Is birdsong music?

The nightingale, the lark ascending; the cuckoo, the dawn chorus; since ancient times man has found beauty in birdsong. It appeals to our senses. It inspires composers. But is it music? **Marcelo Araya-Salas** listens to the nightingale wren and tries to find out if it is singing in tune.

A few months ago I spent three happy weeks with microphone and tape recorder in the rainforest of La Tirimbina Biological Station in northern Costa Rica recording the song of nightingale wrens. Some scientists are luckier than others in where their research takes them. I am one of the lucky ones. The nightingale wren is a small bird, some 11 cm long; it is a speckled brown and grey and, as its name implies, its song is considered particularly beautiful: it is a long series of nearly pure-toned notes, one following another at different pitches. It hardly ever repeats the same pitch two notes running.

Only the males sing. They do it mostly at dawn, in the early morning and late in the afternoon, probably, like most birds, to attract a mate or to mark out territory. Altogether I was able to record eight individual birds. They were lovely to listen to. Why was I recording them? I wanted to find out if what they were singing was music.

For that quest to make any sense, of course, we first have to say just what we mean by "music". Human music is more than just pleasant-sounding noise. It follows strict rules. An infinite number of notes – pitches, frequencies – exist within an octave, and an infinite number of intervals between them; but in "music" only a very few of them are allowed. Frequencies must be in simple ratios to one another if they are to be musical intervals. Scales and intervals between notes are based on those ratios of frequencies. The human ear recognises music as, essentially, harmonics. And this seems to be so in all cultures.

Music is more than pleasant noise. Do birds sing in harmonies as people do, or are their notes more random?

Generally, in Western music, those allowed "musical" ratios are the ones embedded in the notes of one or other of the scales, and these are based on subdivisions of the octave. The familiar do–re–mi–fa–sol–la–ti–do, properly known as the diatonic scale, is the most familiar; there are others (see box). Although these particular scales are human constructs, musical intervals themselves are not based on human convention but are inherent in the physical characteristics of the sounds. Thus two sounds whose frequencies are in the ratio of 5:4 form a musical interval; if the ratio is 7.43:1, they do not. Musical intervals are actually found in the harmonics of notes produced by the human voice – a sung middle C will not be pure but will also contain the frequency for the G above it, as well as many other frequencies. These contained harmonics are what give the human voice its timbre. The same is true of many birdsongs. Our preference for harmonic intervals may have evolved through a sensory predisposition to intervals that reflect the spectral characteristics of our own vocalisation – which means that the same intervals would be expected to occur in other species with similar preferences. Based on this rationale, I compared the song of the nightingale wren to three different human scales of music[1].

What I was asking, therefore, was essentially this: is each note of the wren's song related to the next in the same way that notes of human music are? Do birds sing in fifths, and thirds, and the other divisions – harmonics – of the octave, as human songs are arranged? Can you write birdsong, the tunes that birds sing, as musical notes on a stave?

To put it technically, do the notes of the nightingale wren come in frequencies which are simple ratios of one another? Or do they instead produce random frequencies, discords and dissonances, which only our anthropomorphising and wishful thinking (and perhaps poor hearing compared to that of birds) prevent us from recognising as such? Strangely, no one has researched this before.

Which is not to say that there are no beliefs about it. Since ancient times humans have judged bird signals – plumage as well as vocalisations – by human

Northern nightingale-wren (*Microcerculus philomela*), 1902, by John Gerrard Keulemans (1842–1912)

standards of beauty; some modern researchers have followed them. Baptista and Keister[2] wrote: "Some birdsong is pitched to the same scale as Western music, which is one possible reason for human attraction to these sounds", but they produced no evidence for their statement. Many other examples can be found in ornithological literature: Saunders[3] suggested in 1959 that white-throated sparrows, *Zonotrichia albicollis*, have a musical interval of a perfect fourth between the first and second notes; Borror and Reese[4] suggested a few years earlier that the songs of the wood thrush, *Hylocichla mustelina*, "are so pitched that they follow our musical scale very accurately". It has also been claimed[5] that the canyon wren, *Catherpes mexicanus*, sings in the chromatic scale (musical scale with 12 pitches per octave), and the appropriately named Wing[6] has written that the hermit thrush, *Catharus guttatus*, sings in the pentatonic scale (musical scale with five pitches per octave). But despite all these claims, no formal test has analysed the harmonic properties of bird vocalisations.

