Musical culture, instrument type, and pitch-class properties: Towards a new model of scale structure



SCIENCE

Department of Psychology, Neuroscience & Behaviour

BACKGROUND

Harmonicity theory of scales:

- Based on the overtone series
- Influenced diatonic scale theory and 12-tone equal temperament (12-ET)
- Posits that pitch-classes should occur **exactly** at small-integer interval ratios from the tonic

However, evidence shows that:

- Acoustic pitch production is categorical¹ and encultured,
- Especially in vocal music²

PREDICTIONS

If pitch-class precision and accuracy depend on instrumental pre-tuning, *then*:

1. Pitch-class precision and accuracy should vary significantly between organ, flute, trombone, and the voice

If pitch-class precision and accuracy depend on culture, *then*:

2. Vocal pitch-class precision and accuracy should vary significantly across musical cultures

METHODS

Tarsos analysis

1. Use Tarsos-YIN pitch tracker³ to analyze and select melodic frequency (hz) annotations

<u>A posteriori pitch-class analysis</u>

- 1. Convert annotations to cents
- 2. Input pitch-class boundaries
- 3. Set pitch-classes relative to "tonic" and remove non-discrete classes (e.g., glides, scoops)
- 4. Calculate discrete pitch-class descriptive statistics (e.g., mean pitch, range in cents)
- 5. Calculate "inaccuracy" of each pitch-class = absolute distance between pitch-class mean and nearest multiple of 100-cents from tonic's mean

Statistical analysis

Precision: Analyze group means for pitch-class *range* (unconstrained)

Accuracy: Analyze group means *and* variances for pitch-class *inaccuracy* (values=0-50 cents)

Elizabeth Phillips, Steven Brown Department of Psychology, Neuroscience & Behaviour, McMaster University

EXPERIMENT 1

<u>Stimuli</u>

8 short vocal melodies from around the world, transcribed to sheet music & associated MIDI

Participants

4 Semi-professional Canadian musicians, on:

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1. Organ; 2. Flute; 3. Trombone; 4. Voice
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- <u>Methods</u>
- Participants had sheet music months in advance
- Asked to record "as accurately and precisely as possible. [...] Avoid all vibrato, ornaments, and glides: aim for a pure, steady tone."

<u>Results</u>

Across all musicians and melodies, only 2 errors played. "Best case" tuning for these instruments.





Precision: The fixed-pitch instruments (organ and flute) >> variable-pitch instruments (trombone and voice)

Accuracy: organ >> flute and voice >> trombone



Plotting precision against accuracy reveals that **each** instrument has distinct pitchclass production properties.

A FEW REPRESENTATIVE **PITCH-CLASS HISTROGRAMS**



Low range, low inaccuracy



The wide variance was constant across cultures (Levene test p > 0.2), and indicated tuning that is random with respect to 12-ET

CONCLUSIONS

- 1. Vocal pitch-classes are wide, and often overlap when less than 200 cents apart
- 2. A capella singers generally don't conform to 12-ET tuning
- 3. These vocal constraints are relatively constant across cultures and vocal styles worldwide, but
- 4. Within-culture variance is high due to individual and stylistic differences

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Traditional Irish singer Higher range, higher inaccuracy • Harmonicity theory fails to describe actual music production, especially of the voice • We propose Interval Spacing theory: scales are based on engineering and sensorimotor constraints, categorical pitch production and perception, and cultural evolution

If pitch-classes are at least 100 cents wide (due to vocal imprecision), they will create *interval islands*

Musical scales are a trade-off between distinguishability and reproducibility: pitchclasses should be distant enough to minimize overlap, but still not be overly difficult to sing



IMPLICATIONS

Interval Spacing theory:

M2 M2 M2 M2 M2 M2

FURTHER WORK

- Why were there differences between some cultures?
- Compare the pitch-classes properties according to the degree of vibrato, portamento, melisma, etc., as well as scale size, melodic range, interval
- type, etc.
- What about interval-class analysis?
- Attempt to measure melodic interval-class
- properties (requires note segmentation, which is difficult in vocal recordings)
- What about scale evolution?
- Use these constraints to create a generative
- model of vocal scale structure

REFERENCES

¹Parncutt, R., & Hair, G. (2018). A psychocultural theory of musical interval: Bye bye Pythagoras. Music Perception: An Interdisciplinary Journal, 35(4), 475-501. ² Pfordresher, P. Q., & Brown, S. (2017). Vocal mistuning reveals the origin of musical scales. Journal of Cognitive Psychology, 29(1), 35-52. ³ Six, J., Cornelis, O., & Leman, M. (2013). Tarsos, a modular platform for precise pitch analysis of Western and non-Western music. Journal of New Music Research, *42*(2), 113-129.