SET THEORY IN XENAKIS' *EONTA*

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This paper offers an analysis of *EONTA* based on Set Theory. Using Xenakis' score, we reconstruct the original pitch sets and their logical operations. A comparison with the sets actually employed in *EONTA* reveals significant incongruities. These could be attributed to material conditions in the production of the work (hand-processed cards for the IBM 7090 computer). A far more interesting possibility emerges, however, if we place them in the context of Parmenides' philosophy, to which the work pays homage. This approach may reconcile technical analysis and hermeneutics, and thus lead to a deeper appreciation of the work.

Introduction

EONTA holds a unique place in the music of Xenakis. Composed in 1963-1964 for piano, two trumpets and three trombones, it was the most extensive work he had written to date.[2] Its strong dramatic content, ranging from total silence to sonic chaos, extreme performance demands and choreographic directions for the brass players,[3] render it an unforgettable listening experience.[4] As a musical composition proper, rather than a showcase piece, it fully established Xenakis' reputation in postwar music [Solomos 1996: 48-49]. The fact, moreover, that a work named "Beings" emerged in a divided Berlin at the paroxysm of Cold War bears historical significance.[5]

Yet *EONTA* was not exactly a novelty. It extended and adjusted a line of thinking and application that Xenakis had introduced three years earlier with *Herma*. This last, for solo piano, inaugurated the collaboration of Xenakis with Yuji Takahashi, an "extraordinary pianist-composer" [Xenakis 1965] he had encountered during his visit to Japan in 1961. At least twice as long as *Herma*, the piano part in *EONTA* is hard to imagine without Takahashi's fearless virtuosity and intellectual affinity with Xenakis.[6]

Most important, *Herma* was Xenakis' initial foray to symbolic music.[7] As the composer explains, "This piece is based on logical operations imposed upon classes of pitches; hence I have described it as *Musique symbolique*" [Xenakis 1967 (2)]. He uses four such classes or sets, which he calls *A*, *B*, *C*, and *R*; this last is "referential and incorporates all the notes on the piano." Once he defined the elements (pitches) of each set, Xenakis used them to generate others sets through logical operations. In set theory, these are intersection (common elements between two or more sets), union (aggregate of two or more sets), and negation or complement (subtraction of a set from the universal one).[8] Xenakis then placed this abstract ("*outside time*") material in time through succession or juxtaposition of pitches belonging to particular sets. This became the theoretical frame for *EONTA*, too.

The experimental nature of *Herma* raised a number of issues. Most important among them is the atemporality of set theory, and in fact of mathematics itself [Matossian 1986: 154-155]. If the logical operations determining its pitch content lie outside time, how do they register in music, both in terms of notation and narrative?[9] Aware of the problem, Xenakis added in the score mathematical symbols to indicate the succession of sets; he also used dynamics "to render more clearly the perception of the classes at the moment of their temporal inscription" [Xenakis 1967 (2)].

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[1] This article began life in January 1991, as a music analysis paper for "Informatics and Musicology" taught by Charalambos Spyridis at the Department of Music Studies, Aristoteles University of Thessaloniki. In addition to the authors listed here, the original team of musicology students included Efthalia Leontief and Myrto Economidou. In 1994, the authors reworked the paper under Professor Spyridis' supervision with a view of publishing it. This version is incorporated here as part two.

[2] The award-winning recording of the piece in 1965 has duration of 19 minutes and 40 seconds. According to Xenakis' specification in the score, however, it should last just over 16 minutes.

[3] Pierre Boulez, who conducted the world premiere of *EONTA* in Paris in 1964, used ten brass players; he explained to Xenakis that "the score as it is conceived ... is absolutely unplayable correctly if one does not relay the instrumentalists" [Matossian 1986: 178]. The work's spatial sound movement is explored in Harley 1994: 295-300.

[4] See review of the work by Bruce Archibald, *Notes* 25/3 (March 1969): 597-598.

[5] Xenakis spent the year 1963-1964 in Berlin as composer-in-residence of the Ford Foundation and the Berlin Senate (for the reception of these grants by the Germans, see Russell 1964: 52). On June 26, 1963, just months before Xenakis' arrival in the city, John F. Kennedy delivered his historic speech close to the Berlin Wall. Nouritza Matossian offers a vivid description of Xenakis' state of mind during that period [Matossian 1986: 166-170].

[6] "Yuji Takahashi's piano playing is ... a miracle of accuracy considering the music's inhuman demands" [Stone 1968: 394]. For a pianist's perspective of the work, see Hill 1975: 17-22, and the correspondence it generated: Takahashi 1975: 53-54, and Hill 1976: 54-55. A general discussion of performance problems in *EONTA* and strategies of addressing them appears in Reish 1998: 49-53.

