Reformulating Burmese Harp Tunings
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Slides accompanying this file are accessible at the following url:
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Distinctive in shape, size, construction and playing position (**_Slide 2_**), the Burmese harp has been traditionally tuned by ear; that is, without the intervention of a monochord or more recent devices, such as electronic tuners.

In the latter regard, it is similar to harps and lyres of Antiquity: in Mesopotamia about four millennia ago, Ancient Greece more than 2300 years ago, and Ancient India about 1700 years ago.

Also of plausible relevance to Burmese harp tuning are tunings of fixed-frequency instruments of other Southeast Asian traditions: of Central Java and Thailand, for example.

Although such xylophones and metallophones have also been tuned by ear and employed in Burmese classical music along with the harp, the inharmonic spectra of their tones differ from the harmonic spectra produced by the open strings of the harps and lyres just mentioned.

In particular, open strings produce predictable beats when plucked simultaneously.

→ A monograph by Muriel and Robert Williamson (2000) provides the most detailed account of Burmese harp tuning.

Within a framework of quartertones suggestive of Middle Eastern practices, the Williamsons measured the fundamental frequencies in twelve renditions of four kinds of tuning.

The present report analyzes the Williamsons' measurements, drawing on parallels with the idioms mentioned above.

→ An analysis based on a dichotomy of small and Large steps reveals Myhill's Property (Clough and Myerson 1985: 250, 262-68) in all twelve renditions and is extended to accommodate larger and smaller variants of the two basic step sizes.

As well, an analysis based on harmonic spectra of the tone-pairs in the tunings' generating intervals reveals a dichotomy of roughness and smoothness consistent with variants of the small and Large steps' sizes.

Small and Large Steps

Each of the twelve renditions consists of small and Large intervals between adjacent strings.

Most important, each of the small intervals between adjacent strings is smaller than all of the Large intervals between adjacent strings, which are termed "steps" in what follows.

Statistical analysis confirms this distinction.

Slide 3 shows that, on average, the small and Large steps are, respectively, 182 and 327 cents, with standard deviations of 30 cents each.

This difference is significant, not only at the usual, .05 level, but with a probability smaller than 1 in 100,000, and the effect size is large: 4.89.

Moreover, as a special case of categorical perception, the small and Large steps do not overlap in size.

In this regard, the Williamsons' careful measurements are to the nearest 5 cents, and the largest small step of 237 cents is smaller than the smallest Large step of 256 cents.

→ *Slide 4* displays the succession of step sizes—small (lower-case letter "s") and Large (upper-case letter "L")—from low to high, in each of the 12 renditions of the four kinds of tuning.

In this slide one can note, with only one exception, that the patterns of small and Large intervals are the same in each rendition of each of kind of tuning.

Bold-italic-underlining highlights the exception, which reverses the order of a pair of small and Large intervals in the lowest register.

→ All twelve renditions comprise the following succession of steps, or one of its rotations:

      small small Large small Large

Slide 4 shows that in the *myin* and *palè* tunings, such a 5-step ordering occurs twice in its complete form, beginning at the lowest tones (with the exception just mentioned), and continuing at the 3 highest steps.

In *Slide 5* one can observe that in *hnyìn* tuning, the top 3 steps repeat part of the preceding 5-step pattern, rather than continuing it.

The same slide shows that in *auk* tuning even more 3-step portions, as well as 2-step portions of the 5-step succession, are repeated consistently in each of the renditions.

The small-small-Large-small-Large Pattern

In various cultures, the small-small-Large-small-Large pattern has occurred in various ways.

Slide 6 shows that in *pélog* tuning of Central Java, which Richard Widdess (2005, 191-96) has also discerned in Ancient Indian tuning, any two successive small steps are smaller than any of the Large steps:

> small plus small is *less* than Large

In so-called anhemitonic pentatonic of East Asia, and in many other settings, including Ancient Indian tuning, any two successive small steps are larger than any Large step:

> small plus small is ***greater*** than Large

However, in pentatonic passages of Thai classical music, there is no general relationship between any Large step and any 2 successive small steps (Rahn 2019):

> small plus small is less than Large
> *or* small plus small is greater than Large

→ *Slide 7* shows how anhemitonic pentatonic can be considered a special subset of diatonic heptatonic.

In diatonic heptatonic, all of the small steps are smaller than all of the Large steps.

Since the Large steps of diatonic heptatonic correspond to the small steps of anhemitonic pentatonic, and the Large steps of pentatonic correspond to immediately successive small and Large steps in diatonic, anhemitonic pentatonic will be referred to as "diatonic-pentatonic."

In Central Javanese *pélog*, an analogous relationship holds (Rahn 2016).

