Modeling the effect of scale impurities on tonality perception

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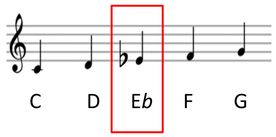
BACKGROUND

Scale impurities are notes of degree 3 or 6 that weaken the perceived majorness or minorness of music.



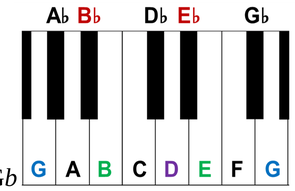
Example: In a musical piece whose predominant key is C major, an E*b* (which is from the parallel minor scale) will weaken the perceived majorness of the music.

Are the effects of scale impurities on scale qualities additive or nonlinear?

METHODS

Stimuli: Tone-scrambles—13 randomly sequenced pure tones (total stimulus duration = 0.845 sec.)

Tonics: G_5, G_6
Dominant: D
Target notes
Major: B or E
Minor: B*b* or E*b*
Other notes: A*b*, A, C, D*b*, D, F, G*b*



"Pure" Tone-Scrambles contain
- 4 Tonics (randomly G_5 or G_6)
- 3 Dominants
- 1 Random ***Target note***
- 5 Random "other" notes

"Impure" Tone-Scrambles contain
- 4 Tonics (randomly G_5 or G_6)
- 3 Dominants
- **2 Random *Target notes* of one type**
- **1 Random *Target note* of the opposite type**
- 3 Chromatic notes

Task: Judge (with trial-by-trial feedback) whether the stimulus contained more **major** or **minor** target notes.

Listener 1 (2) completed 1000 (1400) trials (random mix of Pure and Impure stimuli).

MODELING

Full Model: On a given trial,

$$\text{Listener says} \begin{cases} \text{"major"} & \text{if } \mu + X > \boxed{\text{Criterion}} \\ \text{"minor"} & \text{otherwise} \end{cases}$$

X is a standard normal random variable, and

$$\mu = \sum_{t=1}^{13} W(t)\,[\text{Adjustment}(t) + F(n(t))]$$

where $n(t)$ is the note occurring at tone t of the stimulus,

$\boxed{W(t)}$ = sensitivity to tones occurring at t = 1,2,…,13,

$\boxed{F(n)}$ = relative influence exerted by different notes n of the chromatic scale, and

$$\text{Adjustment}(t) = \begin{cases} \boxed{\text{Correction}_{B\flat}} & \text{if } n(t) \text{ is a singleton } B\flat \\ \boxed{\text{Correction}_{B}} & \text{if } n(t) \text{ is a singleton } B \\ \boxed{\text{Correction}_{E\flat}} & \text{if } n(t) \text{ is a singleton } E\flat \\ \boxed{\text{Correction}_{E}} & \text{if } n(t) \text{ is a singleton } E \\ 0 & \text{otherwise.} \end{cases}$$

Constraints:
1. F sums to 0
2. F^2 sums to 1
3. The mean value of $W > 0$.

Nested Model: Same as full model, except

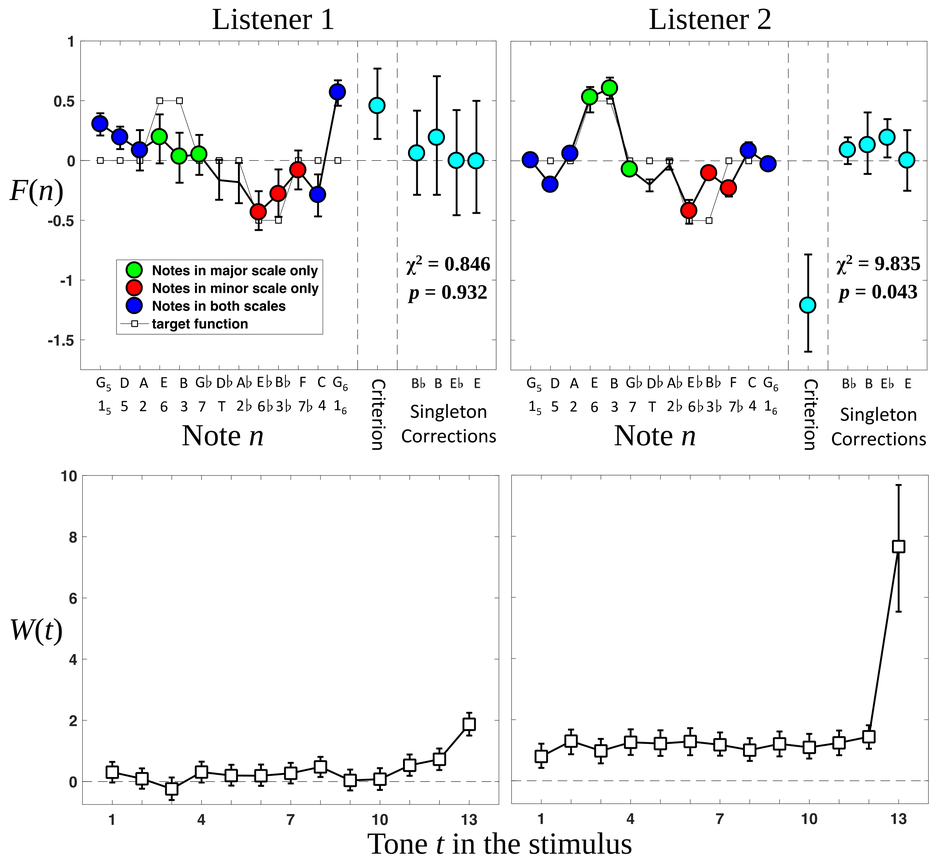
$$\text{Correction}_{B\flat} = \text{Correction}_{B} = \text{Correction}_{E\flat} = \text{Correction}_{E} = 0.$$

Wilks' Theorem: Under the null hypothesis that the nested model captures the true state of the world, the statistic

$$\chi = -2\left[\frac{\text{Max log likelihood of nested model}}{\text{Max log likelihood of full model}}\right]$$

is distributed as chi-square with 4 degrees of freedom (for the additional four parameters in the full model).

RESULTS



DISCUSSION

The listeners achieve very different statistics.
Listener 1 is unlikely to be affected by scale impurities. They are sensitive only to the final tones of each tone-scramble. Accordingly, their singleton corrections are close to 0.
Listener 2's data fit the full model, but their minor singleton corrections are positive. This suggests either (1) Perception of minorness is an accelerating function of the number of minor notes in a stimulus, or (2) Perception of majorness weakens for tone-scrambles with 2 minor and 1 major note, vs. tone-scrambles with only 1 major note.
Conclusion: The full model may be more representative of tonality perception, supporting the nonlinear effect of scale impurities. However, the model assumes that a listener is sensitive to most notes in the stimuli and does not fully capture nuances.

REFERENCE

Chubb, C., Dickson, C. A., Dean, T., Fagan, C., Mann, D. S., Wright, C. E., Guan, M., Silva, A. E., Gregersen, P. K., & Kowalsky, E. (2013). Bimodal distribution of performance in discriminating major/minor modes. *The Journal of the Acoustical Society of America*, *134*(4), 3067-3078.