Musical intervals are based on the regular subdivision of the octave. It is perfectly possible that animals may use these same intervals as rules to organise their vocalisations. It is perfectly possible – but does it actually happen? Is that what birds do? If so, it would raise further intriguing questions, such as *why* they do it. (The same question can, of course, be asked about humans. Various evolutionary mechanisms have been suggested for our love of music, but no definitive answer has yet been found – though Darwin[7] himself suggested that birdsong was "the nearest analogy to language".)

So my question "Is the song of the nightingale wren music?" can be rephrased, somewhat less beautifully, to this: "To what degree do the intervals between adjacent notes of the song of nightingale wren, *Microcerculus philomela*, conform to harmonic intervals?" That was what I was in the rainforest to determine.

Can birds produce and recognise music?

Certainly birds have the physical equipment to make music. The bird equivalent of our vocal chords is the syrinx, and it is well able produce tones of any pitch or frequency within its range. Birds also seem to have the necessary hearing – and, as important, the neural capacity within their brains – to relate harmonically linked sounds. Birds can perceive the harmonic structure of single elements –the harmonies within single notes, which musicians call the timbre – in their songs, and in some cases use it to encode biologically relevant information such as the presence of predators. Some bird species even show relative pitch discrimination as humans do and can discriminate pairs of notes by their frequency ratios – they can *recognise* musical intervals whether or not they produce them. Overall, the available evidence suggests that birds have the abilities they would need to conform their songs to harmonic intervals. To put it anthropomorphically: they could do it if they wanted to.

On the other hand, the opposite is also true. Some musical instruments – piano, flute, clarinet – can only produce frequencies in fixed ratios – discrete notes. Others – violin,

"On the whole, birds appear to be the most æsthetic of all animals, excepting of course man, and they have nearly the same taste for the beautiful as we have. This is shewn by our enjoyment of the singing of birds, and by our women … decking their heads with borrowed plumes, and using gems which are hardly more brilliantly coloured than the naked skin and wattles of certain birds." (Charles Darwin, *The Descent of Man*, 1871) trombone – can produce any note of any frequency at all, on a sliding scale. The human voice-box, and the bird's syrinx, are like the latter. There is no physical reason why a bird should limit the sounds it produces to those whose frequencies are in simple ratios to one another.

Nightingale wren – pure pitch

The song of the nightingale wren is ideal for discovering the presence or absence of harmonic intervals. Trills, rhythms, repetitions, and variations in duration of notes are important parts of most birds' vocalisations; the nightingale wren has none of those in its repertoire. It sticks just to variations in pitch. If you want to hear what it sounds like, downloadable recordings are at `http://www.xeno-canto.org/species/Microcerculus-philomela?&view=3`. Its song is one almost pure steady pitch held for about half a second, followed by another, then another, so the pitch relations between successive notes are easy to analyse. It also has variations from place to place: different populations, in areas just a few kilometres apart, sing slightly differently – they have local accents. The variation is due to different ordering of notes rather than any change in underlying structure. Those local accents gave me a bigger database of songs to study; I could test for the existence of harmonic intervals in many different arrangements of notes.

The science

The hypothesis I was testing was that the frequency ratio of adjacent notes would be closer to harmonic intervals than would be expected by chance. So the nightingale wren was an ideal choice.

Besides my eight birds from La Tirimbina I obtained 73 recordings from bioacoustics archives from eight sites. These recordings belong to nine populations from the Caribbean Slope of Costa Rica and eight populations from other locations in Central America and Mexico. Thus, I had a total of 81 birds, and the recordings fairly represent the song variation across the entire geographical distribution of the species.

To see if musical intervals were there I measured the frequency (i.e. the pitch) of a note in a song, and of the note that followed it. I did this for every note in the bird's song; and

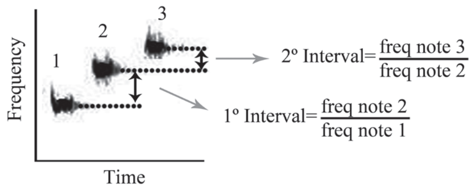

Figure 1. Spectrogram of three notes of the nightingale wren showing the calculation of interval ratios between adjacent notes. Dotted lines indicate the fundamental frequency of the notes (frequency with the highest energy). Interval ratios were defined as the ratio of the fundamental frequency of the second note to the first note of the interval

for every song of every bird. If it was music, dividing the two would give a simple whole-number ratio (Figure 1). If the ratio was 3:2 – better expressed as 1.5:1 – the bird would be singing in a perfect fifth; if the ratio was 4:3 (1.33:1) it would be producing a perfect fourth. (Ratios were divided by 2, several times if necessary, to bring the left-hand side to a number between 1 and 2. This eliminates complications from octaves. A ratio of 3:2 and a ratio of 3:1 are harmonically the same: both are perfect fifths.) But if the ratio between notes was not a simple whole number, the implication is that the bird is not attempting to produce "music".

