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Fractal Musical Rhythms

By Samuel Arbesman
Email Author
February 20, 2012 |
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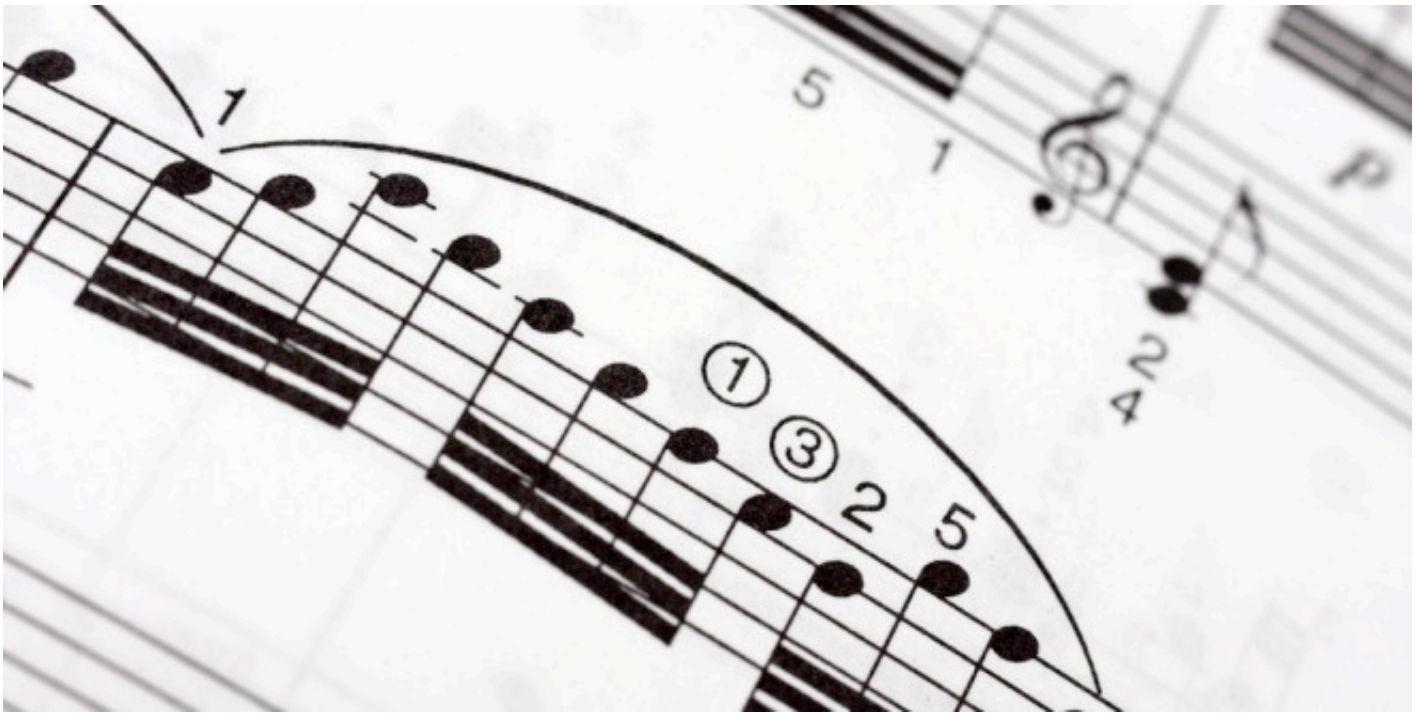


One of Martin Gardner's collections of his Mathematical Games columns from *Scientific American* is titled *Fractal Music, Hypercards and More...* The title article "White, Brown, and Fractal Music" is all about how the pitch structure of different types of music can be easily distinguished by the human ear. We know what white noise is: It's the static we hear in between radio stations. No

sound is correlated with the next one, so we get undifferentiated noise.

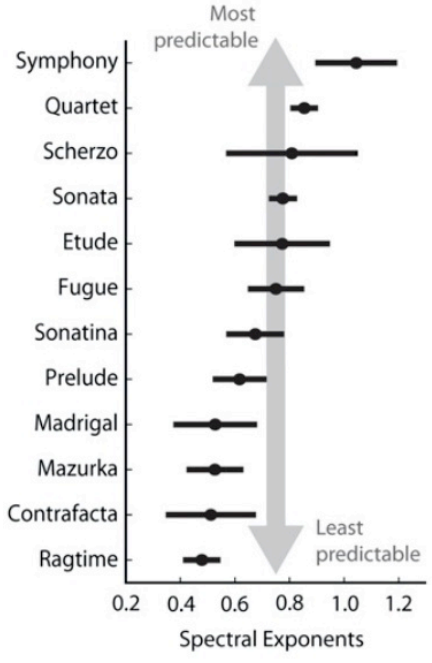
The other extreme is what is known as Brownian, or brown, music. It's based on Brownian motion — random motion of small particles — where every position is only a small distance from the previous position. Brown music is simply a random walk up and down the musical scale.

