Meta-Xenakis

New Perspectives on Iannis Xenakis's Life, Work, and Legacies

Edited by Sharon Kanach and Peter Nelson

https://www.openbookpublishers.com

Sharon Kanach and Peter Nelson (eds), *Meta-Xenakis: New Perspectives on Iannis Xenakis's Life, Work, and Legacies*. Cambridge, UK: Open Book Publishers, 2024, https://doi.org/10.11647/OBP.0390

Digital material and resources associated with this volume are available at https://doi.org/10.11647/OBP.0390#resources

ISBN Paperback: 978-1-80511-224-2
ISBN Hardback: 978-1-80511-225-9
ISBN Digital (PDF): 978-1-80511-226-6
ISBN Digital ebook (epub): 978-1-80511-227-3
ISBN HTML: 978-1-80511-229-7
DOI: 10.11647/OBP.0390

Cover image: Iannis Xenakis at the C.R. MacIntosh Museum, Glasgow, Scotland, 1987. Photo by Henning Lohner, courtesy of CIX Archives, Lohner collection.

Cover design: Jeevanjot Kaur Nagpal

With generous support from: Centre Iannis Xenakis, Xenakis Project of the Americas/The Brook Center, Université de Rouen: BQRI, IRIHS, GRHis, CÉRÉdI.

8. Iannis Xenakis's Materialism: On the Dialectic of Real-time Computation

Ramón del Buey Cañas and Oswaldo Emiddio Vasquez Hadjilyra

Introduction

Xenakis's lifelong preoccupation with physical matter's contingent properties, and his singular interpretation and adaptation of these for the purposes of music composition are well-established in various Western narratives of post-war music history. Informed by physical principles, on the micro scale, Xenakis postulated grains of sound as limiting quanta of sonic energy to be used *en masse* in composition, a postulate whose digital implementation is still alive and well in the techniques of granular synthesis. On the macro scale, he proposed stochastics as an arrangement principle derived from material motion by painstakingly transcribing statistical computations, making use of the computer well before others did, and crucially, after assessing the aesthetic qualities of the computation's results, he would accordingly adjust them in his compositions. In live performances, he welcomed free and non-human variables to play an active role in his works and when considering computers, he wrote code for software like GENDY where stochastic processes were implemented on both micro and macro scales, modulating dynamically both timbre and the composition's temporal structure with dynamic variations taking place at every register. These instances capture a more general trait in Xenakis's work: that of a contingent matter subject to perpetual motion on multiple scales.

Yet any desires to assign to Xenakis a naive fascination for the clamor of a vibrant matter that evades anthropocentric mastery or control would be quickly refused by Xenakis himself in his revised preface to *Formalized Music*, in which he asserts that for a composer it "is absolutely necessary to free oneself, as much as possible, from any and all contingencies."[1] Such assertions are frequent in Xenakis's writings and exemplify one

1 Xenakis, 1992, p. xi.

 https://doi.org/10.11647/OBP.0390.10

of the main challenges to engage with his work in philosophical terms, since, for him, music was one of his ways of dealing with the philosophical problematics of matter. As an avid reader of dialectics (Plato and Marx) but also the materialists of antiquity (Parmenides, Heraclitus, and Lucretius), and a practitioner of applied mathematics with a concrete understanding of the development in physics and information theory of his time, he poses a challenge to his readers who would need to familiarize themselves with all fields to engage properly with the philosophical implication of his propositions. When considering these compositional and philosophical tenets, as well as Xenakis's political commitment to materialist politics, and in the context of an ongoing revival of materialism, it is worth asking: what is Xenakis's materialism and how do we speak about it in the present moment?

In one of the most comprehensive summaries on what new materialism is and what its future beholds, Christopher Gamble, Joshua Hanan, and Thomas Nail in their 2019 essay "What is New Materialism?" identify at least three strands of new materialism: vital, negative, and performative.[2] Without going into great detail about each of the strands, it suffices to state that these authors favor the performative strand as the candidate with the potential to "radically undermine a discrete separation between humans and matter" with "an understanding of science in which every act of observing also constitutes, at once, a transformation of what is being observed." For that strand they coin the term "pedetic materialism," where the criterion of pedesis is defined by an irregular, partly unpredictable motion in matter, that is iteratively related to its immediate past but not determined by it. This aspect, a focus on transformation one step at a time, has some important implications that will be addressed later, especially in relation to real-time computation.