The harmonics – the whole-number ratios – I was seeking are those that are found in three different human musical scales: the diatonic, the pentatonic, and the chromatic (see box). The chromatic may seem the simplest: it is the scale produced by playing every adjacent note, black and white, in turn on a piano keyboard. In fact it is most complex of the three; some of its ratios are obtained not from the adjacent note, but from the note two places away from it; it would demand more complex mental processing from a bird which produced it.

There is, of course, a complication. We cannot expect every bird to sing perfectly in tune, any more that we can expect it of every human. For instance, suppose a bird sings two notes with a ratio of 1.53 in their frequencies. This is close to 1.5, a perfect fifth, but it is not exact. Do we have here a musically challenged bird which is trying but failing to sing in tune – or a bird with perfect pitch and musical ability which does not care whether it is making music or not? A ratio of 1.47 is just as close the other way; both are 0.03 – or 66% – away. I converted all these distances to percentages of the distance to the harmonic interval value. 100% represented a perfect match, an exact harmonic interval, and 0% the furthest distance from harmony that a bird could be – exactly in the middle of two harmonic intervals.

So, for each bird, I had a series of percentage numbers showing how far from musical harmony each of their successive notes were. I compared that to a random distribution of percentages. Each song was, on average, 96 notes long. (The shortest was 15, the longest lasted a Wagnerian 970 notes) A series of 96 random, not deliberately harmonic, notes would be expected, by chance, to have a certain number of harmonies. Each song was compared to the expected random distribution of percentages for an equal number of notes. Did the birds do better than chance?

Did I find enough musical birds to suggest that they were trying to make harmonies? Sadly for the romantic in all of us, the answer is "no". I had 81 birds; I tested each one for the harmonies in each of three different musical scales, giving a total of 3 × 81 = 243 comparisons. And only five of my birds were significantly close to producing music.

Two of those birds had songs that conformed to the chromatic scale. Three were singing in the pentatonic scale. And the song of one of those three also conformed to the diatonic scale. Only two of the musical birds came from the same population, so it is not the case that one small group of birds has learned to produce music.

Three musical scales

(A) The chromatic scale has the 12 intervals used in Western music. (B) The major diatonic scale, of seven notes plus the octave, is the familiar do–re–mi–fa–sol–la–ti–do. (C) The pentatonic scale is a further subset of the above; its five notes, plus the octave, were used by the Ancient Greeks in lyre music, and are used in nearly every riff played on the electric guitar.

F: fundamental; m: minor; M: major; P: perfect; A: augmented. Numbers represent the ordinal position of the note, so that M2 = major second, P5 = perfect fifth.