[7] Xenakis offers the theoretical background of the work in *Formalized Music* [Xenakis 1971: 170-177].

[8] A brief introduction to set theory appears in Wannamaker 2001: A. For a general introduction in Greek, see Moysiadis-Spyridis 1994: 9-32.

[9] "a listener can hardly be expected to perceive, merely by listening, the mathematical sources of the various textures and structures" [Stone 1968: 394].

EONTA seems to address some of the problems in its predecessor. Unlike the metric fluctuations in the beginning of *Herma*, it adopts a fixed 2/2 meter with a pulse of at least one second per half note. The addition of five brass instruments to the piano helps balance the preference for registral extremities in *Herma*. And instead of a rather mechanical succession of sets in the latter, *EONTA* demonstrates flexibility in their use, which accounts to a significant degree for its artistic, if not philosophical, poise.

Set theory in *EONTA*

Preliminary remarks
According to Xenakis, *EONTA* "makes use of stochastic music (based on the theory of probabilities) and of symbolic music (based on logistics)" [Xenakis 1967 (1)]. The former is evident in the opening piano solo (mm. 0-72), which was "calculated on an IBM 7090 computer" [Xenakis 1967 (1)]. The random distribution of notes across the keyboard offers a vivid kaleidoscope in sound, one that perfectly captures Xenakis' original vision of the work: "Reflection in water. Water is the piano" [Matossian 1986: 177].

It is symbolic music, however, that allows Xenakis to generate the large-scale form of *EONTA*. Its significance registers in the score by way of Greek characters, which "indicate choice of particular pitches and of logical operations, and serve as an *aide-mémoire* to analysis" [Xenakis 1967 (1)]. Always preoccupied with methodology, Xenakis offers the key for us to approach his work. In their recurrence and variety of combinations, the Greek letters become constant reminders of the work's theoretical basis, set theory.

Xenakis uses in *EONTA* three basic sets, which he names Σ, Θ, and Ψ. The first one is the universal set in the composition and comprises the entire pitch range of the piano (89 keys). Logical operations between the other two, which are subsets of Σ, generate 13 additional sets, raising the total to 16. Sixteen is actually the maximum number of possible sets here. However, two of them never appear (the intersections of Ψ and Θ, and of Ψ and -Θ). Instead, Xenakis duplicates two already extant sets through different spelling (the negation of the intersection of $\Psi\Theta$ and its negation equals the universal set; and the negation of the intersection of -Ψ and -Θ equals the union of Ψ and Θ).

It is not clear whether the elements of the sets are notes or pitches. Certain instances of pitch equivalence (e.g. second trumpet in mm. 321-322) suggest, however, that the latter is more likely the case. Quarter tones appear in a number of sets, particularly when performed in the brass. The fact that they are present in the union of Ψ and Θ, although neither of the constituent sets includes them, shows that they are variants of pitches in the twelve-tone scale.

Nearly all sets appear more than once. They typically use only a fraction of their elements in each appearance. Actually, there are missing pitches in many of them (we do not consider this a mathematical error). The juxtaposition of different sets occurs between the piano and the brass or, when the piano is not performing, between the trumpets and the trombones.

There are a few semantic ambiguities resulting from the placement of set symbols in the (published) score. The introduction of the brass in m. 40 comes with no set sign, a strong indication that they perform elements of Σ. However, the symbol for this set in the beginning of the piece appears just above the piano part and below the empty staves for the brass. (We treat similarly their appearance in m. 206.) Also, the alternation between two different sets in the piano part in mm. 142-176 is designated only in their first appearance. During the "promenade" section, where trumpets and trombones perform in different sets, it is unclear whether the introduction of "-Ψ" (m. 368) applies to the trombones, especially because in other cases a set symbol appears in parenthesis to avoid confusion (mm. 349, 356, 383). A special instance is "$\Psi\Theta+\Psi\Theta2\uparrow$" in m. 388. Lack of space is the probable reason for its appearance in-between rather than above the trombone parts (this could explain the arrow). There is no information regarding $\Psi\Theta2$, but it must be different from $\Psi\Theta$, for its union with itself makes no sense. (On the other hand, the reappearance of "Σ" in m. 230 is redundant, as there is no set change after its introduction in m. 202.) Unless one is ready to rely on context, these ambiguities may affect (though to a small degree) one's reconstruction of sets in *EONTA*.