In heptatonic *pélog*, all of the small steps are smaller than all of the Large steps.

As well, any two immediately successive small steps are smaller than any Large step, and this relationship holds also for pentatonic passages in *pélog*.

Accordingly, this pentatonic subset will be referred to as "pentatonic-*pélog*."

Finally, in so-called "equiheptatonic" tuning of Thai classical music, any single step is smaller than any two successive steps; any two successive steps are smaller than any three successive steps; and so forth.

The steps in pentatonic passages of Thai classical music have another relationship with their equiheptatonic counterparts.

In contrast to diatonic-pentatonic and pentatonic-*pélog*, in equiheptatonic-pentatonic there is no general relationship between the size of an immediately successive pair of small steps and the size of a Large step, except, of course, that any single small step is smaller than any Large step.

In other words, an immediately successive pair of small steps might be smaller than a Large step, as in heptatonic pelog and pentatonic *pélog*, or an immediately successive pair of small steps might be larger than a Large step, as in diatonic-pentatonic.

But neither of these possibilities occurs exclusively throughout particular instances of "equiheptatonic-pentatonic."

Myhill's Property

Whether any immediately successive pair of small steps is smaller than all the Large steps, or larger than all the Large steps, or bears neither general relationship with the Large steps, each of these small-small-Large-small-Large patterns can be considered to be generated by a single interval.

In each kind of tuning, the generating interval spans 3 steps and its size corresponds to 2 small steps and a Large step.

As well, for each of the tunings, the modular interval spans 5 steps and its size corresponds to 3 small steps and 2 Large steps.

Part 1 of **_Slide 8_** shows the way in which such pentatonic cycles are generated from a 3-step interval whose size corresponds to 2 small steps and one Large step.

Section "A" shows how the 5 tones are generated by successive iterations of the two-smalls-plus-one-Large interval.

Section "B" shows how these generated tones are arranged within a single, 5-step, modular interval whose size corresponds to 3-smalls-plus-2-Larges.

And section "C" shows these tones in registral order (i.e., from lower to higher) and the sizes of the resulting steps.

Part 2 of **_Slide 8_** shows the two sizes that result for each number of steps

As stated in **_Slide 9_**, such a pattern can be regarded as structurally privileged insofar as among all patterns that comprise a particular number of steps (in this case, 5) and in which any intervals that span a certain number of steps differ in size, the number of pairs of intervals that span the same number of steps and that have the same size is maximal.

Specifically, as _**Slide 9**_ shows, (s)(s-1)(s-2)/6 = (0), 1, 4, 10, 20, 35,…, where the number of steps in the modular interval is s = (2), 3, 4, 5, 6, 7, ….

A pattern of this sort has "Myhill's Property" and is "Well Formed" (Carey and Clampitt, 1989).

In this sense, the small-small-Large-small-Large pattern _**maximizes unity**_ among its intervals.

As indicated earlier, all twelve renditions of the four kinds of tuning comprise this _**structurally privileged**_ pattern.

Further, of the three possibilities described, some of the renditions comprise a diatonic-pentatonic pattern, and the rest comprise an equiheptatonic-pentatonic pattern, as shown in _**Slide 10**_.

Transposition and Exchange Tones

Focusing on the small and Large successions, one can interpret the seemingly anomalous 3-step repetition at the top of _hnyìn_ tuning in _**Slide 11**_ as part of a transposition that overlaps the lower small-Large-small-small-Large successions.

This transposition is up two small steps plus one Large step; that is, it is transposed upward by an amount that corresponds to the generating interval.

Such a transposition is analogous to transposition up a perfect 5th in European-derived music.

The **audio file linked to _Slide 12_** illustrates this transpositional overlap.

Moreover, the lower tone of the second small step—which interrupts the lower pattern and is highlighted in the slide—corresponds to a _biàn_ tone, i.e., an exchange tone in East Asian music.

This exchange tone is analogous to D-natural replacing E-flat in E-flat pentatonic.

→ In the Burmese tunings, all the exchange tones are lower than the tones they replace and are analogous to such replacements in East Asian traditions, where D might also be regarded as E-double-flat.

As replacement tones, a pairs of exchange tones is an instance of a single scale degree.

That there might be alternative versions of a single degree in different registers has a precedent in the _synemmenon_ of Ancient Greek music, both before and after 300 BCE.

"Octaves"

Slide 13 **and its accompanying audio file** illustrate the simultaneous octave intervals of the tuning just heard.

Note that, for comprehensibility, I refer to these 5-step intervals as "octaves," even though they would be more accurately termed "sextaves," insofar as they span 6 degrees, rather than 8.

Immediately evident in the audio file is the auditory roughness of the second last interval and the contrasting smoothness or slow undulation of the other intervals.

