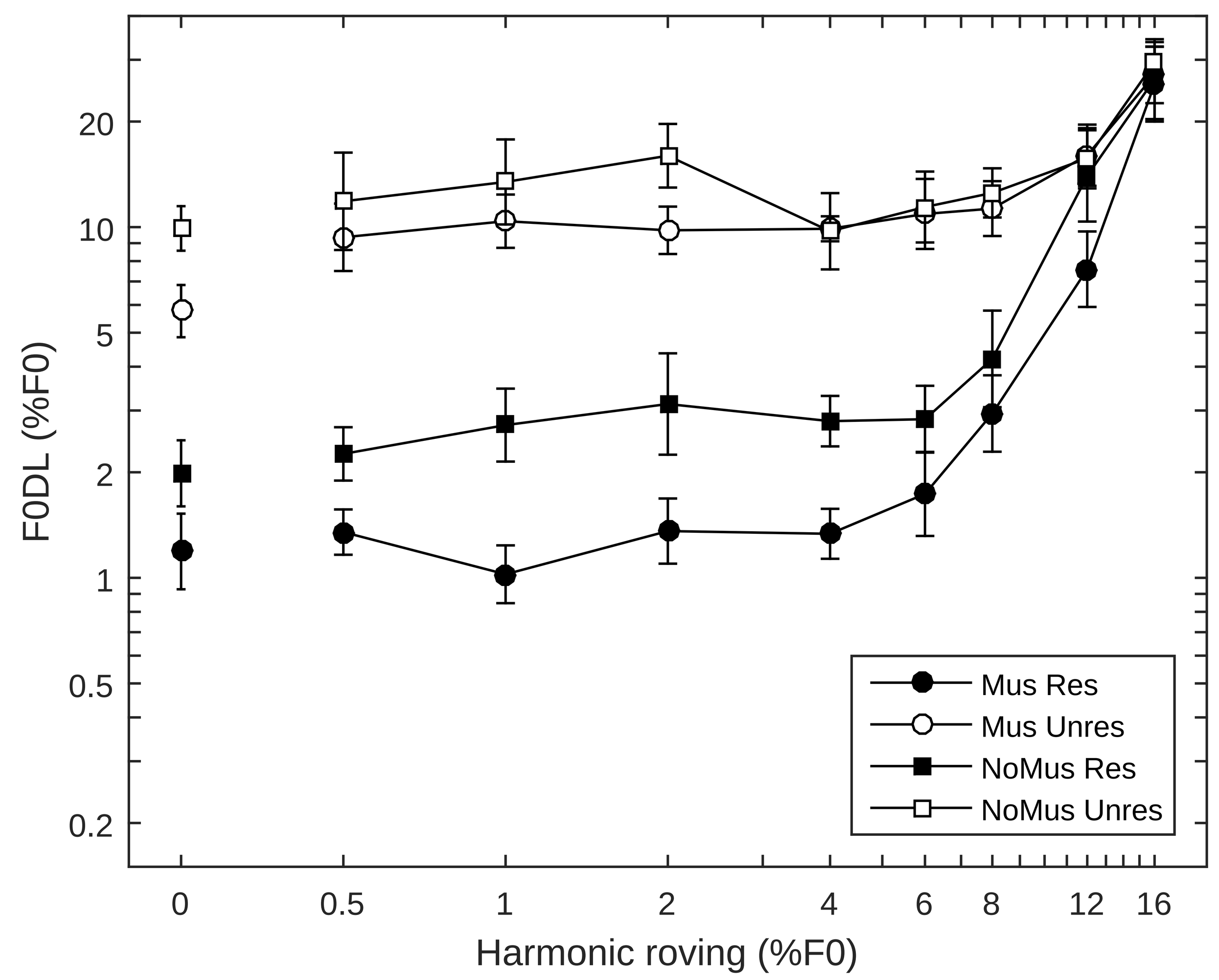

Fig.3 Mean F0DLs as a function of harmonic roving (in %F0) over 7 musicians (Mus, circles) and 6 non-musicians (NoMus, squares), for complex tones bandpass-filtered between 1.5 to 3.5 kHz containing resolved harmonics (Res, black symbols) or only unresolved harmonics (Unres, white symbols). Error bars depict the standard error of the mean.