Our purpose, however, is not to carry out an exercise of historicism that traces back to Xenakis these recent developments according to a hermeneutics of retroprojection, but rather to think alongside Xenakis from our own present moment in order to elaborate a better insight about the theoretical and practical impasses in which we find ourselves. Theoretical impasse, in the first place, because the latest advances in the natural sciences invite philosophy to reconsider its positions on fundamental concepts of accounting for the cosmos. Practical impasse, because it is not only a question of bringing theory down to the material reality and its human and non-human problems, but also a challenge in terms of composing: of doing things with art, of arranging new conditions of perception that become a transformative experience. How could a materialistic perspective help to achieve this double objective? How can Xenakis's work contribute to contemporary philosophical reflection on performativity from a materialist perspective? How to avoid the frequent practice of theoretical collage, which merely joins two autonomous fields of study not only without contributing anything valuable to either of them, but even subtracting the complexity of their respective problematics?

2 Gamble et al., 2019, p. 111–34.

In order to put forward our hypothesis, we think it is necessary to go beyond the ambiguous generality of abstract terms and explore a particular problem from a specific framework, pointing out the aspects of Xenakian thoughts and practices that inform and materialize this case study. Then our premise for providing an answer to these questions, as we have argued elsewhere, could be formulated as follows: the reflection on performative matter will have to take into account the material transformations that take place in time-based media and their techniques, as they carry out their specific modes of computation.[3] In this sense, we take as inspiration a series of characteristic features of UPIC (Unité Polyagogique et Informatique de CEMAMu), especially its pioneer, real-time computation, and defend this kind of materiality as a relevant contribution for contemporary music making and philosophical discussion on materialism.

Composition and Performance

Before examining the case of the UPIC, it is useful to outline how real-time computer music can be accounted for from the viewpoint of performative materialism, and to what extent the way Xenakis understood computation is in line with this philosophical paradigm.

If we look at the most general use of the word "performance" in the context of music we find a valuation in terms of how well a person, machine, etc. does a piece of work or an activity. This perspective is not only limited to the quality of the performed action, but, as Le Mardi Gras Listening Collective has pointed out, it also has a complex and obvious link with the economic process: how to "make music make money."[4] However, these restricted senses of performance in music do not correspond to the approach of performative materialism, according to Karen Barad's claim of a performativity that is not reduced to the narrowness of the representationalist framework: "Performativity, properly construed, is not an invitation to turn everything (including material bodies) into words; on the contrary, performativity is precisely a contestation of the excessive power granted to language to determine what is real."[5] In this sense, how can we speak of performativity in computer music going beyond the aforementioned valuation or its economic profitability? What would such a performativity consist of, and to what extent can we recognize it in Xenakis's practice?

According to Barad, the approach of performative materialism marks an important conceptual shift, altering modern metaphysics and its understanding of matter:

3 Vasquez Hadjilyra, 2022, p. 107–24.
4 Le Mardi Gras Listening Collective, 2020, p. 133–51.
5 Barad, 2003, p. 802.

> *matter is substance in its intra-active becoming—not a thing, but a doing, a congealing of agency. Matter is a stabilizing and destabilizing process of iterative intra-activity* [...] That is, *matter refers to the materiality/materialization of phenomena*, not to an inherent fixed property of abstract independently existing objects of Newtonian physics.[6]

Here it is important to note that the notion of "intra-action" replaces the "interaction" of modern metaphysics, which presupposed the prior existence of independent entities/relata. On the contrary, the approach of performative materialism considers that it is through specific intra-actions that the limits and properties of the "components" of phenomena are determined. In this regard, as Gamble and Hanan have pointed out, "matter's only essential feature, then, is its ontological indeterminacy [...] which enables it to continually undergo iterative yet creative transformations through novel and creative relations that provisionally resolve that indeterminacy in particular ways."[7] In the case of computer music, this perspective completely overturns the understanding of the creative process, in the sense that composition and performance become material determinations of indeterminacy, computationally mediated.

At this point, it is worth saying a few words about Xenakis's ideas on music materiality, computation, and indeterminacy. Two crucial texts in which Xenakis's materialist perspective in this regard can be detected are, on the one hand, "Subtended Philosophy,"[8] the preliminary statement of Xenakis's thesis defense in 1976, and, on the other hand, "Determinacy and Indeterminacy,"[9] a 1996 edition of Xenakis's notes for a series of lectures delivered in Poland in the 1980s and not previously published.

