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Article

Understanding Musical Consonance and Dissonance: Epistemological Considerations from a Systemic Perspective

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Abstract: Different accounts have been given in order to face the problem of the emergence of musical consonance and dissonance. Getting a more adequate comprehension of such phenomenology may require a systemic view to integrate such multidimensionality into a unitary picture in which every partial solution enlightens a particular aspect of the very same problem. Such a systemic viewpoint shifts the focus from *different explanations* to *analytic dimensions* that seem to be embedded in music perception. Taking into consideration these dimensions means understanding consonance and dissonance in an *embodied context*, in which arithmetic, physics, psychology and physiology are part of a *complex and dynamic process of understanding*, which is not reducible to any privileged explanatory level.

Keywords: consonance; dissonance; music; systems understanding; context; embodiment; emergence; dynamism

1. Introduction: A Systemic Approach

One of the main difficulties to develop our understanding through systems theories is connected to conceptualizing systems in terms of their dynamic organization and evolution. In particular, when dealing with living systems and some typically related issues, like development and historicity of the system, we need new explanatory frameworks able to bring back into the same picture both the system and its environment. This aspect also poses the philosophical challenge to explain how the system and the context conceptually imply each other in the process of understanding [1].

There is, in fact, an on-going revolution forcing the scientific community to elaborate new multilevel and complex models especially when dealing with human and biological processes. Such models often emerge as relational dynamic networks with elements that acquire a specific explanatory relevance depending on the level of discussion and on the question posed [2].

Although a kind of relationship between understanding, explanation and contextual factors holds, it is increasingly clear that the understanding process exceeds a mere psychological upshot or acquisition of data. At the crossroads of all these issues there is the question about how such relationships s*hould be understood in explanatory and in conceptual terms*.

In this debate, failure of current models of scientific explanation (deductive-nomological model, statistical relevance, unification, causal-mechanical models, *etc*.) to capture the notion of explanatory relevance has been widely addressed [3]. Part of the difficulty is that, to express such relatively fine-grained judgments of explanatory relevance, we need to talk about relationships between properties or magnitudes and our decisions on which facts or features are relevant, that seem to precede our judgments on causal processes and interactions [4].

In this paper, our aim is to offer a new perspective on the explanation of consonance and dissonance in music. Such perspective implies acknowledging the explanatory relevance of different accounts—in mathematics, physics, physiology and psychology—while shedding light on their epistemological relationships.

In scientific literature, different approaches try to enlighten the phenomenon considered: for example, neural based studies [5], arithmetical studies [6], multicultural and intercultural studies [7]. However, the explanations of the same problem currently still remain at least partly unrelated. Therefore, the need for an interdisciplinary approach is strong, and a wider approach to consonance and dissonance phenomenon has been somehow suggested [8,9]: the urge for new systemic approaches, theories or explanations is arising within the disciplines themselves. Facing these issues, in this paper we suggest that within a systemic perspective, different specific explanations can be seen as parts of a more comprehensive understanding process. Thus, we focus on approaches that are already partially considered by different disciplines, aiming at offering a unitary theoretical understanding of their properties and relationships. For this purpose, the systemic approach could be suitable, since it describes different properties of objects aiming at understanding their inner relational properties. A peculiar property of systemic approach is to guarantee the possibility of being suitable to different objects and to different areas of inquiry, which is the reason why we believe that it can be helpful for understanding the phenomenon considered [10].

2. Consonance and Dissonance Phenomenon

Consonance and dissonance are musical notions which have been widely studied from the ancient Greek philosophy to nowadays. Boethius, in the V century, adopted two opposite couple of terms for characterizing consonance and dissonance: consonance sounds “suaviter et uniformiter” while dissonance is “aspra et iniucunda” [11]. Though giving a satisfactory and complete definition of the terms is still a matter of debate, we can consider *consonance* as the relation that links two or more sounds sounding pleasant together, while *dissonance* as the relation that links two or more sounds sounding unpleasant together [12,13]. To our purposes, we can consider *harmonic intervals* (*i.e.*, two sounds which simultaneously sound together).

From arithmetic to physics, from physiology to harmony, from sociology to cosmology, different approaches have tried to explain the difference between consonant and dissonant sounds. In this paragraph we give just a brief overview of the principal explanations of the phenomenon, to enlighten the epistemological aspects on which we will focus on in the following paragraph.