Since all the rough octaves in the tunings are smaller than the smooth octaves, they might be termed "diminished octaves," in contrast to the smooth octaves, which might be termed "perfect octaves."

Among all twelve renditions of the four kinds of tuning, the 98 perfect octaves are remarkably smooth, especially insofar as all twelve renditions were tuned by ear.

On average, the 98 perfect octaves produce only 2 beats per second, with a standard deviation of 2 per second.

In contrast, the very rough diminished octaves are quite rare.

These 12 diminished octaves produce, on average, 48 beats per second with a standard deviation of 15 beats per second.

Their average beating rate differs significantly—well beyond the usual .05 level—from the average beats per second of the perfect octaves, with a very large effect size of 9.34.

Accordingly, there is no auditory doubt which octaves are perfect and which are diminished.

→ Of importance to actual practice, individual accented tones are doubled at the perfect octave in traditional Burmese harp music.

In contrast, the sizes of the rough, diminished octaves range from 1002 to 1094 cents: in European-derived theory, between a minor 7th and a major 7th, with an average of 1045 cents and a standard deviation 27 cents.

Of importance to the present study, ***the perfect and diminished octaves correspond to two contrasting sizes of the 5-step intervals***: respectively, 3 smalls and 2 Larges versus 4 smalls and one Large.

"Fifths" and "Fourths"

Of great assistance to future analysts, the Williamsons summarized demonstrations of how to produce the four kinds of tuning by expert traditional musician Daw Khin May.

With one important exception to be considered later, and which has had a systematic effect on each kind of tuning, Daw Khin May's demonstrations involve producing an "octave" or a "fifth" with a tone that has already been tuned.

→ In Daw Khin May's demonstrations, perfect 4ths occur as byproducts of perfect octaves and 5ths.

Nevertheless, within the framework of Myhill's Property and because the perfect octaves are so close in size to 1200 cents and zero beats, one expects the perfect 4ths to vary in tandem with the perfect 5ths.

To judge from the musical notations the Williamsons employed to illustrate Daw Khin May's tuning demonstrations, the "octaves," "fifths" and "fourths" in the demonstrations should sound like the perfect octaves, perfect fifths and perfect fourths of European-derived theory.

To be sure, the perfect 5ths and 4ths produce significantly faster beats than the extremely smooth perfect octaves, especially in the upper register, which Daw Khin May tuned after the lower-sounding strings.

Nonetheless, the 2nd and 3rd partials of the 90 smooth 5ths, and the 3rd and 4th partials of the 89 smooth 4ths, average, respectively, 4 and 6 beats per second, with 4- and 6-beat-per-second standard deviations—quite smooth in a larger, global context.

As with smooth octaves, individual accented tones are doubled by smooth perfect 5ths in classical music for Burmese harp.

→ Arguable parallels to this slow beating of perfect 5ths and 4ths in Burmese harp tunings occur in Ancient Indian tuning.

In Ancient Indian tuning, a perfect 5th comprising 13 of the 22 shrutis in an octave would arguably result in about 3 beats per second above middle C4, and half as many above C3, an octave below, and twice as many above C5, an octave above.

As mentioned earlier, smooth and rough octaves differ in size: 3 smalls and 2 Larges versus 4 smalls and 1 Large.

In contrast, rough 5ths and 4ths differ audibly from smooth 5ths and 4ths and yet have ***the same size*** within a Myhill's-Property framework: specifically, 2 smalls plus 1 Large for the 5ths, and 1 small plus 1 Large for the 4ths.

As ***Slide 14*** shows, the average beat rates of the smooth perfect 5ths and 4ths are significantly slower than their quite rough counterparts, with large effect sizes of 2.56 and 3.10.

As well, the average sizes of the smooth and rough 5ths and 4ths differ significantly, with large effect sizes, as shown in ***Slide 15***.

Half-flats

At the outset of her demonstration, Daw Khin May emphasized the importance of a tone that, relative to the 8th string, nominally middle C4, is "about halfway between" B3 and B-flat-3.

The Williamsons identified this pitch with B-half-flat3.

As well, U Myint Maung identified the tone the Williamsons called E-half-flat4, which is a smooth 4th above B-half-flat3, as characteristic of "traditional" harp tuning, in contrast to "modern" tuning.

Most important, the rough 5ths and 4ths comprise one tone that is a half-flat and one tone that is not.

→ This contrast between rough and smooth 5ths and 4ths results in groupings that are parallel to those encountered in Ancient Indian tunings.

Groupings of 5ths and 4ths

The following slides adapt European-derived letter names to show how this contrast between smooth and rough 5ths and 4ths having the same Myhill's-Property size results in groupings within the small-small-Large-small-Large pattern.