It is not by chance that the question that guides Xenakis's reflection on "subtended philosophy" is directed towards the form and architecture of the materials involved in music making. In this sense, the recurrence of vocabulary from the natural sciences to characterize this creative process informed by philosophy and mathematics is striking: "fossilizations," "solidification, materialization," "expression of the billions of exchanges, reactions and energy transformations of the body and the brain cells," "cellular condensations and movements," "vibrations," "coagulations," "colored pebbles which are my musical, architectural and visual works and my writings," etc. According to Xenakis, these manifestations are always imbricated in "continuous formations and transformations," and it is precisely the materiality of this process and its modes—Xenakis distinguishes three, "indispensable and coordinated": the inferential (rational), the experimental (technical) and the revelatory (intuitional)—the last being what interests us most here. In this, motion always participates in the philosophical impulse "which pushes us toward truth, revelation, research, general quest, interrogation, and harsh systematic criticism [...] in all possible domains,"

6 Author's italics. Ibid., p. 822. For a more detailed discussion of the notion of "iterative intra-activity," see: Barad, 2011, p. 121–58.
7 Gamble and Hanan, 2021, p. xiii.
8 Xenakis, 1985, p. 1–10.
9 Xenakis, 1996, p. 143.

and mathematics "as a philosophical catalyst, as a molding tool for forming auditory or visual edifices, but also as springboard toward self-liberation." Computer music materiality, therefore, would be a "necessary solidification, materialization of this intelligence."[10]

Regarding this dialectic between determinacy and indeterminacy, Xenakis's 1996 article is suggestive: "The problem encompassed by determinacy and indeterminacy is a permanent one in music, both for composition and also for performance." Here it is not necessary to delve too deeply into the complexity of performative materialism and its pedetic aspect to discover this back-and-forth motion constituting one of its most important cores: "Without any radical exteriority between things, moreover, performative materialism refuses any ultimate or unchanging totality of what is possible. Instead, a generative "ontological indeterminacy" prevails at the heart of such an account."[11] It is interesting that, in the aforementioned text, Xenakis considers determinacy and indeterminacy together, as if they were two aspects of the same totality: "To be and not to be is the same."[12] But from our point of view, there is another key aspect of the article's approach: the invitation to consider the "very important and deep question" about determinacy not only from a philosophical perspective, but also "against a background of physics and computer science."[13]

To understand this computational materiality, we could establish a relationship with Georges Bataille's (1897–1962) critique of modern metaphysics, when he states that the focus should be placed not on meaning but on uses, and on how uses condition matter, with matter remaining formless.[14] Real-time computer music, in this sense, would not be distinct from such a conception, but a material composition and performance of indeterminacy. In this way, we could say that the discrete separation between "composing music" and "performing music" is dissolved, and, as we will see in the case of UPIC, such dissolution or at least its intention would be encapsulated by and through real-time computation technique. But this transformation is not without theoretical problems. Any linguistic formulation of this performativity is inevitably an abstraction, and we must take care, as Isabelle Stengers has warned, that its aim will not be "to produce new definitions of what we consensually perceive and name, but to induce empirically felt variations in the way our experience matters."[15]

In this sense, another historical precedent of interest would be the unfinished project by Th. W. Adorno (1903–69), outlined in his lecture *Vers une musique informelle*. According to Adorno, "*musique informelle*" denotes:

10 Xenakis, 1985, p. 1.
11 Gamble et al., 2019, p. 121.
12 Xenakis, 1996, p. 155.
13 Ibid., p. 143.
14 "Formless," in Bataille, 1985.
15 Stengers, 2008, p. 96.

> a type of music which has discarded all forms which are external or abstract or which confront it in an inflexible way [...] should be completely free of anything irreducibly alien to itself or superimposed on it, it should nevertheless constitute itself, and not in terms of external laws.[16]

In our view, the most interesting aspect of this position is its difference with respect to other of Xenakis's coetaneous proposals centered on reduced listening (Pierre Schaeffer (1910–95)) and self-referentiality of sounds (John Cage (1912–92)), since, contrary to these, "*musique informelle*" would sustain the critical function of the sound material as opposed to the abstraction of the form without incurring the metaphysical and positivist assumption that sound devoid of all meaning would be its own meaning: rather, what is irreducible in this case would be the dialectical relation between determinacy (form) and indeterminacy (formlessness) as such.

In the case of real-time computer music, this dissolution of the border between composing and performing can be addressed from what Sharon Kanach has pointed out as a "dialectical merger" in Xenakis's creative process:

> Although Xenakis searched for universal structures that not only permeate but also govern our natural world, he was never interested in simply replicating such structures as literal translations, nor did he proceed by means of metaphor [...]. Even though each of his works can be appreciated without previous knowledge of its underlying philosophical question, that question's mere—albeit hidden—existence may explain why his music never leaves one indifferent. Each of his creations represents a point of dialectical merger between, on the one hand, mathematical and scientific thought and, on the other hand, intuition.[17]

