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Laws of form:
the congruence between musical theory and neuroscience

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Commentary on
Trulla, LL, Di Stefano, N, Giuliani, A, 2018, "Computational Approach to Musical Consonance and Dissonance", *Frontiers in Psychology*, vol 9, pp. 381-388.

An old (but evergreen) quest

The development of a 'physically grounded' (and thus both necessary and natural) musical theory establishing a 'just intonation' scale and then separating music and noise dates back to Pythagoras. The (largely mythical) foundation narrative of the ancient Greek philosopher and mathematician discovering the basis of consonance in the 'simplicity' of natural ratio of the beat frequencies of two smiths, simultaneously hammering two pieces of iron together with the invention of monochord (that some scholars dated back to Sumers) posited the 'musical beauty' into the realm of quantitative sciences. Musical theory entered modern sciences since their beginning: Galileo Galilei (the son of a prominent musician and music theorist, Vincenzo) made many experiments with monochord and developed a physical explanation to Pythagoras definition of consonance (Galilei, 1638). Galilei was the first one to try and to connect the 'perceived' quality of the chords with the physical nature of their generation. Moreover, the 'equal tempered scale' definitively formalized by Johann Sebastian Bach (still at the bases of the western and, with only slight modifications, of any other musical tradition) is largely consistent with Galilei's observations (Plomp and Levelt, 1965).

The development of physiology and neuroscience produced an impressive body of evidence of the 'biological bases' of consonance/dissonance perception (Foo et al., 2016; Park et al., 2011).

But, with the advent of dodecaphonic music at the beginning of the twentieth century and with the actual political/philosophical debate on the 'nature vs. nurture' opposition, the evident correlation between musical theory and human perception entered into a (largely political) arena. Roughly the question became 'Yes, we agree that the physical features of sound match with their neurological representation, but how can be sure that this is a consequence of the 'cultural milieu' (i.e. the sounds we are exposed to that shape our nervous system by a continuous learning/adaptation process) more than a 'wired' necessary coherence between nature and music ?'.

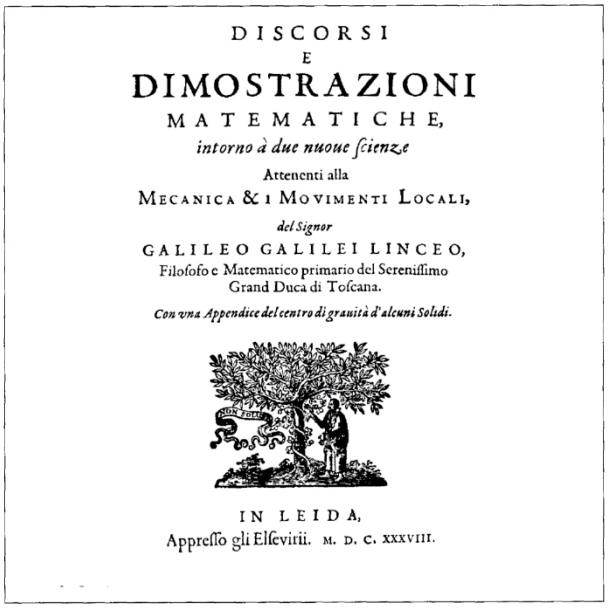
DISCORSI
E
DIMOSTRAZIONI
MATEMATICHE,
intorno à due nuoue ſcienze
Attenenti alla
MECANICA & I MOVIMENTI LOCALI,
del Signor
GALILEO GALILEI LINCEO,
Filoſofo e Matematico primario del Sereniſſimo
Grand Duca di Toſcana.
Con vna Appendice del centro di grauità d'alcuni Soldi.
IN LEIDA,
Appreſſo gli Elſeuirii. M. D. C. XXXVIII.

Fig.1. Galileo Galilei: *Discorsi e Dimostrazioni Matematiche Intorno a Due Nuove Scienze* (1638).

The recent Nature paper (Mc Dermott et al. 2016) reporting the existence of isolated Amazonian populations that are not able to catch the difference between consonant and dissonant sounds, re-opened the question about the 'natural and necessary' character of the consonance. This is an important finding, the abundant literature of the preference for consonance in preschool (less than two years old) children (Di Stefano et al. 2017) notwithstanding. McDermott et al. (and many other scholars) arbitrarily conflate the 'personal preferences' with the 'natural character' of sounds (by the way any composer since medieval times inserted dissonant tracts in musical compositions, a 'consonant only' piece tends to be very boring indeed). The more or less explicit goal is to demonstrate the 'arbitrariness' of any 'natural pattern' according to the relativistic analytical philosophy trends of these times.