2: Spectral region/Resolvability

Methods:

F0DLs as a function of harmonic roving:

- 4 normal-hearing listeners, all 8+ years of formal musical training
- 2-AFC task, weighted up-down tracking rule (75%)
- Spectral region 1.5-3.5 kHz (LF) or 7.5-17.5 kHz (HF)
- Resolved condition: F0=300 Hz (LF) or 1500 Hz (HF) (harm. 5-13)
- Unresolved condition: F0=75 Hz (LF) or 375 Hz (HF) (harm. 17-55)

Preliminary results:

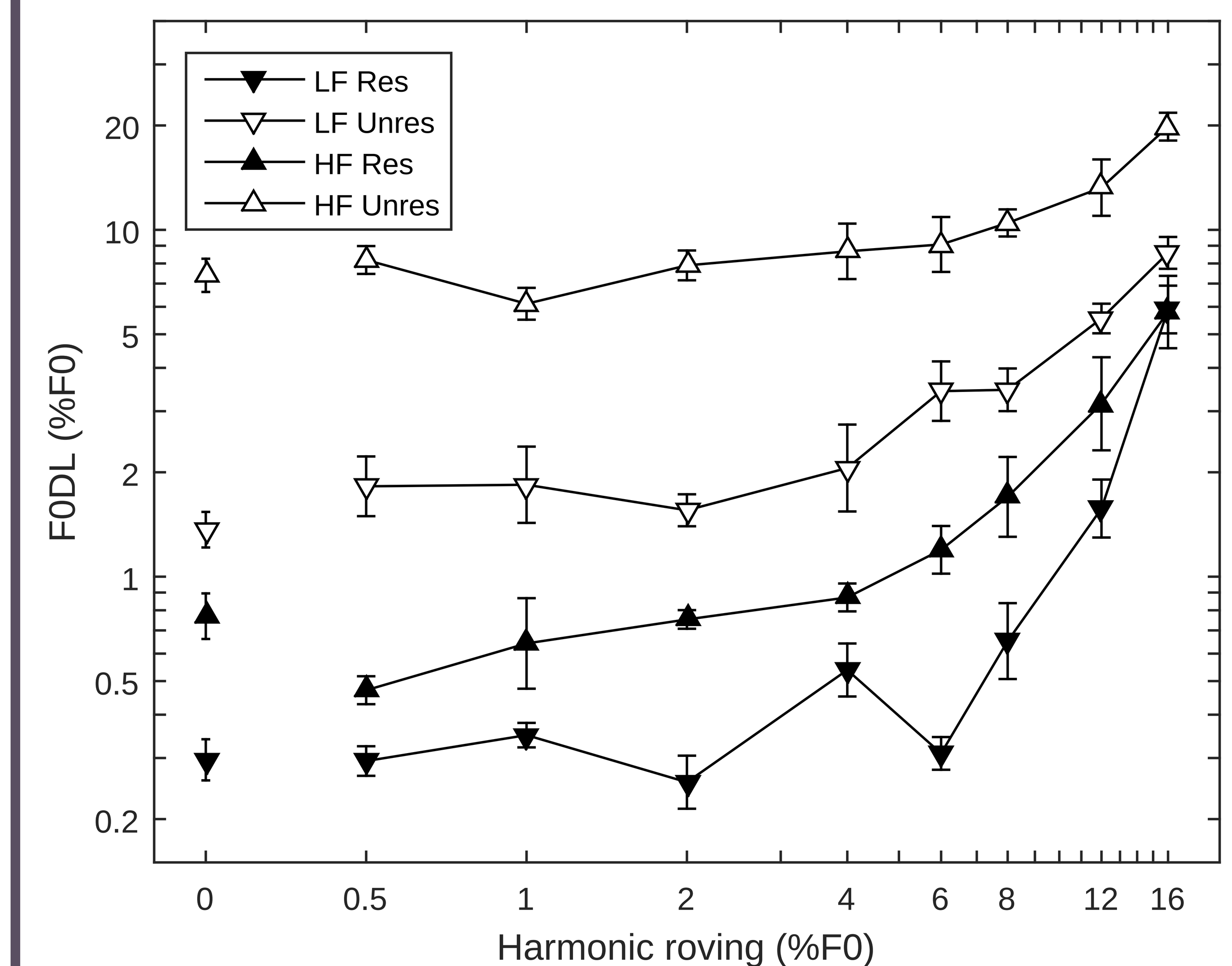

Fig.4 Mean F0DLs as a function of harmonic roving (in %F0) over 4 musicians, for complex tones bandpass-filtered in a low-frequency (LF: 1.5-3.5 kHz, down triangles) or high-frequency region (HF: 7.5-17.5 kHz, up triangles) containing resolved harmonics (Res, black symbols) or only unresolved harmonics (Unres, white symbols). Error bars depict the standard error of the mean.

3: Individual harmonics

Methods:

Frequency difference limens (FDLs) as a function of roving:

- 2 normal-hearing listeners, both 8+ years of formal musical training
- 2-AFC task, weighted up-down tracking rule (75%)
- Pure-tones at 1.5, 2.4, 3.3 kHz (harmonics 5, 8, 11 for LF region)
- Pure-tones at 7.5, 12.0 kHz (harmonics 5, 8 for HF region)
- Roving applied to nominal frequency F

Preliminary results:

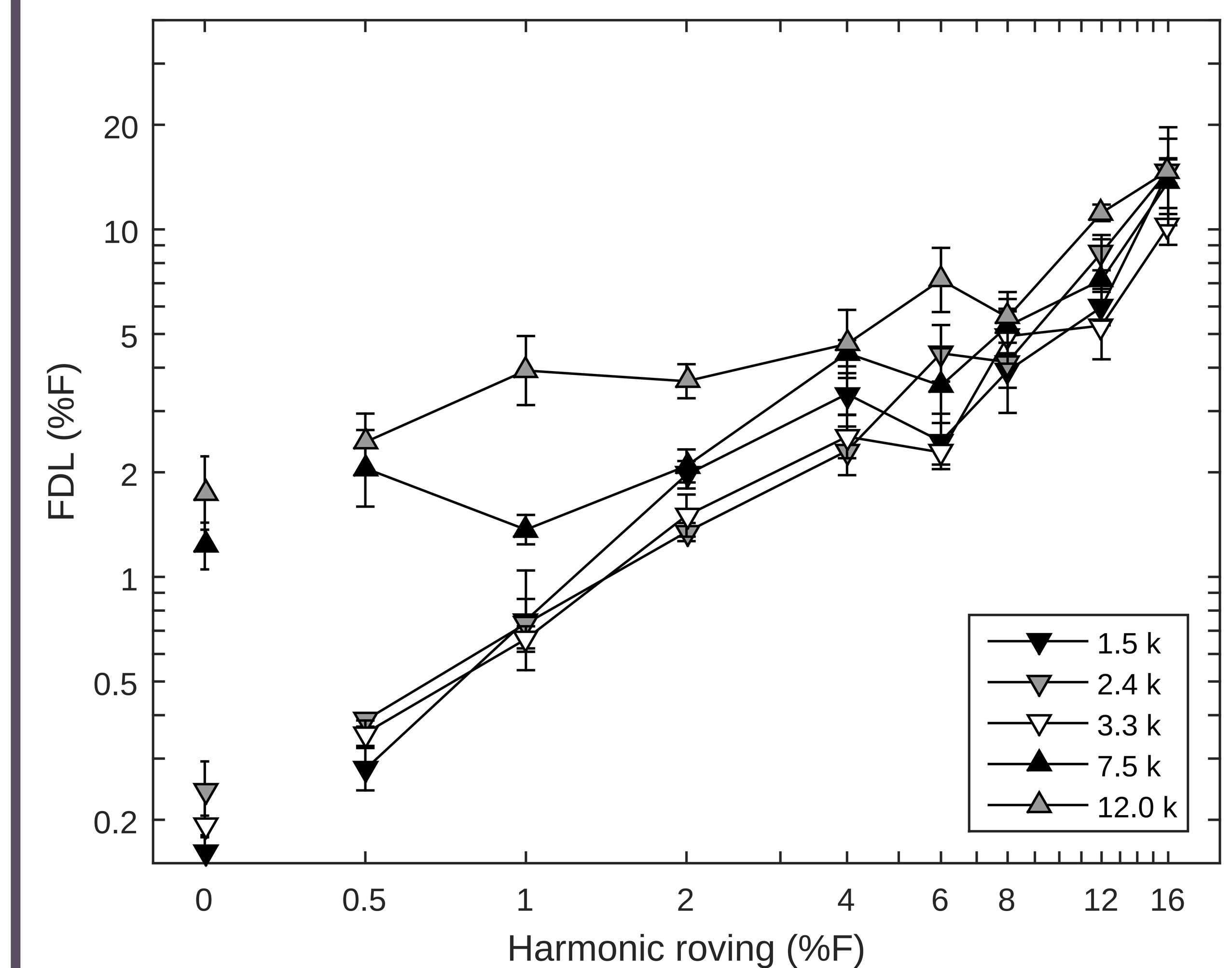

Fig.5 Mean FDLs as a function of harmonic roving (in %F) over 2 musicians, for pure tones with nominal frequencies corresponding to harmonics 5 (black symbols), 8 (gray symbols), and 11 (white symbols) of the complex tones used in Experiment 2 for the LF region (down triangles) and the HF region (up triangles).

Discussion

Effect of harmonic roving on F0DLs

- Performance unaffected up to a certain roving amount and progressively worse above (Fig.3)
  - Internal (additive) noise limits performance up to ca. 6% roving
  - External (mutiplicative) noise limits performance above this value

Influence of musical training

- Better performance with musicianship
  - For *both* resolved and unresolved conditions (Figs.3-4)
  - Longer musical experience leads to even better performance (Fig.4)
  - Consistent with an overall reduction of additive internal noise with musical training
- Musicianship does *not* affect the amount of roving necessary to affect performance
  - Musicians not more robust to external stimulus degradations than non-musicians in terms of place or periodicity cues
  - Suggests frequency selectivity is independent of musical training
- Thresholds below 1 semitone (ca. 6%F0) in the HF resolved condition (Fig.4)
  - Confirms that complex pitch does exist when all audible components are above 6 kHz (Oxenham *et al.*, 2011)

F0DLs in low vs. high spectral regions

- Similar effect of roving in both spectral regions (Fig.4)
  - Suggest similar robustness to external noise in both regions
- Overall worse performance in HF region than in LF region (Fig.4)