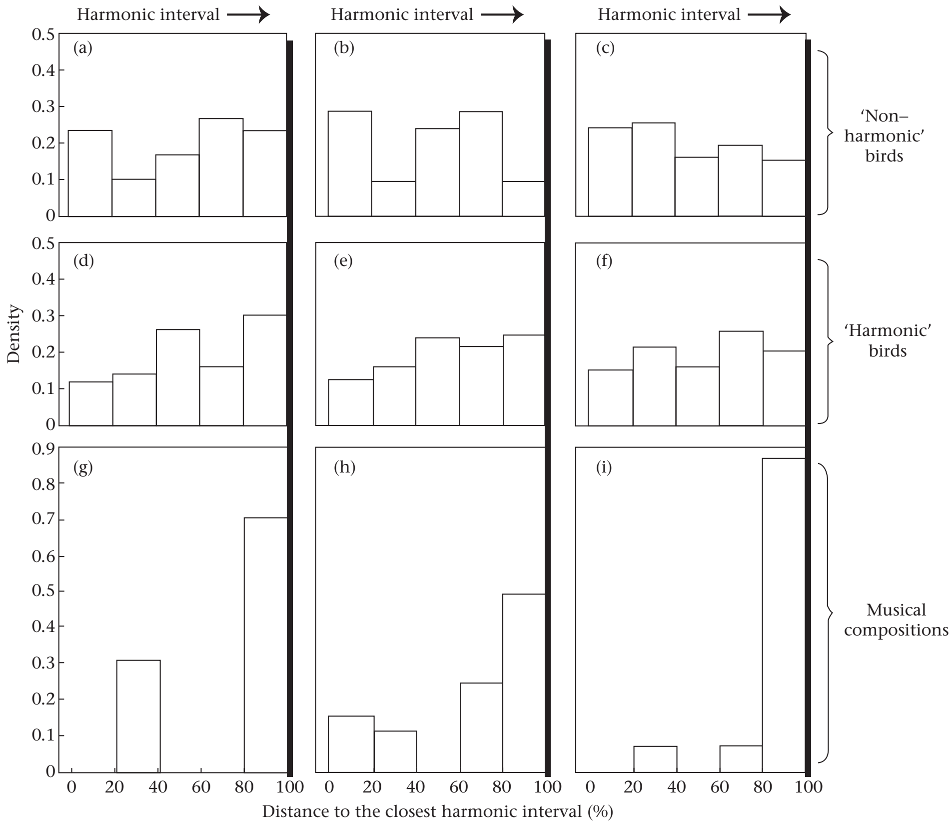

Figure 2. Distance to harmonic intervals (in the chromatic scale) of adjacent note ratios from nightingale wrens and from human composers. The bars show proportions of intervals that are at various distances from perfect harmony.

The top row, (a)–(c), shows three "non-harmonic" nightingale wrens, whose adjacent note ratios were non-significantly close to harmonic intervals. The middle row, (d)–(f), shows three "harmonic" birds, whose adjacent note ratios were significantly close to harmonic intervals; the bottom row shows three human compositions from classical music: (g) Bach's *Cello Suite No. 3*, Prelude, played by Janos Starker; (h) Bach's *Suite No. 3 for Cello Solo in C Major*, played by Carlos Prieto; (i) Kodály's *Cello Solo Sonata*, first movement, played by Inbal Segev.

Distances are shown as percentages. In the histograms, 100% represents the closest distance (a perfect harmonic interval; thick lines) and 0% represents the furthest distance (exactly in the middle of two harmonic intervals).

Even the "musical" birds did not by any means sing every note in tune. The first row of Figure 2 shows graphically how far away the notes of three of the unmusical birds were from harmony: for each of them about one-fifth of their notes were about as dissonant as notes can be. The second row shows three of our "harmonic" birds – but even for those, one-tenth of their notes were as far as notes can get from harmony, while only about a third of their intervals were at the musical end of the spectrum.

The figure also shows a comparison I made to test my statistics: I used the same method to test whether human compositions were "musical". I took classical compositions, such as Bach's *Six Suites for Unaccompanied Cello*; I took jazz standards such as 'Autumn Leaves', and popular music as well – 24 compositions in all. All were played on continuous pitch instruments, such as cello, violin and trombone; and, happily, the intervals in all of them turned out to be significantly close to intervals in the chromatic scale. Twenty-one were significantly close to the diatonic and pentatonic scales as well. Figure 2 shows three of the classical compositions. The chunks of non-harmonic intervals were probably due to transitions or ornaments around a central note.

Discussion

I am not saying that the song of the nightingale wren is not beautiful. It is. I find it beautiful, at least. What I am saying is that it does not conform to the harmonic rules of human music. It is not organised by the most characteristic rules than humans use in musical composition. When we hear it as "music" we are probably projecting our own subconscious biases or indulging in wishful thinking.

Overall, the frequency relation between adjacent notes did not fit with harmonic intervals, nor was there any consistency in the particular scale used in the few cases (2.5% of all examined) where harmonic scales were detected. The few songs that did conform to musical scales are probably an unintended matching to harmony, which can be expected based on my large sample size of 81 birds and 243 comparisons. Given the uncommon use of harmonic intervals in this species, my results strongly suggest that it is not an intentional feature of these birdsongs.

Nightingale wren song is unusual among birdsongs in the extent to which frequency alone, rather than duration or patterns of trills, is dominant. If the harmonic relationship between notes is not used to organise notes in this species, it would seem even less likely that it occurs in other birds with more complex songs. Nevertheless, we cannot rule it out. The harmonic birdsong hypothesis remains to be tested in other species. It may be that the sheer simplicity of the nightingale wren's song is a factor in its lack of harmonies. There is room yet to discover, or at least to investigate, musicality in birds.

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