Therefore, the 'question on music' becomes a 'cultural battle' for the existence of a 'natural world outthere' that we study by means of our personal (and thus historically and philosophically shaped) approach but that whose 'real' existence does not rely on our personal ideas. This is why the commented paper is of utmost importance for the reader of Organisms.

2. The very basic skeleton of music

The authors approach the old issue of consonance/dissonance discrimination by focusing at the most basic level of sound generation: a composed (AB) signal resulting from the addition of two computer generated basic signals (A and B amplitude time series). The two basic signals were a glissando from 360 to 840 Hz (A) and a constant frequency at 400 Hz (B) respectively. The glissando spans all the space of an octave, while constant signal corresponds to the metronome 'A' tone (La in the Continental European/Italian notation). The glissando changes continuously its frequency, thus the production of consonant chords happens 'on the run', with no possibility to be analyzed by a Fourier-like approach. That fact makes frequency as inextricably related to time and rules out any a-priori separation of 'specific tones' (by the way, the same categorization of a continuous spectrum into seven categories we name as 'tones' could be an arbitrary construct). No listener is present: the combined AB (A+B) signal is analyzed by means of Recurrence Quantification Analysis (RQA, Marwan et al. 2007), a model-independent technique that in this case is only applied to count the 'amount of recurrences' (i.e. the repeating of the same pattern of instantaneous amplitudes) along the AB combined signal.

This approach allowed to perfectly reconstruct the Bach's 'consonance scale' of chords so giving a proof-of-concept of the Galilean approach: consonant chords are 'special' since their birth, appearing as 'discrete recurrence peaks' along the series, without any listener intervention. This is the main message, that was further complemented with the discovery of fractal nature of consonance distribution, consistent with recent findings about 'phase transitions' in neural processing (Lots and Stone, 2008).

All in all, we can affirm that organisms are 'At home in the Universe' (Kauffmann, 1996): the same self-organization laws shape sound production and neural perception as well as tissue organization and cell shape. This has nothing to do with 'personal preferences'; the issues must be separated, but the cultural battle of some intellectuals to deny any reality to the natural world in order conflate any idea to 'personal preference' is a dangerous (and wrong) position that represents a menace for the development of both science and civilization.

References

Di Stefano, N., Focaroli, V., Giuliani, A., Formica, D., Taffoni, F., and Keller, F. 2017 A new research method to test auditory preferences in young listeners: results from a consonance versus dissonance perception study. *Psychol Music* vol 45, pp. 699–712.

Foo, F., King-Stephens, D., Weber, P., Laxer, K., Parvizi, J., and Knight, R. T 2016 Differential processing of consonance and dissonance within the human superior temporal gyrus. *Front. Hum. Neurosci,* vol 10, pp. 154.

Galilei G. 1638 *Discorsi e Dimostrazioni matematiche intorno a due nuove scienze attinenti alla meccanica ed ai movimenti locali*, Elsevier (Leiden). [English translation: *Dialogues Concerning Two New Sciences*, 1954, Eds. & Translators Crew H. and de Salvio A., Dover Publications Inc., New York]

Lots, I. S., & Stone, L. 2008. Perception of musical consonance and dissonance: an outcome of neural synchronization. *Journal of The Royal Society Interface*, vol 5, n. 29, pp. 1429-1434.

Marwan, N., Romano, M. C., Thiel, M., and Kurths, J. 2007. Recurrence plots for the analysis of complex systems. *Phys. Rep*. vol 438, pp. 237–3

McDermott, J., Schultz, A. F., Undurraga, E. A., and Godoy, R. A. 2016. Indifference to dissonance in native Amazonians reveals cultural variations in music perception. *Nature* vol 535, pp. 547–550.

Park, J. Y., Park, H., Kim, J. I., & Park, H. J. 2011 Consonant chords stimulate higher EEG gamma activity than dissonant chords. *Neuroscience letters*, vol 488, n. 1, pp. 101-105.

Plomp, R., and Levelt, W. J. M. 1965. Tonal consonance and critical bandwidth. *J. Acoust. Soc. Am*. Vol 38, pp. 548–560

Kauffman, S. 1996 *At home in the universe: The search for the laws of self-organization and complexity*. Oxford University press.