  - Resolved case: may be due to a loss of temporal fine-structure (TFS) cues, while place cues remain available
  - Unresolved case: due to a loss of TFS cues and/or a sluggishness of temporal envelope coding with increasing envelope repetition rate

Comparing F0DLs and FDLs for individual harmonics

- Effect of roving on FDLs dependent on spectral region (Fig.5)
  - LF: FDLs largely independent of F and increase as soon as roving introduced
  - HF: Increasing FDLs with F, little roving effect up to a certain amount
  - Suggests different mechanisms for pitch discrimination of pure tones at low vs. high frequencies
- F0DLs not consistent with optimal integration of information across harmonics in LF region, more so in HF region
  - Consistent with performance being limited by different sources of internal noise in LF (possibly central noise) and HF (possibly peripheral noise) regions (Oxenham and Micheyl, 2013)

Conclusions

- The results demonstrate a systematic relationship between pitch discrimination performance and stimulus variability that could be used to quantify the internal noise and provide strong constraints for physiologically-inspired models of pitch perception.
- They are consistent with a reduction of internal noise, but no better spectral or temporal resolution, with musical training.
- They suggest differences in pitch mechanisms, or in the limitiations to these mechanisms, at low and high frequencies.
- Ongoing work will compare how an excitation-pattern based place model and an autocorrelation based temporal model of pitch perception can account for the present data.

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