The characterization of this art/science alloy as dialectical is relevant and points towards new directions in the development of performative materialism: a conception, at times, too focused on encouraging closer attention to the sciences by the humanities and neglecting relevant artistic contributions, and at other times, too focused on idolizing technological achievements and neglecting the possibilities of uses informed by alternative forms of computation. At this point, we would like to warn that, as Fredric Jameson has pointed out, the adjective "dialectical" constitutes one of the three names for dialectic (the others being "the dialectic" and "dialectics") and brings with it idiosyncratic complexities and potentialities. We believe that it is this modality of dialectics, i.e. "dialectical," that can contribute the most to philosophical reflection and artistic creation based on alternative forms of computation, but we must leave the detailed treatment of this idea for another time.[18]

In a similar line of thought, a suggestive conception of "doing" or "use" has been analyzed by Peter Nelson with regard to UPIC, by drawing attention to the way in which this apparatus fuses its formations:

16 Adorno, 1962, p. 272.
17 Kanach, 2010, p. 126–7.
18 Jameson, 2009, p. 3–70.

> The seeming simplicity of the arrangement of these elements belies the openness of the apparatus to multiple reconfigurations. Its productions figure not as score and performance, but as simultaneous manifestations of the same productive impulse. Thus, the drawings rendered in the production of Xenakis's work for UPIC, *Mycenae Alpha* are as important as the sound they produce.[19]

Perhaps the attributes described in this fragment are not too far removed from the characteristics that "pedetic materialism" has identified as the fundamental features of matter, where the criterion of pedesis is defined by an irregular, partly unpredictable motion in matter, that is iteratively related to its immediate past but not determined by it. But now the question would be: how is this indeterminacy or *informelle* condition composed and performed in the context of Xenakis's real-time computer music, and in what ways can this "doing" or "use" be inspiring for a performative, material understanding of our computational instruments? We believe that the UPIC real-time version offers a powerful starting point for addressing these questions. In this sense, paraphrasing Stengers again, our working hypothesis consists in arguing that we need to feel variations empirically, in the way that performativity matters, by attending to a specific way in which Xenakis's computational praxis operates. But before addressing the case of UPIC, let us first turn towards the materialist perspective from which Xenakis understood information theory and computation.

Physics, Information Theory, and Computation

Recent publications on the historical nexus of information and computation theory and their role in shaping Xenakis's compositional decisions indicate a close affiliation with the work of French polymath and information theorist Abraham Moles (1920–92).[20] Anne-Sylvie Barthel-Calvet, in her text "Iannis Xenakis and the Men of Information Theory," provided new information on the relationship of affinity between Moles and Xenakis, such as the frequency of the meetings they had in Paris, or the praise that Moles dedicated to Xenakis in Gravesano and in generous gestures, as when he inscribed an offprint of his article "Some Basic Aspects of an Information Theory of Music" (1958) with the words "To Xenakis, who achieves what others talk about."[21]

Even if many of Xenakis's ideas were already formulated and deduced intuitively from his studies of quantum physics, both his time in Gravesano and the relationship with Moles developed thereafter—including the formation of MIAM, a study group

19 Nelson, 2022.

20 Olga Touloumi and Makis Solomos have made valuable contributions on the importance of physics and thermodynamics for Xenakis. See Touloumi, 2012, p. 101–25; Solomos, 2021, p. 179–92. Jennifer Iverson and Anne-Sylvie Barthel-Calvet have shed much light on the influence of information theory and cybernetics on Xenakis's work. See Iverson, 2019; Barthel-Calvet, 2022. Peter Hoffmann and Inigo Wilkins have made crucial contributions on the relationship between computation and indeterminacy in Xenakis's work. See Hoffmann, 2009; Wilkins, 2016.

21 Barthel-Calvet, 2022.

for mathematics and music founded in 1960 by Abraham Moles with Iannis Xenakis, Alain de Chambure (1922–2010), and Michel Philippot (1925–96)—enriched further his engagement with information theory and played a critical role in the way he interpreted and applied different computations in his own work, some of which can be witnessed in some of UPIC's design decisions and computation capabilities. Due to a shared translation of concepts from science to sound, but also a disjunction between different strands in information theory, we begin by considering some of Moles's propositions. Far from being congruent to Xenakis's own adaptation and compositional decisions, Moles's approach to information theory was nevertheless indicative of a possible alternative to Claude Elwood Shannon's (1916–2001) dictum, of information stripped of meaning, which grants us better access to Xenakis's own computational thinking.