Sets
The following is the note content of the sets (numbers represent octave):

Σ all chromatic semitones from **0:** A to **8:** C# (with the exception of the last pitch, all black keys consistently receive multiple spellings)

Θ **1:** Db, F#, G, **2:** C, D, F, G#, B, **3:** C, C#, D#, Eb, E, A#, Bb, **4:** C#, F, F#, G#, B, **5:** C, C#, D, E, F#, G, G#, A#, B, **6:** C#, D, D#, G, Ab, A, **7:** C, E, F, F#, A#, B

Ψ **1:** G, **2:** F, G#, A#, Bb, B, **3:** C, D#, Eb, G#, A#, Bb, **4:** C, C#, Db, D, E, F, F#, A, B, **5:** C, D, Eb, E, F#, G, G#, A, A#, Bb

-Θ **0:** A, **1:** C, C#, Db, D, Eb, E, F, G#, **2:** C, C#, D#, Eb, E, F#, G#, A, **3:** F#, G#, **4:** D, E, A, B, **5:** G, **6:** C, C#, E, F, Ab, A, A#, B, **7:** C, C#, E, F, G, G#, A#

-Ψ	**1**: D, F, G#, A, A#, **2**: D, E, F, **3**: C#, D, F#, G, A, B, **4**: C, E, G, G#, Ab, A, A#, **5**: C#, D, E, F, F#, Gb, G#, A#, Bb, B, **6**: C, E, F, G#, A#, B, **7**: C#, D, D#, G, **8**: C
-(ΨΘ)	**4**: D, Eb, Ab, **5**: E, A
Ψ+Θ	**2**: F, G, G#, Bb, B, **3**: C, Eb, E, G#, Bb, **4**: C#, E, F, F#, Ab, A, Bb, B, **5**: C, C#, D, E, F#, G, G#, A, A#, Bb, B
-(Ψ+Θ)	**0**: B, **1**: D, E, F, G#, A#, **2**: D#, E, A, **3**: C#, D, E, F, G, A, B, **4**: C, D, E, G, A#, **5**: D#, F, **6**: C, F, F#, G#, B, **7**: C#, G#, A
-ΨΘ	**1**: Ab, A, **4**: G#, **5**: C#, F#, A#, Bb, B
-(-ΨΘ)	**3**: C#, D, Eb, E, F, F#, G, G#, Ab, A, A#, Bb, B, **4**: C, C#, Db, D, D#, Eb, E, F, F#, Gb, G, Ab, A, **5**: F, G# [several pitches appear only as quarter tones]
-(Ψ-Θ)	**3**: G#, A#, **4**: G#, A#, Bb, B, **5**: C#, D, D#, F, F#, A#, B, **6**: C
-(-Ψ-Θ)	**1**: G, A, **2**: F, F#, G, G#, Bb, B, **3**: C, Eb, E, G#, A
ΨΘ+(-Ψ-Θ)	**1**: G, A, **2**: E, F, F#, G, A, **3**: C, C#, D, E, F, F#, G, A, A#, Bb, B, **4**: C, D, Eb, E, F, G, Ab, A, A#, Bb (B), **5**: C, C#, Db, D, Eb, F, F#, Gb, B, **6**: C
-[ΨΘ+(-Ψ-Θ)]	**3**: G#, Ab, **4**: C#, Db, D, D#, F#, Gb, G, G#, Ab, A, A#, B, **5**: C, C#, Db, D#, (Eb: m. 388), E, F, F#, Gb, G, G#, Ab, A, A#, Bb, B, **6**: C
ΨΘ+ΨΘ2↑	**2**: B, **3**: D, Eb, E, G, G#, A, B, **4**: C#, D, E, F, F#, G
-(ΨΘ -Ψ-Θ)	**0**: A, **1**: C, C#, D#, Eb, Bb, B, **2**: C#, D, Eb, E, **4**: D, E, **6**: A, **7**: D, E, F, F#, G, G#, A, **8**: C

Remarks

Σ	universal set; contains all pitches in the piano (A₀-C#₈); appears predominantly in the piano part and rarely in the brass
Θ	subset of Σ; intersects (has common elements) with Ψ; appears twice and only in the piano (mm. 95-99, 365-368)
Ψ	subset of Σ; intersects (has common elements) with Θ; appears only in the brass (mm. 144-147, 155-162, 190-194, 342-345)
-Θ	(=Σ-Θ) negation of Θ; appears only once, first in the brass and then in the piano (mm. 55-91); mathematical errors: has common notes with Θ (Db₁, C₂, G#₂, B₄, G₅, C#₆, Ab₆, A₆, C₇, E₇, F₇, A#₇); particularly visible is the case of C#₆ in mm. 80 and 99
-Ψ	(=Σ-Ψ) negation of Ψ; appears once in the piano (mm. 190-194) and of its four brief appearances in the brass section, three come as vertical sonorities (mm. 162-165, 398, 402); its appearance in mm. 368-373 (or 374) presents a semantic ambiguity, for context indicates that the set applies only to the trumpets; a cluster of notes (F#₂, G₂, A₂, C₃, E₃, F₃, D₄, Eb₄, and Bb₄) may or may not belong to this set; mathematical errors: has common notes with Ψ (F₂, C₄, E₄, A₄, D₅, E₅, F#₅, G#₅, A#₅, Bb₅, and perhaps C₃, D₄); particularly evident are the cases of E₄ and E₅ in m. 194 (piano and second trumpet, and piano and first trombone)
ΨΘ	*intersection of Ψ and Θ; does not appear in the work*
-(ΨΘ)	negation of the intersection of Ψ and Θ; appears only once (mm. 166-190) as a five-note sonority in the brass (G#₃ may also belong in this set); mathematical error: includes the note E₅, which belongs both to Ψ and to Θ (ΨΘ)

