Research team develops mathematical model to explain harmony in music

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(PhysOrg.com) -- Bernardo Spagnolo of the University of Palermo in Italy and his Russian colleagues have developed a model that they believe explains why it is we humans hear some notes as harmonious, and others as dissonant. The team, as described in their paper in *Physical Review Letters*, say that such harmony can be explained by our auditory neural system.

Most people can hear the difference between harmony and general noise. It's evident in a guitar chord: strike the notes C, E and G together and you get the familiar C Major Chord, so often heard in popular music. Mess up one note though, and everyone will wince. The same can be seen watching American (or other country) Idol; not when a contestant singing A cappella goes off key, but when a singer hits (or misses) a note that harmonizes with a note played on an accompanying instrument.

There have been many theories suggested over the years as to how and why we hear some groupings of notes as pleasing and others as wrong, or off. Some have suggested that our brains simply receive a stream of notes and make of it what we will. Spagnolo et al, however, disagree, and they have a model that they say proves it.

In their paper, the team says that we humans have different neurons in different parts of our ears that respond to different frequencies. Say perhaps one group responds to the C note on a guitar, and another to an E, etc., these are called sensory neurons. But that's not enough to account for "liking" the two being heard at the same time. To explain this, the researchers suggest that we also have a third type of neuron called an interneuron. In their model, they suggest that the sensory neurons send signals to the interneuron, which then sends signals based on what its "heard" from them to the brain.

What's more, the team says that the sensory neurons conform to the "leaky integrate-and-fire" equation whereby the stimuli (in this case sound) drives up the voltage until it reaches a saturation point, whereby it then discharges it's information (in this case to an interneuron), which then sends signals to the brain. If the sensory neurons were to all fire constantly, the interneurons would be inundated and unable to process all the information from multiple sensory neurons.

The team then applied information theory that says that the less random a signal is the more information it has and came up with a number they call a regularity. And it's this regularity that explains our "likening" different notes when heard together. "Good" notes played together result in a high regularity (because they have more information in them) while dissonant notes produce lower regularity.

And that is why we smile when listening to two or three people who harmonize perfectly together, but frown when hearing the results of those less gifted.

More information: Regularity of Spike Trains and Harmony Perception in a Model of the Auditory System, *Phys. Rev. Lett*. 107, 108103 (2011). DOI:10.1103/PhysRevLett.107.108103

Abstract
Spike train regularity of the noisy neural auditory system model under the influence of two sinusoidal signals with different frequencies is investigated. For the increasing ratio m/n of the input signal frequencies (m, n are natural numbers) the linear growth of the regularity is found at the fixed difference (m-n). It is shown that the spike train regularity in the model is high for harmonious chords of input tones and low for dissonant ones.

via [Focus]

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