In these slides, an upward arrow indicates a pitch about half a semitone above its European-derived counterpart.

For example, B-flat followed by an upward arrow indicates a pitch about a quartertone higher than B-flat.

Slide 16 shows that in all 3 renditions of *hnyìn* tuning, the lowest strings produce smooth 5ths and 4ths among F, C, and G.

As well, these lowest strings produce smooth 5ths between E-half-flat and B-half-flat. However, the 5ths between B-half-flat and F are small and rough.

In the highest strings, this grouping changes to include smooth 5ths between F, C, G, and D, and the rough 5ths between B-half-flat and F isolate the B-half-flat from the other four tones.

As well, one can note that the lowering of E-half-flat to D in the highest strings can be understood as a *métabole*—E-half-flat and D being exchange tones.

→ Whereas all the renditions of *hnyìn* tuning are identified as "traditional" (i.e., old), one can discern among the renditions of *auk* tuning depicted in *Slide 17* a change from older to more recent tuning practices.

The **audio file linked to _Slide 17_** contrasts 2 rough 5ths in _auk_, followed by 2 slow, smoothly undulating 5ths.

There are no half-flat pitches in the modern rendition of _auk_.

In the revised rendition, which intentionally adapted the traditional tuning to accommodate recent performance norms, B-flat replaced the traditional B-half-flat.

All the same, each of the renditions retained the pattern of employing lowered exchange tones in the highest register.

In _Slide 18_**,** one can observe among _myin_ tunings a decrease in half-flat pitches from traditional to more recent renditions.

Slide 19 shows a similar change in U Myint Maung's traditional and modern renditions of _palè_.

However, Daw Khin May's rendition bears a somewhat mixed relationship with this general trend.

→ In _Slide 20_, one can discern similar groupings in the seven-degree _ma-grāma_ tuning of Ancient India.

Employing the current convention for trans-notating Ancient Indian music, the 7 steps of _ma-grama_ comprise 3 perfect 5ths plus 2 isolated perfect 5ths.

As well, the "diatonic-pentatonic" subsets of _ma-grama_ comprise various perfect-cycles and isolates.

Half-flat Microtones and Myhill's Property

A final consideration involves a theoretical question of great importance:

In what sense are the intervals that arise from half-flat microtones consistent with Myhill's Property?

Detailed examination of the renditions shows that the small steps have 3 variants: tiny, small, and medium.

As well, the Large steps have 3 variants: Broad, Large, and Grand.

As _Slide 21_ shows, these variants—and their sums— are related to each other by a transitive smaller-than relation, within and between the small and Large categories.

Nonetheless, the difference between small and Large steps is maintained along with these distinctions, in manner analogous to _**conditioned allophonic variation**_ in speech.

Slide 22 compares the small-versus-Large dichotomy of a Myhill's-Property formulation with a more nuanced analysis that contrasts small and medium, and Broad and Large.

In the more nuanced analysis, perfect 5ths comprise small, medium and Large steps and reduced 5ths comprise 2 (nuanced) smalls and a Large, or small, medium and Broad steps.

→ Across all 12 renditions, the sizes of small and medium steps overlap, as do the sizes of Broad and Large steps.

However, with a single exception, such overlaps do not occur within individual renditions.

Moreover, the single exception involves only a single pitch in one of the renditions of *hnyìn* tuning.

Summary

Slide 23 summarizes the preceding observations.

The contrast between small and Large steps is maintained in both the "equiheptatonic" pentatonic and the "diatonic" pentatonic renditions.

As well, in "diatonic" pentatonic, 2 small steps are bigger than 1 Large step.

The "diatonic" pentatonic renditions and the "equiheptatonic" pentatonic renditions are consistent with Myhill's Property.

Within a framework of Myhill's Property, a contrast between smoother and rougher rates of beating by octaves of 2 sizes identify overlapping transpositions and exchange tones.

The contrast between small and Large steps is consistent with further, microtonal distinctions.

Within the small category, there are tiny, small, and medium variants.

Within the Large category, there are Broad, Large and Grand variants.

These variants are consistent with smoother and rougher beat rates of 5ths and 4ths that otherwise are of the same size according to Myhill's Property.

In turn, the smoother and rougher beat rates of 5ths and 4ths identify groups of tones among the 5 steps.

Conclusion
By way of conclusion, one can anticipate that structures clearly evident in Burmese tunings would inform analyses of particular pieces and cognate idioms in ***other cultural and historical*** settings.

Most important, the coherence of a two-level structure in Burmese tunings seems analytically promising in other contexts where open strings with harmonic spectra have been tuned by ear.

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