Ψ+Θ	union of Ψ and Θ; appears only once, in the brass (mm. 195-202), and includes a fraction of the elements of its constituent sets mathematical errors: a number of its notes belong neither to Ψ nor to Θ (G2, Bb4, and perhaps Ab4, though there is a G#4 in Θ)
-(Ψ+Θ)	negation of the union of Ψ and Θ; appears only once, in the piano (mm. 195-201 or 202) mathematical errors: has common notes with the union of Ψ and Θ (E3, E4, and perhaps A#4 (there is a Bb4 in unison)); visible case is the E3 in m. 198 (piano and second trombone)
-ΨΘ	intersection of Θ and the negation of Ψ; appears twice (mm. 375-379; 469-481); three of its notes conclude the work
Ψ-Θ	*intersection of Ψ and the negation of Θ; does not appear in the work*
-(-ΨΘ)	negation of the intersection of Θ and the negation of Ψ; appears twice, in the brass (mm. 100-142, 150-153)
-(Ψ-Θ)	negation of the intersection of Ψ and the negation of Θ; appears as a two-note cluster in the piano (mm. 148, 153, 158, 176), and in the trumpets (mm. 383-388)
-(-Ψ-Θ)	negation of the intersection of the negations of Ψ and Θ (equals Ψ+Θ); appears only once, in the trombones (mm. 378-388)
ΨΘ+(-Ψ-Θ)	union of the intersection of Ψ and Θ and the intersection of their respective negations; appears only in the brass, twice as a five-note sonority (mm. 310-322, 460-466) and also in the trombones section of the "promenade" (mm. 349-351, 358-375)
-[ΨΘ+(-Ψ-Θ)]	negation of the previous set; appears only in the trumpets and mainly in the "promenade" section (mm. 335-341, 345-359, 388-393) Mathematical errors: has common notes with the previous set (D4, G4, Ab4, A#4, C5, Db5, F5, Gb5, B5, C6, and perhaps B4 and Eb5)
ΨΘ+ΨΘ2↑	union of ΨΘ and ΨΘ2↑; appears only once, in the trombones (mm. 388-393); it is probably not an abbreviated form of "ΨΘ+(-Ψ-Θ)" because it has notes foreign to the latter
-(ΨΘ -Ψ-Θ)	negation of the intersection of the intersection of Ψ and Θ and their respective negations; this is nothing but the universal set Σ; appears twice, initially as a two-note cluster (mm. 142, 153, 158, 160, 164, 176) and then just before the final return of Σ in the piano (mm. 390-392), this time reaching the registral borderlines of the universal set (A0-C8)

Length of appearance

(number of bars that include at least one element of each set):

Σ	344
-(-ΨΘ)	42
ΨΘ+(-Ψ-Θ)	39
-Θ	37
-[ΨΘ+(-Ψ-Θ)]	29
-(ΨΘ)	25
Ψ	21
-ΨΘ	18
-Ψ	17
-(-Ψ-Θ)	11
Θ	9
-(Ψ-Θ)	9
-(ΨΘ -Ψ-Θ)	9
Ψ+Θ	8
-(Ψ+Θ)	8
ΨΘ+ΨΘ2↑	6