Starting with entropy, a concept found in both physics and information theory, Jennifer Iverson, in *Electronic Inspirations: Technologies of the Cold War Musical Avant-Garde* summarizes Xenakis's rendition:

> [The] equations that Xenakis adapted—the Maxwell–Boltzmann and Gaussian distribution functions—are relatable to the paradigms of information theory. He may have known these equations from engineering and physics, but they connect mathematically to Shannon's information theory around concepts such as entropy, albeit from somewhat different angles. In information theory, entropy is a measure of the amount of information in a message; as Shannon theorized, all possible information (the highest entropy value) is constrained by linguistic redundancies and statistical predictions. In physics, entropy is a measure of randomness within a system, such as the relative disorder of molecules within a gas. The concept of entropy is not used in exactly the same way in cryptography and thermodynamics, for example, but Xenakis's dual information-theoretic and physical-science experiences do intersect on certain shared or translatable concepts: randomness, statistical modeling, and predictability.[22]

The inexactitudes of translating and applying these adaptations in music composition, along with Xenakis's critical commentaries on the more dominant implementation of information theory, help us frame one of his main objections: any analysis based solely on bits or quanta of information transmitted and received is incapable of determining the aesthetic value of music. By that same token, Xenakis asserts that a composer's responsibility lies in assessing value while remaining skeptical of its outcome, which is why, despite his recourse to scientific method and the certainties that it affords, time and again Xenakis insists on "the supreme criterion [...] the aesthetic efficiency of the music which resulted."[23] This may ring as platitude, as too obvious to state, but given the ongoing automation of music creation, molding both attention and appreciation of music experience, with datasets prefiguring the training of future AI-assisted techniques in composition, questions concerning agency and control over aesthetic

22 Iverson, 2019, p. 132.
23 Xenakis, 1992, p. xi.

value should be resurging, even if the present discourse on materiality aspires to direct them towards agency of the non- or other-than-human.

Nevertheless, it is precisely that sense of aesthetic value in informational processes that Moles tried to recuperate in his theorization of information in *Information Theory and Esthetic Perception* ([1958] 1966). By directly modulating sonic material and deducing principles from its perception, Moles tried to extend information to aesthetics by tracing it back to the material substratum of their media, marking in that way an important digression from the more pragmatic program of reductive precision and efficiency that was laid down by Claude E. Shannon and Warren Weaver (1894–1978) in their dematerialized conception of information that would ultimately dominate its discourse. In the case of music, even if Shannon considered the cases of continuously transmitted sound, the aim was still predominantly directed towards its discrete case employed in communication and was thus postulated in a limited form which assumed much of the Western canons of music and its means of signification, i.e., a discrete notation system[24].

For Moles, however, information theory entailed an investigation into the material histories of technologies and media, in which writing, printing, transmitting, and computing, all delineate different moments of what has been all along a material process of communication. "The invention of printing led the materiality of writing to be discovered" which, with the increase of signs and symbols, and their ability to be transmitted through radio, telegraphy, and television, made it possible to conceive "the existence of a materiality of communication no matter what the mode of communication"[25] was. Music, with its information, holds a unique position here in that its dematerialization through recording and transmission is what accounts for its substantiation. In Moles's words, "'materia musica' is born of recording," lending itself to be observed and studied, as a manufactured, temporal item, as "a mapping of *time into space*."[26] Its once elusive temporal structures, in their new coagulated forms, assume qualities that used to be preserved for objects that occupy space. With the advancements in digital reproduction of music, with a mode of transmission that is currently undergoing a new phase of dematerialization, it is worth keeping in mind Moles's proposition that since communication entails the complexification of the space-time medium between transmitter and receiver, then information, as a measurable quantity, describes the process of communication as such. According to Moles, an information "message is a complex *form*, and its rate of information measures the complexity of the form [...] The message transfers complexity from one point of the world to another."[27] As the delta between transmitter and receiver diminishes, communication and its complexification now takes place in a new register, that of the transformation of

24 Shannon and Weaver, 1964, p. 25.
25 Moles, 1966, p. 192.
26 Ibid., p. 106.
27 Ibid., p. 197.

information in communication, and this is where Moles's theorization offers a unique perspective to recuperate and implement in our understanding of computation: unlike his predecessors, for Moles, information is always a coagulation of semantic and aesthetic information, comprised of a universal logic that renders it transmittable but that is always confronted with diffracting interpretations unique to every single receiver. Hence, the semantic and aesthetic, as virtual extremes, subtend a dialectical dipole of several non-exhaustive dualities (order/disorder, predictable/unpredictable, banal/original, redundant/informative, intelligible/novel, simple/complex), which cannot exist in isolation and which can never be reduced to their complementarity. Instead, they all fluctuate and operate *together* in the performances where both communication and computation exist. With this in mind, then, the role of a composer's agency within the constraints and potentials of instrument design acquires a more fruitful meaning.

