ARTICLE

Analysis and perception in post-tonal music: an example from Kurtág's String Quartet Op. 1

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ABSTRACT In this study, two different types of analysis of a piece of post-tonal music (the fifth movement of the String Quartet Op.1 (1959) by G. Kurtág) are compared: an analysis performed by seven professional music analysts using the musical score, and a perceptual analysis carried out by two groups of subjects (18 musicians and 25 non-musicians) while listening in real time. Three possible macroforms proposed by the analysts were compared with those perceived by the listeners. The results show that the macroforms hypothesized by the analysts represented the basic framework for those perceived by the listeners; moreover, the musical competence possessed by the musicians who took part in the listening exercise does not, on the whole, appear to have affected the perception of the macroform of a post-tonal piece of music.

KEYWORDS: *categorization, contemporary music, cues abstraction, grammar, macroform, segmentations*

Introduction[1]

The problems arising from the analysis of post-tonal music are very different from those found in tonal music, both in terms of music theory (Forte, 1973; Hasty, 1981; Lerdahl, 1989), and the cognitive listening processes involved (Imberty, 1987, 1993; Deliège, 1989, 2001a, 2001b; Butler, 1990; Deliège and El Ahmadi, 1990; Dibben, 1999). This is mainly, but not exclusively, on account of the lack of widely shared rules in post-tonal music. In this article we set out to compare the results of an analytical approach to the score of a piece of post-tonal music, with those of a perceptual analysis of the same piece carried out in real time. The study is part of a wider project recently launched by the Gruppo di Analisi e Teoria Musicale (GATM), a national research group based in the Department of Music at Bologna University,

whose aim is to investigate the 'macroform' in post-tonal music, that is, the problem of the overall form of a piece (Baroni, 2003).

General outline of the study

Generally speaking, it can be said that during the analysis of a score (or with the aid of a score) certain analytic criteria are applied that derive from the cognitive listening processes, even though these are not always explicit or used systematically (Cross, 1998). In some cases, however, the analyst makes explicit use of criteria deriving from the perceptual and cognitive processes of an average listener, albeit a model listener (see Lerdhal and Jackendoff, 1983). The issue of the perceptual pertinence of an analysis remains an open question that is still under discussion in theoretical studies (Nattiez, 1997; Lerdhal, 1997; Cross, 1998) and numerous investigations have been performed to examine the perceptual suppositions of certain analytical models (Deliège, 1987; Bigand et al., 1994; Dibben, 1999).

The present study can be placed somewhere between questions of a truly analytical nature on the one hand and the cognitive issues involved in real-time listening on the other. We investigate, for instance, whether the perceptual criteria used by analysts when analyzing the macroform of a piece of atonal music can be predictive of a listening situation and whether it is possible to verify these criteria in such a situation. In addition, we try to find out if the musical competence of the listener, or his/her familiarity with the post-tonal repertoire, can influence the perception of macroform while listening in real time.

GRAMMAR AND GRAMMATICAL COMPETENCE

To understand the distinction between the approach used by the analyst, even when attempting to perform a 'perceptual' analysis of a piece, and that of the listener who tries to retain the piece of music in his/her mind, we refer to previously formulated grammar theories (Lerdhal and Jackendoff, 1983; Baroni and Callegari, 1984; Johnsons-Laird, 1991; Baroni et al., 2003): 'The rules of music, when explicitly formulated, are fundamentally a reflection on how music is made and listened to, an attempt to describe rationally the organization of sounds which a composer, a musician, a listener will put into effect when intuitively performing a musical activity' (Baroni et al., 2003: 4). The relationship between the 'grammar' used by the analyst and the 'grammatical competence' of the listener is that the former is an explicit rendition of the rules implicit in the latter. It should, of course, be born in mind that when applied to the score such a 'grammar' loses certain elements characteristic of listening perception, which depend on temporal structures and the processes of memorization.

In the case of listening to post-tonal music, we are not always dealing with grammatical rules as such. The procedures applied while listening to this type

of music are often not based on pre-established systems of organizing sound that are socially accepted and codified by common rules; it is true that in some cases certain rules deriving from the tonal tradition continue to work, while in other cases we are dealing with aspects of the language not based on culturally transmitted rules, but on experimental ideas which have not yet been 'grammaticized', whose perception may, however, sometimes be explained in cognitive terms.