Structure

Measure number	Piano	Trumpets	Trombones
0	Σ	--	--
40		Σ	Σ
55		-Θ	-Θ
77	-Θ		
95	Θ	--	--
100	Σ	-(-ΨΘ)	-(-ΨΘ)
142	-(ΨΘ·-Ψ-Θ)		
144	Σ	Ψ	--
148	-(Ψ-Θ)	--	--
150	Σ	-(-ΨΘ)	-(-ΨΘ)
153	-(ΨΘ·-Ψ-Θ) / -(Ψ-Θ)		
155	Σ	Ψ	--
158	-(Ψ-Θ) / -(ΨΘ·-Ψ-Θ) / -(Ψ-Θ)		--
160	-(ΨΘ·-Ψ-Θ)		--
162	Σ	-Ψ	-Ψ
164	-(ΨΘ·-Ψ-Θ)		
166	Σ	-(ΨΘ)	-(ΨΘ)
176	-(Ψ-Θ) / -(ΨΘ·-Ψ-Θ)		
185	Σ		
190	-Ψ	Ψ	Ψ
195	-(Ψ+Θ)	Ψ+Θ	Ψ+Θ
202	Σ	--	--
206		Σ	Σ
230	Σ		
310	Σ	ΨΘ+(-Ψ-Θ)	ΨΘ+(-Ψ-Θ)
322		Σ	Σ
335	--	-[ΨΘ+(-Ψ-Θ)]	--
342	--	Ψ	Ψ
345	--	-[ΨΘ+(-Ψ-Θ)]	--
349	--		ΨΘ+(-Ψ-Θ)
358	--		ΨΘ+(-Ψ-Θ)
365	Θ	ΨΘ+(-Ψ-Θ)	
368	--	-Ψ	ΨΘ+(-Ψ-Θ)
375	--	-ΨΘ	--
378	--		-(-Ψ-Θ)
383	--	-(Ψ-Θ)	
388	--	-[ΨΘ+(-Ψ-Θ)]	ΨΘ+ΨΘ2↑
390	-(ΨΘ·-Ψ-Θ)		
393	Σ	Σ	Σ
398		-Ψ	-Ψ
399		Σ	Σ
402		-Ψ / Σ	-Ψ / Σ
405		Σ	Σ
460	Σ	ΨΘ+(-Ψ-Θ)	ΨΘ+(-Ψ-Θ)
469	--	-ΨΘ	-ΨΘ

It says a lot about the artistic vitality of *EONTA* the fact that it can be analyzed in various ways. Kurt Stone recognizes "approximately fourteen more or less clearly differentiated sections, each one dealing with a different manipulation of the given resources" [Stone 1968: 394]. Theodore van Huijstee proposes nine sections [Huijstee 1981:

409],[10] while the authors of this paper initially settled with seven parts, based on the simultaneous change of sets in all instruments.[11] Clearly, there are three parameters in defining structure here: sets, textures, and spatial arrangement of the brass; general pauses, too, may serve as borderlines.[12]

The first major incision occurs in the area of mm. 92-99, and I would favor the latter measure as its end. In this section, the piano undergoes a major transformation from a chaotic environment (random distribution of notes) to a disciplined and individualized line (mm. 95-99). The catalyst for this change is the three interventions of the brass, which enter almost stealthily in m. 40 and by m. 82 assert themselves both aurally (ear-piercing tremolos) and spatially (they perform behind the piano). The ensuing general pause is more than welcome and renders the meditative piano line in mm. 95-99 utterly expressive. ·

The second major part ends in m. 202 and comprises two sections. The first of these (mm. 100-140) explores sounds familiar to anyone who has spent a summer in New England: the alarming approach of scores of mosquitoes. For first-time visitors, as Xenakis was in the summer of 1963,[13] the experience can be hair-raising. Given that he conceived EONTA after "spending an afternoon boating in Tanglewood" [Matossian 1986: 176], it may be fair to call the section "mosquitoes raid." In the face of such menace coming out of the brass, the piano assumes a more cautious role bordering on accompaniment. Its highly diversified texture eventually dilutes into a chordal pedal point, beginning in m. 139. The range of mm. 140-168 provides a point of repose through pedal points and antiphonal texture punctuated by two-note clusters in the piano. Out of this static environment emerges a rhythmic and dynamics crescendo (mm. 168-190), which leads to an explosion of kinetic energy (mm. 190-202) with ascending lines in the brass, relentless tremolos, and the juxtaposition of mutually exclusive sets in the piano and the brass (Ψ and $\Psi+\Theta$ with their respective negations). I would openly call this section the peak of EONTA.

The third major part starts in m. 202 with the return of Σ in the piano. There is a particularly long section up to m. 309. For the first time, the piano and the brass develop a dialectical relation, responding one to the other. The trademark juxtaposition of five and six notes in the piano parts disappears, leaving a largely chordal texture. In the section of mm. 310-334, the dialectics cease before a polarization between the piano and the brass, these last acting like a solid rock of sound hammering the piano harp.

The fourth part certainly begins with the promenade of the brass, the most theatrical moment in the work. In agreement with their free traffic on the stage, the brass acquire maximum independence with separate lines. In the absence of the piano, set differentiation takes place within the two groups of performers. In m. 393, the piano reasserts itself. For a moment, the brass resist through chordal outbursts, but beginning in m. 405 they embrace the universality of Σ. From then on, and until m. 459, all instruments perform together in maximum cooperation.

The return of the brass to their initial chordal texture in m. 460 may be seen as initiating the last section, which concludes with protracted pedals and the piano in full silence.

Overall, the variety of textures and succession of episodes in EONTA generate a surprising dramatic force and account for its artistic vitality. Repeated hearings of the work erode the aesthetic prejudices of the listener and help him concentrate on musical configurations and the formal aspects of natural sound.