UPIC: Real-time Composition and Computational Performance

At this point, we can address the peculiarity of the late 1980s and 1990s versions of UPIC and its real-time computation. Although the exploration of UPIC's potentialities continues today with several versions of UPISketch developed at the Iannis Xenakis Center, the first real-time version dates from 1987, improved in the 1990s, and was the most advanced version of UPIC that Xenakis worked with (earlier, Xenakis had also worked with the first generation of UPIC, with which he composed *Mycènes Alpha*). We owe to the CEMAMu team (Gérard Marino, Jean-Michel Raczinski and Cornelia Colyer, among others) and composer Brigitte Robindoré the explanation of the synthesis methods implemented in it, including additive synthesis, subtractive synthesis, graphical synthesis, resynthesis, frequency modulation, amplitude modulation, synthesis by aliasing or granular synthesis. Here the so-called Frequency Table should be highlighted. This tool enabled, by means of four superimposable tables or grids invisible to the eye, the placing of arcs within different frequency spaces determined by the user, with a range as wide as 0.01–22,050 Hz. This computational development, with its capacity to transform the invisible into the visible, and frequencies below 20 Hz into highly complex waveforms audible in the infrasonic range, is an extraordinary case of materiality, in which formless matter is "condensed" to the threshold of aesthetic perception.

Moreover, UPIC's real-time computing capacity not only offered a material mediation between the *informelle* and the *formelle* on the sound and visual level, but also on the conceptual level. As Robindoré points out:

> Interestingly, the Frequency Table further introduced a concept that was potentially as impactful as the continuum: *the tempered discontinuum*. With a function called "discrete/non-discrete," the user could define how the frequency space was to be moved through. If non-discrete, then a diagonal arc would sound like a *glissando*, the classical use of the continuum with the UPIC. However, if "discrete" were chosen, the user could create

> equal temperaments between 1–99 divisions per octave. The same diagonal arc would then sound like discrete steps in a defined temperament. For those who wished to utilize non-tempered scales, the arcs would have to be drawn individually within a non-discrete frequency table. These features were almost never used, although they contained very intriguing possibilities of exploration into tempered scales beyond 12-tones, for those who wished to compose with determined pitches.[28]

In this sense, we consider the discrete/non-discrete function a computational contribution belonging to the same family of material answers that Xenakis offered to the philosophical question of continuity, some of them examples of what we could call a "computation without computers," such as the *glissando* technique, and other examples of a paradigm shift in our understanding of the nature of sound and the nature of music, such as granular synthesis. The use in real-time of this computation opens up a whole field of creative possibilities, establishing forms of continuity between the traces drawn and the sounds heard that are revolutionary, not only if we compare them with the relationship between the composition of a score and its performance, but also with respect to the understanding of sonic matter itself as intra-active becoming and pedetic motion, according to the terms of performative materialism:

> an envelope could share the same visual description as a waveform yet retain its own time-varying amplitude function. In real-time use, these parameters could be swapped or redrawn almost instantaneously, extending the concept of synthesis to a type of sonic metamorphosis in real time—a continuum in its own right.[29]

Finally, a third inspiring element for the artistic use of materialistic developments appears when we look at the first performance of UPIC's real-time capacities, carried out by Xenakis himself in 1987, with *Taurhiphanie* (1987), for UPIC, light effects and amplified bulls and horses.[30] In this sense, as Raczinski has pointed out, Xenakis was a pioneer not only in revolutionizing music composition with an interface such as UPIC, but also in diverting (*détourner*) his own invention from its primary goals.[31] In the original concept of *Taurhiphanie*, the bulls were to be equipped with high frequency (HF) microphones to capture their breathing and roaring, and the UPIC would then have been used by Xenakis to improvise with these materials. It is worth noting here that such controlled integration of a non-anthropocentric indeterminacy resonates with other previous works for UPIC, such as the *Polytope de Mycènes* (1978), where "children or goats carrying electric torches draw in the fields or on the mountain luminous tracings that merge at night with the celestial constellations."[32] Although lack of rehearsal time and technological limitations frustrated the realization of this idea (during the *Taurhiphanie* concert of 13 July 1987, Xenakis finally manipulated pre-

28 Condorcet (Robindoré), 2020, p. 406–8.
29 Ibid., p. 408.
30 In 1988, Xenakis created a concert version of this same work.
31 Raczinski, 2001.
32 Xenakis, 1982, p. 202.

recorded sounds), its spirit points to interesting possibilities of musical determination with respect to one of the fundamental tenets of performative materialism, concerned with radically undermining a discrete separation between humans and matter, and in our contemporary concerns: the role of the non-human. As Xenakis himself stated, by reintroducing animals into compositions and materializing real-time computation, "music became then Nature."[33]

Conclusions

Following the dialectical movements of the aesthetic theory of information that Moles proposed as well as the characteristics in UPIC, we can now begin to understand some of the computational thinking in Xenakis's work (even if some of processes do not even entail a computational method at all) and its philosophical implications. Xenakis's criticisms of certain developments, as well as of the assumptions of his contemporaries, become crucial for understanding his relationship to computation and materialism. So, to conclude, we briefly condense these as concrete philosophical problems that Xenakis addressed, both directly and indirectly, that can be further pursued when considering the role of information in music composition, the role of real-time computation in performance, and are available to be tested against the various strands of materialist thinking.

