Beyond harmonicity: Vocal-melodic theories are necessary for studying the global origin of musical scales

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BACKGROUND

The dominant theory about the origin of musical scales is ***harmonicity theory***

- based on the overtone series
- used as the basis of early *instrumental tuning*
- later influenced *diatonic scale theory*

However, harmonicity theory has been challenged by a wealth of empirical evidence[1]

- actual pitch perception and production is *categorical*, not mathematically perfect

Harmonicity theory is especially challenged by ***vocal and non-Western scales***

We propose an alternative model of scale origins: ***interval spacing theory***

- based on the properties of vocal-melodic scales and sensorimotor constraints[2]

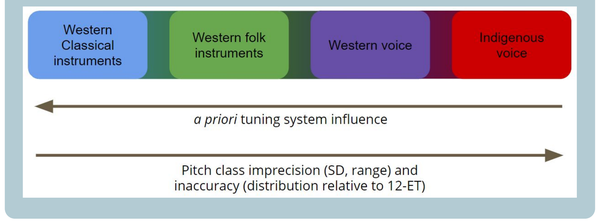
Harmonicity Theory	**Interval Spacing Theory**
Music as a science	Music as an art
Fixed-pitch instruments	The voice
Mathematical perfection	Emotional communication
Physics	Biology
Harmony	Melody
Pitch classes	Interval classes
Prescriptive (*a priori* tuning)	Descriptive (*a posteriori* tuning)
Harmonic/overtone compression	Interval island model
Octave divided into intervals	Interval islands strung together
Perfect harmonic ratios	Imperfect physiological mechanisms
Perfect tuning	Vocal imprecision
Too strict with precision	Cannot measure inaccuracy

Research question

Based on melodic pitch production, does harmonicity or interval spacing theory offer a better model of musical scales, especially considering non-Western and vocal scales?

Predictions

The *precision* and *accuracy* of pitch classes' diatonic tuning will decrease as the degree of *a priori* tuning influence decreases



MATERIALS

Recordings of solo, unaccompanied adults, each 20 – 160 seconds, n per group = 50 (±4):

Instrumental:
1. Western classical flute
2. Irish folk flute

Vocal:
3. Dutch folk
4. Indigenous Taiwanese

Note: aerophones used to closely match voice

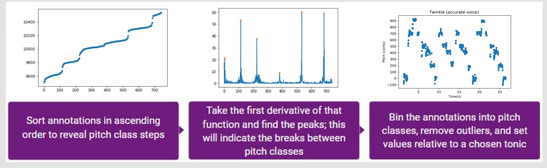
METHODS

Tarsos analysis

1. Analyze recordings using Tarsos-YIN pitch tracker[3]
2. Select and export the relevant melodic frequency annotations

A posteriori pitch class analysis

1. Import annotations, convert to cents, clean



2. Calculate pitch class descriptive statistics
3. Calculate 'inaccuracy' of each pitch class = absolute distance between pitch class mean and nearest multiple of 100-cents from tonic's mean

Statistical analysis

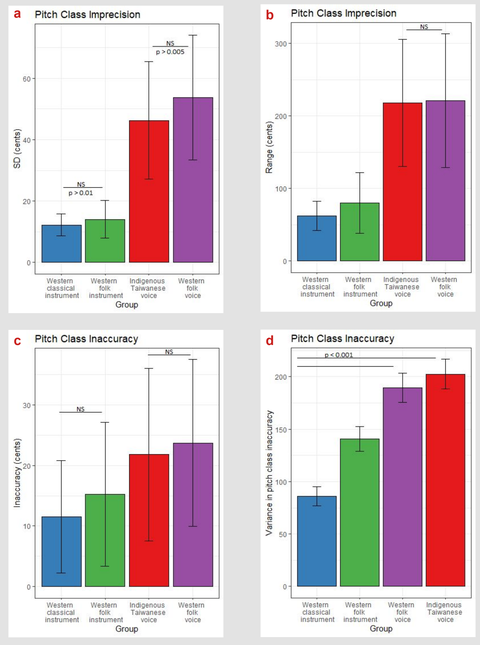
1. Randomly sample 150 pitch classes per group
2. For **precision:** (standard deviation and range): Test differences between group means
3. For **accuracy**: Test differences between group means *and* group variances

RESULTS

Data do not meet normality or equal variance assumptions (Shapiro-Wilks and Levene tests significant at $p < 0.001$ for all datasets)

Used multiple-comparisons method that is robust to non-heteroscedasticity and controls the family-wise error rate to test differences between means[4] (**Figures a-c**)

Used multiple pairwise Levene tests (Bonferroni p-values adjustment) to test differences between the variance of inaccuracy (**Figure d**)



Note: Non-diatonic singing should result in a high inaccuracy *variance*, not necessarily a high mean inaccuracy (random distribution relative to 12-ET)

CONCLUSIONS

1. **Pre-tuned instruments produce pitch classes that are significantly more precise than those of the voice**
2. **Vocal constraints are constant across multiple cultures**
3. **Singers (without Western art music context) don't conform to diatonic tuning**

So What?

- Harmonicity theory is overly prescriptive and fails to describe actual music production, especially non-Western vocal-melodic music
- Interval spacing theory, which uses an *a posteriori* view of scales based on sensorimotor constraints, categorical pitch production and perception, and cultural evolution, is a better explanatory model

FURTHER WORK

Confirm instrument effect: instrumental samples had higher tempos, wider/higher range, and more notes, and there were no variable-pitch aerophones

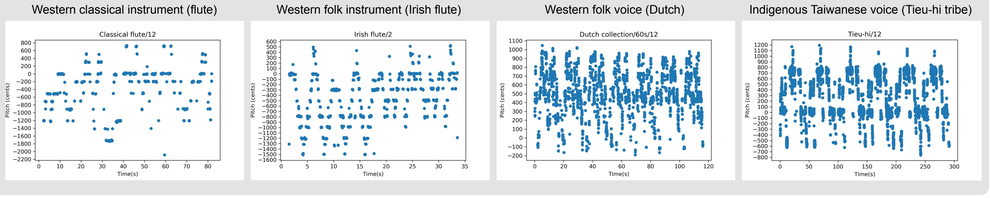
- Compose and analyze non-idiomatic melodies played by organ, flute, trombone, and voice

Confirm lack of culture effect: vocal samples are not globally representative, and confounded with performance context and level of formal training

- Replicate with large and diverse global corpus of song, and compare trained vs untrained singers in different performance contexts

Scale structure analysis: match the observed vocal constraints to scale structural properties, potentially in support of interval spacing theory of scale origins

REPRESENTATIVE MELOGRAPHS PER GROUP



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[4] Herberich, E., Sikorski, J., & Hothorn, T. (2010). A robust procedure for comparing multiple means under heteroscedasticity in unbalanced designs. *PloS one, 5*(3), e9788.