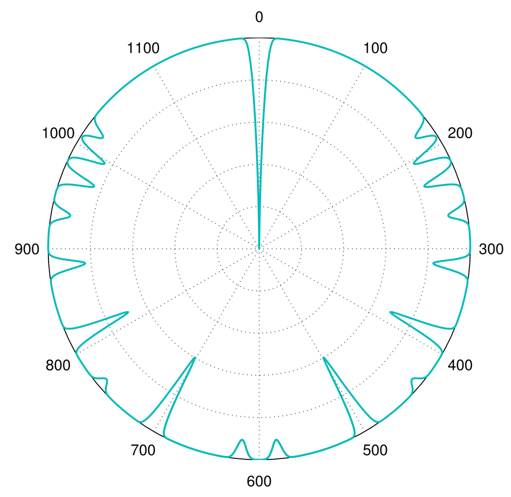
Spectral pitch distance and microtonal melodies



Spectral Pitch Distance & Microtonal Melodies

Andrew J. Milne[1], Anthony Prechtl[2], Robin Laney[1], David B. Sharp[1]

[1] *The Open University, UK;* [2] *Independent Researcher, US*

The Open University

1. Preliminary Definitions...

Spectral distance is a measure of the similarity of tones based on the frequencies and amplitudes of their partials; if two tones have many partials at similar pitches, their spectral distance is low. *Setharian tones* have their partials aligned to the tuning they are played in; e.g., if a melody is played in a 5-tone equal tuning (5-TET), a Setharian tone will have all its partials tuned to steps of 5-TET (see Box A, upper figure) [2]. *Pseudo-Setharian tones* have their partials aligned to a tuning different to the one they are played in; e.g., if a melody is played in 5-TET, a pseudo-Setharian tone may have all its partials tuned to steps of 7-TET, 12-TET, 17-TET, or any other non-5-TET tuning (see Box A, lower figure). The spectral distance between Setharian tones is typically lower than that between pseudo-Setharian tones.

2. Contribution

We demonstrate that the perceived affinity of tones in a melody is greater when using Setharian—rather than pseudo-Setharian—tones. This has two direct implications:

1) a microtonal melody can be made to sound more in-tune (have greater affinity) by using Setharian tones;

2) in Western music, the melodic affinity of tones separated by perfect fourths, perfect fifths and major seconds may be due, in part, to the harmonic partials that are produced by most Western instruments (including the human voice). This is because such intervals have relatively small spectral distances (see Box B).

3. The Experiment

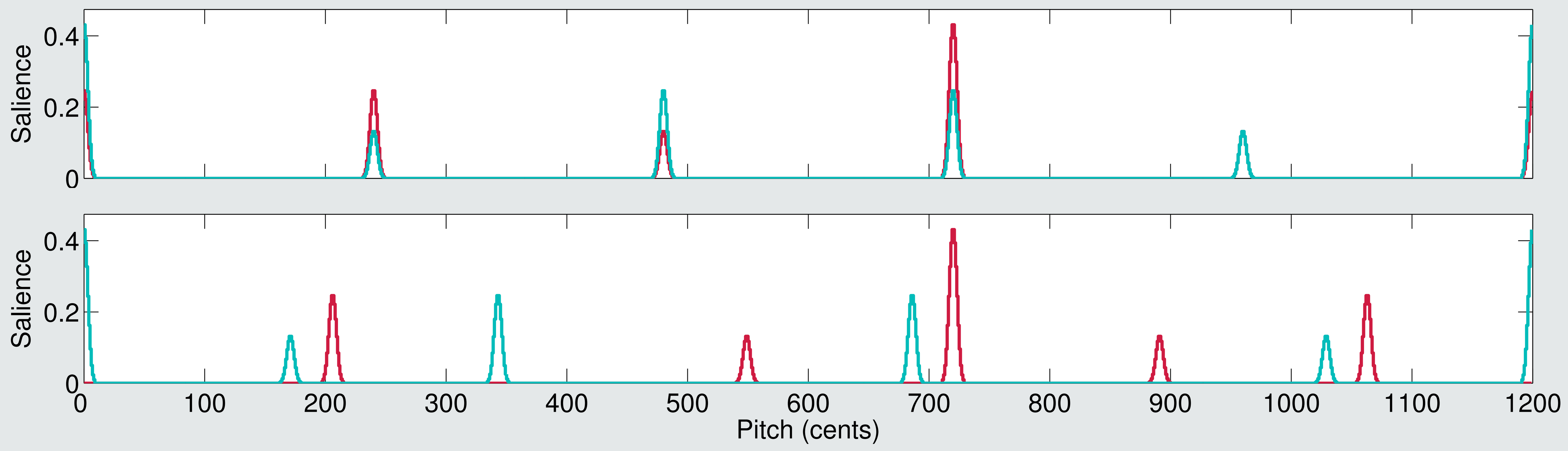
Ten participants listened to 60 different randomly generated microtonal melodies. Each melody was randomly tuned to one of eleven different equal tunings with the following numbers of steps (per octave): 3, 4, 5, 7, 10, 11, 12, 13, 15, 16, or 17 (why these tunings?—see Box C). Each melody was played with two timbres: A Setharian timbre with partials tuned to the steps of the equal tuning used by the melody, or a pseudo-Setharian timbre with partials tuned to the steps of a different equal tuning (randomly chosen from the above). Participants were asked to choose which of the two timbres made the tones in the melody have the "greatest affinity", "best fit", and sound most "in tune".