Explanations

The presence of mathematical errors in EONTA is undeniable though not surprising.[14] Similar inconsistencies appear in Herma as well [Wannamker 2001: 4]. Although not a threat to the artistic integrity of the respective works, these problems question the accuracy (or commitment) of translating mathematical operations into music.[15] The possibility that such anomalies may have theoretical ground (e.g. "fuzzy sets") has been dismissed [Wannamaker 2001: n.13]. Typesetting problems, though present in EONTA (e.g. in m. 378, there is no change to bass clef in the first trombone), may not account for so large a number of mistakes. The most likely explanation comes from the method of composing the work. As Xenakis states in the score, "Some of the instrumental parts, notably the piano solo at the opening, were calculated on an IBM 7090 computer at the Place Vendôme, Paris" [Xenakis 1967 (1)]. The programming of IBM 7090 and the decoding of its output into musical notation involved hand processed cards.[16] It is possible that mistakes may have occurred in the performance of these tasks (e.g. punching the data cards).

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[10] mm. 0-39, 40-94, 95-139, 140-189, 190-201, 202-308, 309-334, 335-374, 375-404, 405-449, and 450-481.

[11] mm. 0-99, 100-143, 144-189, 190-194, 195-348, 349-392, and 393-481.

[12] For other discussions/descriptions of EONTA, see Huijstee 1981: 408-416, and, particularly, Harley 2004: 33-38.

[13] "In the spring of 1963 came an invitation from Aaron Copland to the Summer Course in the Berkshire Music Centre at Tanglewood"; Xenakis entered the USA in June [Matossian 1986: 163, 165].

[14] James Harley alludes to EONTA's "inconsistency in pitch organization" but without offering any details or examples (Harley 2004: 37).

[15] See Solomos-Faraklas 1987: 162. It is interesting to note that a short review of Formalized Music in the American Mathematical Monthly seems to question the soundness of Xenakis' mathematics [Steen 1972: 435]. Xenakis himself acknowledged Yuji Takahashi's help in addressing mathematical errors in his book [Bois 1967: 18].

[16] Xenakis describes his work with the computer in Bois 1967: 11-12.

The Parmenides link

A curious homage

Instead of being a liability, the mathematical errors in *EONTA* generate sufficient tension to help us approach the work from a different angle. Both in the score and in public statements, Xenakis makes explicit the philosophical context of *EONTA*. The composition "is so entitled [*sic*] in homage to Parmenides" [Xenakis 1967 (1)].

The Eleatic philosopher of the late 4th-century BC had been a constant presence in Xenakis' thinking at least since 1958.[17] At that moment in his career, Xenakis "wanted to do away with all of the inherited rules of composition in order to create new ones." The "scientific-musical vision" he began to develop had a philosophical premise:

> "*For it is the same thing to think and to be*"
> (*The Poem*, Parmenides)
> and my paraphrase
> "For it is the same thing not to be and to be" [Xenakis 1992: 260].

Xenakis would return to this idea frequently.[18] If Pythagoras had discovered a universal principle in numbers, Parmenides was able to define Being and refute Herakleitean change through deductive reasoning [Guthrie 1965: 23-25, 32]. (The Parmenidean opposition to Herakleitos parallels Xenakis' own polemic against aleatoric music.) For Xenakis, Pythagoras legitimized the search of universal principles in music composition,[19] and Parmenides sanctioned the denial of indeterminacy and validated a stochastic approach to music: "The *Poem* of Parmenides implicitly admits that necessity, need, causality, and justice identify with logic; since Being is born from this logic, pure chance is as impossible as not-Being. ... If logic indeed implies the absence of chance, than one can know all and even construct everything with logic. The problem of choice, of decision, and of the future, is resolved" [Xenakis 1971: 204].

There is a major, actually fundamental, problem with Xenakis' paraphrase from 1958, however. As the father of philosophical monism, Parmenides accepts that only Being exists ("for there is Being, but nothing is not" [Tarán 1965: 54]). He arrives in this affirmation by introducing the alternative that "not being" may also exist; but this is only an invention to help him climb the ladder of deductive reasoning. In Fragment VI, actually, Parmenides bemoans the lack of reasoning in mortals, "by whom to be and not to be are considered the same and yet not the same" ("οις το πέλειν τε και ουκ είναι ταυτόν νενόμισται κου ταυτόν": 6.8-9) [Tarán 1965: 54]. Xenakis' paraphrase, then, is an example of what Parmenides considers illusion, not reality. Even more, the fact that Parmenides' passage is very likely a reference to Herakleitos, who espouses contradictions [Tarán 1965: 69-72], means that Xenakis actually paraphrases the latter.