In between though, is what is known as 1/f noise. Sometimes also called pink noise, this music has some correlation, but less than brown music and more than white noise. It is defined as a power law decay in the correlations between pitch over time. The equivalent in motion include what are called Lévy flights, which are similar to how bank notes travel around the United States: sometimes traveling very short distances, and at other points hopping across the country. (Note: This type of power law is related to the normal type of power laws that many of us have heard of, where the "popularity" of phenomena follows a heavy-tailed distribution.)

Most music that we actually listen to is 1/f noise. It has the right combination of pattern and unexpectedness, and is pleasing to the human ear. And as a fun bonus, if you look at the shape of the curve described by 1/f music, it has a fractal shape. Just as shapes in nature are often fractals — self-similar objects at all scales — so is it true with human-created music.

While this property of music has been long-known when it comes to pitch, in a new paper in *PNAS*, a research team led by Daniel Levitin set out to see if there is a similarly fractal structure in musical rhythms.

Surprisingly, while rhythm is quite regular, it turns out that it is not as predictable as we might have expected. As the authors note, "Because music has a beat and is based on repetition, it has been said that 'what' the next musical event will be is not always easy to guess, but 'when' it is likely to happen can be easily predicted." But if you look at the timing of musical notes, they are not as regularly spaced as we might expect and in fact have a certain fractal structure as well. Using a large collection of music that spans centuries, the researchers find that musical rhythm obeys a 1/f pattern, with different types of music being able to fit to this power law (though varying in the exponent of the power law).



But more important than the fractal nature of the rhythms are the variations in the predictability of this exponent for different types of music and different composers. For example, composers with a more varied style, such as Mozart or Joplin, composed

music with more varied spectral exponents, as compared to Beethoven or Vivaldi. Musical styles also varied, with ragtime or madrigals being far less predictable than symphonies or scherzos.
While this is a fun result, I wonder we could get a 1/f pattern simply having a metronome-like regular rhythm, overlaid with some random notes? Perhaps the power law fits are not quite as unique as we might expect.
But quibbles aside, these sort of regularities for aesthetics are intriguing. Our brains seem particularly well suited for processing certain types of sounds, and find ones that have a fractal structure to be particularly pleasing. The next step is to discover a musical style that is emphatically not fractal. Something sung by William Shatner perhaps?
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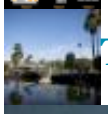
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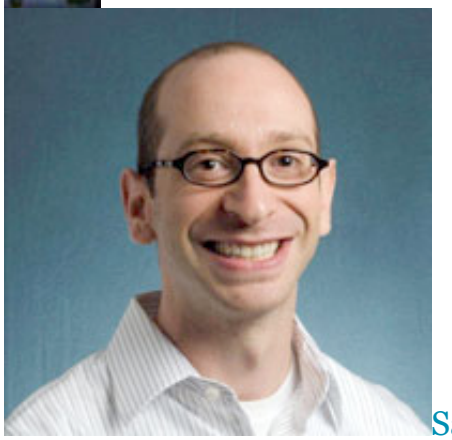
Samuel Arbesman is a senior scholar at the Ewing Marion Kauffman Foundation and author of the forthcoming book 'The Half-Life of Facts'. His research and essays explore how to quantify all aspects of society.
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Maybe something about how memorable a song is based on it's distribution? At a Berklee School of Music workshop a couple of years ago, John Mayer described creating interesting pop melodies as having larger intervals and more rhythmic variation than is currently common. Much modern pop music having very limited spectral distribution (or musical intervalic spread), and correspondingly being forgotten months later.
There used to be a show called "Name That Tune" where contestants would wager that they could name an upcoming tune in some number of notes, usually less than 5-7. Which would be just about impossible with much of current pop music, since it has no melodic variation. Or as this article refers to it, spectral distribution.

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Lurch

as a life long pro musician who has worked with forensic audio, i have often thought fractals are part of audio. if you look at a waveform in 3 dimensions, the patterns are very similar as other forms in nature.... all nature down to the atom are made of fractals. fractals are the building blocks of nature...

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metavitae

Fractal Music?

Didn't Tool already do this with "Rosetta Stoned" or "Schism"?

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AmishRakeFighter

I thought that was Fibonacci/Golden Ratio

02/22/2012 10:01 AM in reply to metavitae Like Reply

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@galtsgulchblog: Great post (and totally agree). What is this generation's "My Sharona?"

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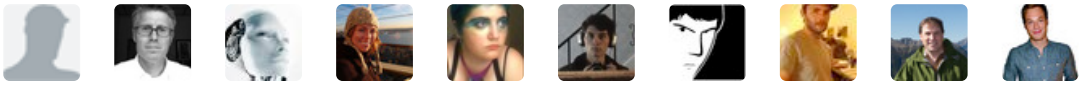

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