2.1. Arithmetical Approach

Consonance and dissonance in music were first approached systematically by Pythagoreans and explained in terms of frequency ratio of intervals. Pythagoras, in the VI century B.C., postulated that the simpler the frequency ratio, the more consonant the interval: frequency ratio of 2:1 gives the octave, which is the most consonant; frequency ratio of 3:2 give fifths and frequency ratio of 4:3 give fourths and so on decreasing in consonance. The Pythagorean “tetractys”, composed by integers 1-2-3-4, gives reason for all the perfect consonances [14].

Pythagoras enlightened the numeric dimension of music, which has important consequences not only for the theory of music but also for the material structure of musical instruments. The construction of musical instruments, in fact, is deeply related to numeric proportions: length of organ pipe, length and width of strings can be explained in terms of frequency ratio [15].

Pythagoras’ mathematics is metaphysic. Everything in the universe, from the whole world to the single creature, is ruled by numbers. Since numbers are order, the universe is a *kosmos*. Numbers, for Pythagoreans, are the deepest reasons of reality: “The issue of consonance and dissonance was for the Pythagoreans not a matter of devising a theory that was harmonious with their hearing, but rather one of hearing the numerical truth that they discovered to be inherent to nature” [16].

2.2. Physical Explanation

In physics sound is pressure changes in the air or other medium and is represented as a wave. Perceived sound properties, as pitch, timbre and loudness, have their physical correlates in wave properties (*i.e.*, fundamental frequency, waveforms and amplitude of wave). While arithmetic focuses only on the fundamental frequency of sounds, physics considers *complex* sounds, composed by several harmonics [17,18].

Thus, in the physical explanation of consonance, the notion of “critical bandwidth” plays an essential role. Critical bandwidth can be considered the maximum frequency difference between two tones to interfere with one another. If two tones interfere, beating will be hearable. In physical explanation, beating is strictly related to consonance: the more we hear beats, the less consonant the interval (see for example [19]).

In this perspective, combination of sounds becomes increasingly complex, since we have to consider not only the fundamental frequency ratio but also the matching of partials and their overlapping.

2.3. Physiological Explanation

Consonance and dissonance have been approached also considering the physiological component of human beings, since we deal with acoustical perceptions. In this approach, the human component (anatomy of hearing apparatus) and physical wave properties are considered together from a unitary perspective.

Consonance and dissonance depend on *how* the sound waves hit the tympanic membrane and *how* “regular” is their beating. Consonance is associated to most regular beating of tympanic membrane [19]. Since the elasticity of the basilar membrane in the cochlea is non-homogeneous, the same interval at different frequencies has different effect on perceiving system [20,21].

Several studies show that regularity of the stimulation is reflected into the regularity of the brain response: consonant stimuli produce different reactions within the brain in respect to dissonant stimuli (see for example [22]).

An analogue physiological level can be also traced in animal world [23,24], suggesting that consonance and dissonance discrimination is present in different species.

2.4. Psychological Explanation

Consonance and dissonance have been treated in psychological terms since the beginning of the 20th century (see for example [25]). In these studies, subjects are asked to judge different consonant and dissonant stimuli through different parameters like “smoothness”, “fusion”, “pleasantness”. Then, data analysis searched for correlations between the parameters and intervals, aiming at a clearer characterization of consonance and dissonance and at a deeper understanding of their properties.

Fusion [26] is a specific property of human perceptual experience, which regards all different kinds of perceptions (acoustical, visual, spatial), and depends on both human psychological structure and properties of the *perceptum*. We can perceive two sounds as *fuse*, but not, for example, a sound and a color. Consonant sounds are *perceived* as a unique sound, while dissonant sounds can’t be *perceived* as one. The degree of fusion increases as consonance increases and, *vice versa*, the degree of dissonance increases as fusion decreases.

Smoothness and pleasantness are supposed to characterize consonant music, while roughness and unpleasantness are supposed to be paired, and they characterize dissonant music. Literature has demonstrated that the definition of the psychological attributes of consonant and dissonant intervals is not so straightforward, since dissonant intervals are as well fused as most consonant ones and pleasantness is not a determinant of fusion, although fusion may determine pleasantness [27].

What characterizes all these different approaches is the belief that the reasons of consonance and dissonance lie in the properties of the psychological structure of humans.

2.5. Cultural Explanation

The cultural explanation of consonance and dissonance lies on the distinction between "sensory consonance" and "perceptual consonance". The notion of "sensory consonance" is related with the "hard" roots of perception, whether biological or psychological, while the notion of "perceptual consonance" opens to a wider understanding of perception in which not only biological properties but also cultural influences effectively act in the perceptual process.