4. Results

A binomial test shows that, given a choice between Setharian and pseudo-Setharian tones, participants felt the former produced melodies with "greater affinity", "better fit", and sounded most "in tune". Whether the results were consistent across all the different equal tunings tested has not yet been analysed. The significance of this result is very high—there is a 1 in 47 million chance it is due only to a chance relationship; participants chose Setharian timbres on 63% of occasions and pseudo-Setharian on 37% (% difference = 26%).

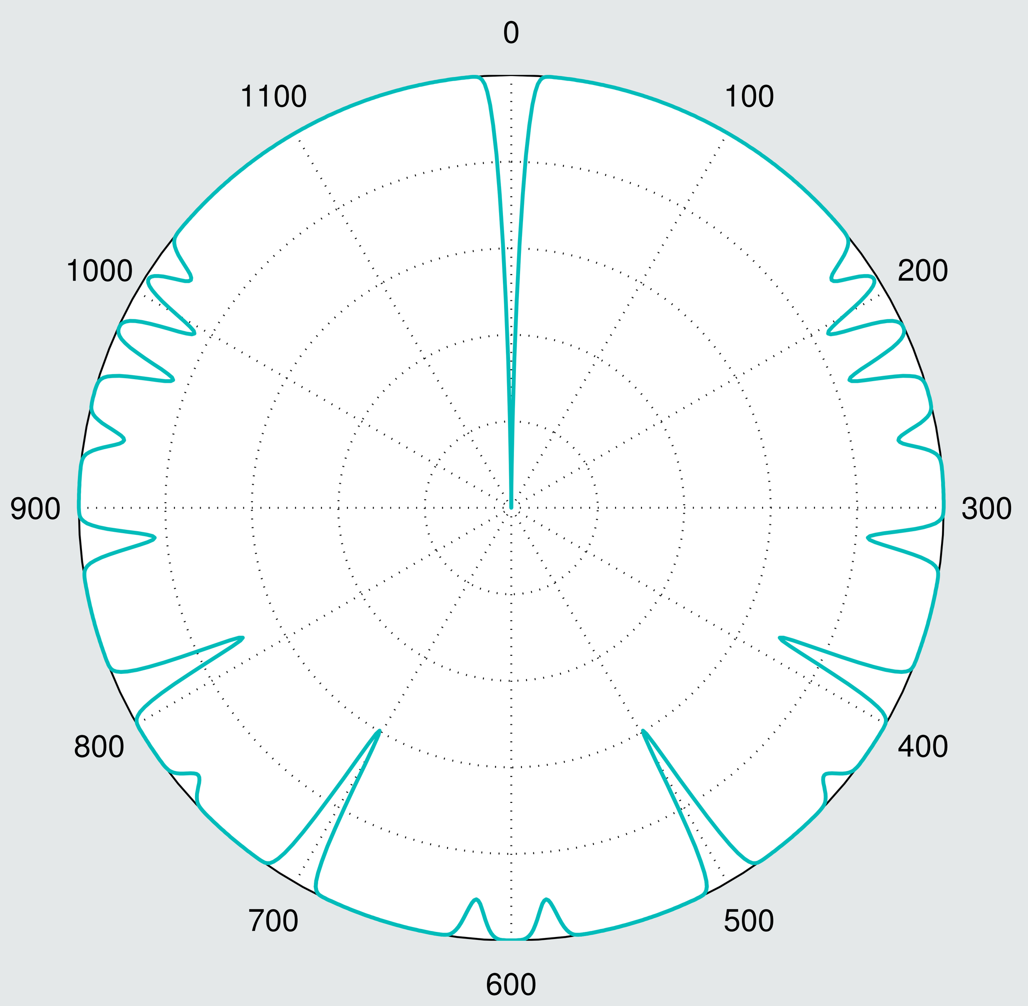
A. Spectral Distances between Setharian & Pseudo-Setharian Tones