1. UPIC's use of *gestural* drawing offered a primordial and prelingual condensation of time and space that challenged the symbolic order of musical notation. At the level of sonic physical matter, Xenakis's postulate of quanta, as vectorial *glissandi*, that condense and complexify the spatio-temporal form resists its discretization into symbolic abstraction.
2. Xenakis's well known critique of the serialist school, and their assumption of the twelve-tone technique, can now be understood also as a critique against the reductionism imposed by information theory upon the transmission of aesthetic messages, whereby the restriction to twelve tones is nothing but an informatic compromise to which music has no reason to conform or to exhaust itself in banal permutations.
3. Xenakis's critique of Harmonic Analysis based on Fourier functions is both a problem of construction and presupposition of temporality. Much like computation that presupposes the construction of information as one comprised of discrete abstracted symbols to be encoded along an infinite, unidirectional tape (Turing machine), the Fourier series assumes the circular form (which evades, categorically, matter itself) in order to reconstruct the complexity of that evasion by assuming the very infinity of its own temporal timeline.

33 Xenakis, 1988, p. 105. Authors' translation.

4. The role of agency and decision-making by the composer is reconfigured once again, but not as one where humans seek to dominate nature with their computational tools. Instead, that new relationship is one that acknowledges the irreducibility of contingency in the compositional process by constructing instruments that resist the all-too-easy danger of becoming subject to the determination of the tool itself. Unlike ongoing trends in materialist thinking and posthumanist thought that seek to decenter the human role in decision-making, given the recent developments in automated processes and AI techniques in composition, whereby intention and aesthetic content are diffused and distributed across datasets, the role of choice and intention calls upon a newly formed set of responsibilities and challenges, to which Xenakis's work has been attuned all along.

References

ADORNO, Theodor W. ([1961] 1962), "Vers une musique informelle," in Theodor W. Adorno, *Quasi una fantasia: Essays on Modern Music*, London, Verso, p. 269–322.

BARAD, Karen (2003), "Posthumanist Performativity: Toward an Understanding of How Matter Comes to Matter," *Signs*, vol. 28, no. 3, *Gender and Science: New Issues* (Spring), p. 801–31.

BARAD, Karen (2011), "Nature's Queer Performativity," *Qui Parle*, vol. 19, no. 2 (Spring/Summer), p. 121–8, https://doi.org/10.5250/quiparle.19.2.0121

BARTHEL-CALVET, Anne-Sylvie (2022), "Iannis Xenakis and the Men of Information Theory," in Anne-Sylvie Barthel-Calvet and Brent C. Murray (eds.), *Revisiting the Historiography of Postwar Avant-Garde Music*, New York, Routledge, p. 128–51, https://doi.org/10.4324/9781315108162-7

BATAILLE, Georges ([1929] 1985), "Formless," in George Bataille, *Visions of Excess: Selected Writings 1927–1939*, Minneapolis, Minnesota, University of Minnesota Press, p. 31.

CONDORCET (ROBINDORÉ), Brigitte (2020), "Beyond the Continuum: The Undiscovered Terrains of the UPIC," in Peter Weibel, Ludger Brümmer, and Sharon Kanach (eds.), *From Xenakis's UPIC to Graphic Notation Today*, Berlin and Karlsruhe, Hatje Cantz Verlag/ZKM, p. 406–8, https://zkm.de/en/from-xenakiss-upic-to-graphic-notation-today

GAMBLE, Christopher N. and HANAN, Joshua S. (eds.) (2021), *Figures of Entanglement. Diffractive Readings of Barad, New Materialism, and Rhetorical Theory and Criticism*, London, Routledge, https://doi.org/10.4324/9781003024057

GAMBLE, Christopher N., HANAN, Joshua S., and NAIL, Thomas (2019), "What Is New Materialism?," *Angelaki*, vol. 24, no. 6, p. 111–34, https://doi.org/10.1080/0969725x.2019.1684704

HOFFMANN, Peter (2009), "Music Out of Nothing? A Rigorous Approach to Algorithmic Composition by Iannis Xenakis," doctoral dissertation, Technische, Universität Berlin.