Whether a composer fully understands a thinker of twenty-four centuries earlier may be irrelevant here. It is Xenakis himself, though, who declares: "EONTA is a kind of homage to Parmenides" [Bois 1967: 18]. Considering the latter's monism, it is impossible for us to ignore this major discrepancy: For Parmenides, Being ("εόν") is "ungenerated and imperishable, whole, unique, immovable and complete" ("ως αγένητον εόν και ανώλεθρόν εστιν, ούλον μουνογενές τε και ατρεμές ηδέ τελεστόν": 8:3-4) [Tarán 1965: 85]. Xenakis, on the other hand, adopts the plural form "Beings." The only reference to "εόντα" in Parmenides is a negative one: "For never shall this be forced: that things that are not exist" ("ου γαρ μήποτε τούτο δαμήι είναι μη εόντα": 7:1) [Tarán 1965: 73]. According to Leonardo Tarán, "It is important to notice that non-Being in the fragment is expressed by the plural; and, since this is followed by a polemic against the senses, it appears that Parmenides is here referring to the phenomenal world (which for him does not exist)" [Tarán 1965: 75]. Where is Xenakis' homage to be found, then, if the title itself of *EONTA* stands in opposition to Parmenides?

The philosophy of Parmenides is, of course, notoriously difficult to grasp. His work survives in a few fragments amounting to several dozen lines. That he expressed his ideas in poetic form (*On Nature*) makes things even more complicated. And the absence of a philosophical terminology at the time he was writing creates yet another layer of cognitive distance from his ideas (how exactly he understood εόν is still elusive to us).

Still, the surviving fragments of Parmenides and his reception by later philosophers (most famously by Plato) leave no doubt as to the core ideas of his philosophy. Reasoning is superior to sensory experience; only deduction can lead to objective reality; what can be thought does exist; differentiation and change are illusions because existence is by definition perfect, immutable and ever-present.[20]

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[17] For general introductions to Parmenides and his philosophy, see Guthrie 1965: 1-80, and Freeman 1966: 140-152.

[18] "Je reviens toujours à la formidable phrase de Parménide: "C'est la même chose de penser et d'être." L'être n'est donc pas l'objectivité, c'est un concept plus général. Si l'on peut imaginer quelque chose, ça exist, ou ça pourrait exister" [Xenakis 1972: 29]. See also Xenakis 1971: 24, Xenakis 1985: 36, and Xenakis 1987: 43-44.

[19] Xenakis' effort to create a musical *lingua franca* is recognized in Butchers 1968: 5.

[20] It goes without saying that Parmenides' monism is least popular with musicians, who live and breathe in the myriads of sound combinations. The closest realization of his principle in music would probably be a single continuous sound (a cosmic pedal point), but that would have signaled the end of music as we know it. I ventured to offer one such example, actually titled *The End of Music*, at a public concert in Thessaloniki in 1990, to the surprise and utter amusement of the audience.

Xenakis the Parmenidean composer

Clearly, neither the title nor the content of *EONTA* allude to Parmenides' philosophy (set theory itself is incompatible with monism). On the contrary, they explore a world of maximum differentiation and violent contrasts, which can best be described as Herakleitean. This is not to say that Xenakis confused his ancient Greek philosophers. His affinity with Parmenides is a given, but it occurs on intellectual rather than executive levels.

W. K. C. Guthrie helps us understand why Xenakis was attracted to Parmenides in the first place: "The realm of truth is rather like the mathematical model or world-image of the modern physicist with its relationship to the physical world reversed. ... Reverse the relationships, call the physicist's model reality and the physical world a construction of the human intellect and imagination, and we shall approach very closely to the Parmenidean ontology" [Guthrie 1965: 51-52]. What Xenakis found in the Eleatic philosopher was the supremacy of mind over matter, an aspiration familiar to architects, who have to translate mental representations into three-dimensional objects of the largest scale.

Throughout his career, Xenakis emphasized the intellectual essence of music in contradistinction to a sense-based craftsmanship: "the qualification 'beautiful' or 'ugly' makes no sense for sound, nor for the music that derives from it; the quantity of intelligence carried by the sounds must be the true criterion of the validity of a particular music" [Xenakis 1971: ix]. At times, he even reached Adornian tone: "what we are witnessing is an industrialization of music which has already started, whether we like it or not. It already floods our ears in many public places, shops, radio, TV, and airlines, the world over. It permits a consumption of music on a fantastic scale, never before approached. But this music is of the lowest kind, made from a collection of outdated clichés from the dregs of the musical mind" [Xenakis 1971: 200]. The way out lies "in dominating and transforming this poison that is discharged into our ears" [Xenakis 1971: 200], and this can be done through reasoning.