The stress on cultural components of consonance and dissonance perception rejects any decisive relevance of biological elements in explaining the phenomenon considered. The main argument is very straightforward and simple: since different cultures use consonance and dissonance in different ways, consonance and dissonance can't be grounded elsewhere than in cultural exposure and habits [28,29]. The differences considered are not only trans-cultural, for example between Western and Eastern music, but also between different ages in the same culture, for example between Baroque and Dodecaphony. In this perspective, the conclusion is that consonance and dissonance are a matter of individual preference. All the reasons lie *ex parte subjecti*: "Consonance is not an absolute entity dependent on the natural properties of the stimulus object as was previously supposed. There is no reason to believe that any intervals are absolutely consonant or dissonant. It is on this assumption that the elementarists are in error. Judging a musical interval consonant or dissonant is merely a kind of psychological behaviour which is determined by many conditions which operate in an individual's life history" [30].

A systemic approach may well be fruitful and interested in accounting for cultural influences on perception, since culture is essentially a complex system. Cultural approach enlightens, in fact, the need to integrate the biological properties of humans with the essential counterpart of biology that is culture. In this perspective, biological level of understanding is uninformative respect to what humans create starting from their raw perceptions. The cultural approach, therefore, stress the active and effective influence of traditions and habits which are somehow neglected in all the previous approaches.

3. Analytical Dimension of the Phenomenon: The Relevance of the Context

When facing complex multidimensional phenomena, accuracy of an explanatory account depends not only on the level of details gained through different methodologies, but also on interplay and reciprocal dependence between the scientific question and the phenomenon under inquiry. The different accounts considered above grasp different analytical dimensions of consonance and dissonance, which can be defined, in a general way, as kind of regularities that scientific inquiry focuses on. Every accounts "tells *its* truth" about the phenomenon, but no one "tells *the* truth".

Arithmetic approach considers sounds in abstract, and therefore can be considered a *discrete* dimension. Integers ratios stand for sounds. In this perspective, all the octaves are equal just because they are expressed by 2:1 ratio. The same happens for fifths or fourths or any other interval. Arithmetic *conceptualizes* sounds, but it doesn't *perceive* sounds. This aspect is particularly relevant if we consider that the same fifth played, for example, by two violins and two clarinets is arithmetically the same but physically different, *i.e.*, they result in different waves (different timbre).

Therefore, physics emerges as a new explanatory level, as an explanatory account, which is able to capture the *continuous* dimension. In such an account, a sound is more adequately represented as a continuous entity by a wave. However, neither arithmetic nor physics focus on the structures of the perceiving body.

Table 1. Relationship between explanatory accounts and analytical dimension.

Explanatory accounts	Analytical dimension	Object of Inquiry
Arithmetic	*Discrete*	System
Physics	*Continuous*	
Physiology/Psychology	*Context dependency*	System-Environment Relationship

As represented in Table 1, at the level of physiological and psychological explanations, the context starts to be relevant [31]. This shift implies a deep change in perspective that highlights a fundamental property of music perception: its context dependency. In arithmetical terms, a fifth C-G at 20 Hz is the same in respect to the same fifth C-G at 20 KHz, because their frequency ratio is always 2:3. However, if you are *listening to* consonance, arithmetic no more describes the phenomenon adequately: *hearing* a fifth at 20 Hz is really different from hearing the same interval at 20 KHz, because the basilar membrane response to the same interval changes at different frequencies.

When the context becomes relevant in such terms, the relationship between the system and environment start to be *semantic*: the *dynamic interaction* become essential, *i.e.*, where the meaning properly grows, while at a arithmetical and physical level no interaction is necessary. Semantic, here, means that something becomes significant in different ways as it differently interacts with the context. For example, the same orchestral excerpts rearranged would give totally different result in terms of musical perception, but obviously not in terms of harmonic analysis or tonal analysis. Thus, in arithmetical terms the original version and the altered one are exactly the same. From the physics' perspective, they are different because resulting timbre is different, and so corresponding waveform are different. From the physiological/psychological perspective, they differ because human perceiving system is sensitive to waveforms' changes.

4. Emergence as Embodied Dynamism

A systemic perspective allows us to consider the relationship between elements as proper objects of inquiry. When addressing emergent properties that are conceptually described through relative terms—like consonance and dissonance in our case study—the central question is understanding the *nature of the interaction* of elements involved. The emergent character of musical consonance and dissonance appears, in epistemological terms, when the context dependency becomes relevant in a semantic way (see par. 3). As far as psychological and physiological explanations are more comprehensive than the physical and mathematical ones, such emergent character might have some explanatory priority over consonance and dissonance.