IVERSON, Jennifer (2019), *Electronic Inspirations. Technologies of the Cold War Musical Avant-Garde*, Oxford, Oxford University Press, https://doi.org/10.1093/oso/9780190868192.001.0001

JAMESON, Fredric (2009), "The Three Names of the Dialectic," in Fredric Jameson, *Valences of the Dialectic*, New York and London, Verso, p. 3–70.

KANACH, Sharon (2010), "Music to Be Seen: Tracing Xenakis's Creative Process," in Sharon Kanach and Carey Lovelace (eds.), *Iannis Xenakis: Composer, Architect, Visionary*, New York, Drawing Papers, p. 95–127.

LE MARDI GRAS LISTENING COLLECTIVE (2020), "Music and Economic Planning," *South Atlantic Quarterly*, vol. 119, no. 1, p. 133–51, https://doi.org/10.1215/00382876-8007701

MARINO, Gérard, RACZINSKI, Jean-Michel, and SERRA, Marie-Hélène (1990), "The New UPIC System," in Stephen Arnold and Graham Hair (eds.), *Proceedings of the 1990 International Computer Music Conference*, p. 249–52.

MARINO, Gérard, SERRA, Marie-Hélène, and RACZINSKI, Jean-Michel (1993), "The UPIC System: Origins and Innovations," *Perspectives of New Music*, vol. 31, no. 1, p. 258–69.

MOLES, Abraham ([1958] 1966), *Information Theory and Esthetic Perception*, Urbana, Illinois, and London, University of Illinois Press.

NELSON, Peter (2022), "What's the Use of Music?", in *Proceedings of the Xenakis 22: Centenary International Symposium*, Athens and Nafplio (Greece), 24–9 May 2022, https://xenakis2022.uoa.gr/

RACZINSKI, Jean-Michel (2001), "L'UPIC, outil de composition pour quelles musiques?," in Sylvie Dallet and Anne Veitl (eds.) *Du sonore au musical, Cinquante années de recherches concrètes (1948–1998)*, Paris, L'Harmattan, p. 77–88.

SHANNON, Claude E. and WEAVER, Warren (1964), *The Mathematical Theory of Communication*, Urbana, Illinois, The University of Illinois Press.

SOLOMOS, Makis (2021), "Xenakis and Nature: From Natural Sciences to an Environmental Music?," in Simone Caputo and Candida Felici (eds.), *Out of Nature. Music, Nature, Sound Sources and Acoustic Ecology = Chigiana, Journal of Musicological Studies*, vol. 3, no. 2, p. 179–92.

STENGERS, Isabelle (2008), "A Constructivist Reading of *Process and Reality," Theory Culture Society*, vol. 25, no. 4, p. 91–110.

TOULOUMI, Olga (2012), "The Politics of Totality: Iannis Xenakis' *Polytope de Mycènes*," in Sharon Kanach (ed.), *Xenakis Matters*, New York, Pendragon Press, p. 101–25.

VASQUEZ HADJILYRA, Oswaldo Emiddio (2022), "Computation and Material Transformations: Dematerialisation, Rematerialisation, and Immaterialisation in Time-Based Media," in Natasha Lushetich, Iain Campbell, and Dominic Smith (eds.), *Contingency and Plasticity in Everyday Technologies*, Lanham, Rowman, and Littlefield, p. 107–24.

WILKINS, Inigo (2016), "Irreversible Noise: The Rationalisation of Randomness and the Fetishisation of Indeterminacy," doctoral dissertation, Goldsmiths, University of London.

XENAKIS, Iannis ([1982] 2008), "Polytopes," in Iannis Xenakis, *Music and Architecture: Architectural Projects, Texts, and Realizations*, compilation, translation, and commentary by Sharon Kanach, Hillsdale, New York, Pendragon, p. 202.

XENAKIS, Iannis (1985), *Arts-Sciences, Alloys: The Thesis Defence of Iannis Xenakis before Olivier Messiaen, Michel Ragon, Olivier Revault d'Allonnes, Michel Serres, and Bernard Teyssèdre*, translated by Sharon Kanach, Hillsdale, New York, Pendragon.

XENAKIS, Iannis (1988), "Le mois de Iannis Xenakis," *Le Journal de l'année*, Paris, Larousse, p. 198.

XENAKIS, Iannis (1992), *Formalized Music: Thought and Mathematics in Music*, additional material compiled and edited by Sharon Kanach (rev. ed.), Stuyvesant, New York, Pendragon.

XENAKIS, Iannis (1996), "Determinacy and Indeterminacy," *Organised Sound*, vol. 1, no. 3, p. 143–55.