Parmenides was the first to equate thinking and being: "for the same thing can be thought and can exist" ("το γαρ αυτό νοείν έστιν τε και είναι": 3:1) [Tarán 1965: 41]. Reasoning is the gate to the true nature of things, therefore one should "judge with reason" ("κρίναι δε λόγωι" 7:5) [Tarán 1965: 73]. Similarly, Xenakis proposes that "Reflection on *that which is* leads us directly to the reconstruction ... of the ideas basic to musical composition, and above all to the rejection of every idea that does not undergo the inquiry (έλεγχος, δίζησις)" [Xenakis 1971: 207]. Composition becomes, then, a mental discipline, where everything is determined by the mind and with no regard to sensory perception. The very idea of introducing algebra and logical operations in music is an effort by Xenakis to move the seat of creativity from the temporal (sense-dependent) to the atemporal (mind-dependent). It is on this level of mental processes, rather than on the mechanical translation of relationships into music semantics, that we will find Xenakis' homage to Parmenides. Retreating from the senses, and adopting an axiomatic method of composition, Xenakis follows the Parmenidean Way of Truth. Indeed, this view finds support in a remarkable statement of Yuji Takahashi: "The 'rhythm' in *Herma* and in *Eonta* is stochastic: that is, the notation is only an approximation" [Takahashi 1975: 53].

A Parmenidean "reconciliation"?

There is no reconciliation in Parmenides' philosophy, if only because of lack of opposites to be reconciled. However, we may use the "Parmenides" tag in *EONTA* to bridge mathematical analysis and hermeneutics. Undoubtedly, the work contains serious mistakes in its application of set theory and projects an erroneous view of Parmenides' philosophy. But since we listeners and performers experience *EONTA* in time and through our senses, we may actually have missed the artwork that Xenakis created on mental levels. If the world of senses is one of contradiction, as Parmenides accepts, there is nothing surprising about *EONTA*'s "mistakes." They are the natural consequence of transferring atemporal constructions into a temporal dimension. As the work emerged from abstract, mental levels, it can still discharge its intelligence notwithstanding errors in typesetting or performance.

A reading of *EONTA* in the context of Parmenides' philosophy may also lead to surprising insights and help explain otherwise baffling details in the work. What seems an incomprehensible aural experience can turn into a fascinating listening once we are willing to view sets as beings in constant interaction with one another. To be sure, we will need to have access to the score; but this brings closer music listening and contemplating.

That Xenakis begins to count bar numbers from the second measure is absurd unless we recall that for Parmenides there is no beginning or end in existence: "It is indifferent to me where I make a beginning; for there I come back again" ("ξυνόν δε μοί εστιν, οππόθεν άρξωμαι· τόθι γαρ πάλιν ίξομαι αύθις": 5:1-2) [Tarán 1965: 51]. This also makes intelligible the work's final pedal point (mm. 476-481).

The ontological perspective of Parmenides also helps us identify the work's climax. The simultaneous appearance of a set and its negation (*Ψ* and -*Ψ* in mm. 190-194, and *Ψ+Θ* and -(*Ψ+Θ*) in mm. 195-202; see also mm. 349-351 and 358-359) is a Parmenidean impossibility, for something cannot both exist and not exist (the negation of a set is actually its absence from the universal set). At the same time, it illustrates Xenakis' distorted paraphrase of the philosopher "For it is the same to be as not to be" [Xenakis 1971: 24] because the opposites cancel each other. Considering Xenakis' eclectic understanding of Parmenides, one may study *EONTA* as an exploration of ontological states, ranging from the undifferentiated chaos of the opening solo, to the confrontation of mutually exclusive sets, and the integration of all instruments later in the work. An interesting example for contemplation is the relationship of -(*ΨΘ* -*Ψ-Θ*) and *Σ*, two identical sets. Does it make a tautology for the one to precede or succeed the other or should they be taken as independent entities?

The final reconciliation in *EONTA* involves three points, Xenakis, Parmenides, and us listeners/analysts. By placing Greek characters in the score, Xenakis invited us to examine it as an application of set theory. Our mathematical analysis revealed many errors. These in turn, prompted us to investigate the philosophical premise of the work, following Xenakis' second lead in the score: Parmenides. Once again, we discovered major inconsistencies, between Parmenidean philosophy and Xenakis' ideas and their realization in *EONTA*. Parmenides, however, warned us that anything in the sense-defined world of mortals (including music scores) is deceptive, so we should not be surprised by the errors we discovered. Thought is what really counts and Xenakis helped us think and reason to a degree we had never suspected. We may now return to mathematics and, from a higher turn of the spiral, see Xenakis, Parmenides, and us as three distinct sets, which find their hermeneutic intersection in *EONTA*. Set theory and hermeneutics thus are not only reconciled but form natural complements in our study of Xenakis' music.

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