The context, in which the system-environment relationship, as we said above, is semantic, is properly where the emergence of consonance and dissonance phenomena arises, which can be considered as an "Embodied Dynamism". The term "Embodied", here, aims to stress the fact that system-environment relationship is, at this level, intrinsically mutual, *i.e.*, they co-evolve dynamically. In arithmetical or physical level the context is, instead, fixed. When dealing with embodied dynamic networks, the mutual influences between context and phenomenon are the proper object of inquiry.

In this perspective, every different account deals with the emergent original data, which is nevertheless a sort of ontological *primum*. A relevant epistemological question deals therefore with the "distinction between explaining how something does what it does and explaining what it does" [32]. In our case study, physiology explanation deals with *how* we perceive, giving an accurate description of the mechanism that rules the acquisition and processing of hearing information. Psychology explanation deals with *what* we perceive, answering that we perceive different sounds that are more or less fused as one (characteristics of the *perceptum*). That is, any explanation that is able to grasp the "what" aspect is actually able to grasp the emergent feature of music. Let us therefore programmatically address the peculiarity of these relationships between emergence, context dependency and the peculiar unitary character of music.

In terms of multidimensionality, emergence implies different compatible explanatory levels grasping different dynamic dimension of the system. This is why we cannot definitely choose which is the privileged level the phenomenon should be explained at: there is no chance for any *experimentum crucis*, because there are no alternative theories in conflict and no privileged causal level. Systemic approach to consonance and dissonance widen the perspective to the *living context* that is properly where actual perception and cognitive activity do exist. In human experience aesthetics, arithmetic, physics, physiology are fused in a *complex and dynamic process*. Every attempt to find the definite reason or cause in one of this partial aspect loses the unity of the whole. Moreover, as happens for more complex biological dynamic behaviors [33], systemic approach avoids the risk of making methodological recommendations about the ontological restrictions—frequent in epistemological or ontological reductionism—and also avoids deriving methodological indications from holistic principles. For example, the different theories of consonance suffer a too narrow consideration of the dynamics involved: the Pythagorean theory of consonance, the theory of beats, the cultural theory of consonance, the theory of tonal fusion, consider only a particular aspect of the phenomenon as the fundamental one, losing the complexity of the phenomenon itself and reducing sound and intervals relationship to integers ratio relationship, to matching between waves, to smooth or fuse auditory sensations, to aesthetics preference and judgments. Extensions and updates of traditional concepts may turn out to be insufficient to maintain a unitary theoretical framework because of the complexity that biological and physiological processes entails and the different nature of properties under inquiry. Moreover, the problems involved in developing a new theoretical understanding ask for a new conceptualization of the context-dependencies that are fundamental for the explanation.

5. Conclusion

The novelty of the systemic approach to consonance and dissonance is not its object but the way the object is re-approached. We saw how different explanatory accounts may be seen as specific elements of a more comprehensive process of understanding, in which each level shed light on a specific quality of the phenomenon considered. Bringing into the same picture the system and its context, a *systemic perspective* clarifies the epistemological relevance of what we have defined "analytical dimensions" of the consonance and dissonance emergence. It also explains the role of relevant explanatory elements within the process of understanding embodied dynamics. A systemic perspective, finally allows us to avoid reductionist and relativist perspectives or excessive simplifications driven by mere pluralistic accounts of human understanding and scientific knowledge. Depending on the explanatory contexts, meanings can change and require different epistemologies.

What may emerge is an *epistemology* able to ground real interdisciplinary or—more precisely—cross-disciplinary approaches which overcome the epistemological tensions on causal and explanatory notions still affecting the philosophical consideration on the understanding of multi-level and systemic dynamics.

Perspectives changes take place when somebody is able to shift the common perception of what is relevant and for what reason. This issue is also linked with the point—which needs to be further developed in philosophy of science and especially in life and cognitive sciences—on the relativity of the chosen model and the relevance of framing the problem in an adequate way. The systemic approach sketched here and applied to consonance and dissonance can also expand the body of knowledge on *scientific practice* and on *interdisciplinary work* and thus guide changes in policy and practice that are crucial to establishing successful and well-functioning research institutions.

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Author Contributions

Authors have equally contributed to the paper, though Section 2 and 3 have been written by Nicola Di Stefano, while Section 1 and 4 by Marta Bertolaso. The conclusion (Section 5) has been written by both authors.

Conflicts of Interest

The authors declare no conflict of interest.

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