Each figure shows the (octave-reduced) spectra of two tones—the "red" tone is tuned three steps of 5-TET (720 cents) above the "turqoise" tone. In the upper figure, both tones are Setharian—they have timbres aligned to the underlying 5-TET tuning; in the lower figure, both tones are pseudo-Setharian—they have timbres aligned to 7-TET. The cosine spectral distance between the two Setharian tones is .15; the cosine spectral distance between the two pseudo-Setharian tones is 1 (the maximum possible distance). Typically, when the timbre is aligned to the underlying tuning (as in the upper figure) the spectral distance between tones is smaller than when the timbre is aligned to a different tuning (as in the lower figure).



The experiment shows that listeners feel melodic tones like the former pair (with lower spectral distances) fit together better than those like the latter pair (with greater spectral distances).

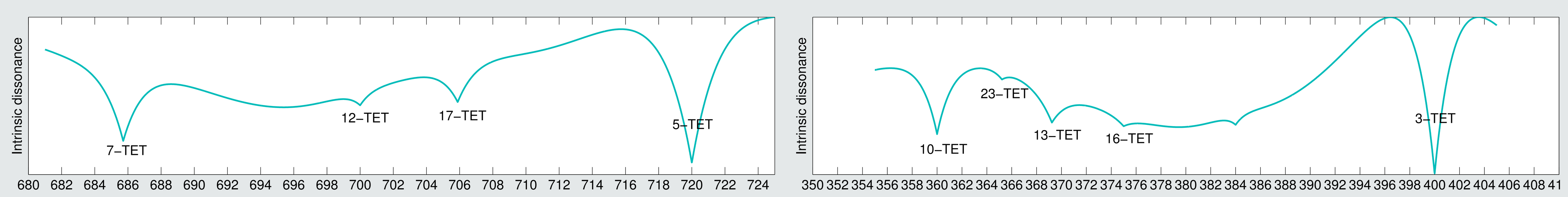
B. Spectral Distances between Tones with Harmonic Partials



Western music typically uses instruments that produce tones with harmonic partials (e.g., the human voice). The figure shows the spectral distance between two such tones as a function of their pitch difference (in cents). The spectral distance model suggests that, when tuned to 12-TET, tones separated by a major second, perfect fourth, perfect fifth, or minor seventh, have relatively small spectral distances. All other 12-TET intervals have a maximal spectral distance of 1. The experimental data suggest that low spectral distance melodic intervals such as these are perceived as having greater melodic affinity or fit. The melodic affinity of different intervals in Western music may, therefore, be effectively modelled by their spectral distance.

C. Intrinsic Dissonance of Setharian Tones

A single Setharian tone with partials aligned to an equal tuning (with a small number of steps) is typically intrinsically consonant. Conversely, a Setharian tone aligned to a tuning close to, but not the same as, such an equal tuning is typically intrinsically dissonant. To reduce the influence of intrinsic consonance/dissonance on participants' responses, the tunings used for the experiment were chosen because they produce Setharian timbres located at local dissonance minima. Tones with harmonic partials were also avoided because their familiarity may become an unwanted factor—Setharian and pseudo-Setharian tones are equally unfamiliar.



The vertical axis shows the *intrinsic dissonance* of a single Setharian tone (caused by the beating of its partials). The horizontal axis shows the size (in cents) of the interval generating the tuning to which the timbre is matched. When the size of the generating interval is an integer ratio, m/n, of the octave (which is 1200 cents), an equal tuning with n steps per octave is produced. There are local intrinsic dissonance minima at equal tunings with low values of n (typically, $n \lessapprox 25$).

References

[1] Milne, A.J., Sethares, W.A., Laney, R., and Sharp, D.B. "Metrics for pitch collections," *Proceedings of ICMPC11*, Aug. 2010.

[2] Sethares, W.A. *Tuning, Timbre, Spectrum, Scale*, 2nd ed. London: Springer-Verlag, 2005.