Nevertheless, the distinction between the intuitive competence of the listener and the explicit conceptualization of the analyst still holds true even under these conditions. The analyst tends to think in conceptual categories, transforming a categorical perception or simply a perception that obeys general cognitive laws, into definite concepts, even to the extent of setting them in areas where such concepts have not yet been definitively codified by music theory.

Another essential difference between the listener and the analyst who puts him/herself in the place of a listener is that time, for the latter, is always freely reversible. In a musical score, time is transformed into a space where it is possible to stop at any point. Moreover, as Cook pointed out (1990), the visual perception of the score may also affect the analysis of the analyst as he/she listens. In the context of our study, the analyst should nevertheless be aware of the perceptual difficulties and problems related to memory encountered by a listener and his/her task is precisely that of rendering these problems explicit (see also Cross, 1998). The analyst must therefore consider questions such as: what perception and memorization difficulties might the listener face in the piece I am analysing? Which structures can be clearly perceived? Which of them can be memorized?

SEGMENTATION AND MACROFORM

As already mentioned, the aim of the GATM project is to investigate the concept of macroform in post-tonal music. The term 'macroform' and the concept we wish to identify by this term need to be carefully defined, since they are not always used in the same way (as is also the case with other musical terms).

By the term 'macroform', we refer to the global form of a piece, that is, the division of the piece into its largest parts with reference to its overall structure. In musicological literature, various terms are used in a similar sense but with meanings that are sometimes quite different, for example, 'large dimensions' (La Rue, 1970), or 'large scale form' (Levinson, 1997).[2] In the field of psychology, Imberty (1981, 1993) uses the term 'macrostructure', which originates from the field of linguistics (Kintsch and Van Dijk, 1975), but is here considered from a perceptual point of view: a 'scheme for structuring time, where sound events are arranged *a priori* according to rules drawn from the perceptual mechanisms involved in the detection of changes within the continuum of sound'[3] (Imberty, 1981: 90). Our use of the word basically

derives from Imberty's concept of macrostructure, but we have felt the need to distinguish between the concept of division into parts, which only identifies the macroform, and that of the perception of change, which we have defined with the term 'segmentation'. The importance of the process of segmentation and the identification of the criteria applied during this activity is an issue that has in fact been recognized in analytical studies ever since the famous study by Ruwet (1966).

The reasons for choosing a particular segmentation vary considerably, but generally speaking they include: repetition (Ruwet, 1966), change or discontinuity (Imberty, 1981), rhythmic grouping (in metrically organized music, Lerdahl and Jackendoff, 1983) and the principles of difference and similarity (Deliège and Mélen, 1997; Deliège 2001a, 2001b). Although the term 'segmentation' is invariably used as a synonym for the division into parts, the analysis carried out during the research of the GATM group has clearly shown that segmentation is not a sufficient criterion to identify the main parts of a piece (i.e. its macroform) since the perception of a strong local discontinuity does not necessarily produce a division in terms of the piece as a whole. A very long pause, for example, may give rise to the perception of a segmentation, but this does not necessarily constitute a separate self-contained section. On the other hand, parts of a piece can sometimes be found which are apparently different from one another even though there is no well-defined segmentation point dividing them.

The analysis of macroform poses different problems to that of segmentation, especially where memory is concerned. The question is: when we reach the end of the composition have we already mentally elaborated a possible division of the piece into parts? And are we able to say the exact number of parts and identify them? Do we identify the parts as a result of their qualities and homogeneity or on the basis of local discontinuities? With regards to tonal music, Deliège (Deliège and Mélen, 1997; Deliège, 1998) proposed a particular experimental procedure, a 'mental line' that tries to test the ability to memorize the quality and the order of succession of the parts identified in a piece while listening.

For the purposes of this article, then, the term 'segmentation' will be used only to indicate the exact point where two sections are separated, a local phenomenon brought about by the presence of a contrast or discontinuity that involves one or more parameters of the musical material (duration, dynamics, timbre, density, register, etc.). The term 'macroform', on the other hand, is used to indicate the result of a process of memorization involving the division of a piece of music into its largest parts, where each part has structural coherence and homogeneity. As already mentioned, the macroform is not necessarily brought about by the hierarchy of the segmentations.

Finally, one last remark should be made about the difference between the criteria involved in the division into parts of a post-tonal and a tonal piece. In the former it appears to be, above all, a question of identifying

certain qualities of sameness and difference which can easily be perceived and memorized, allowing the listener to abstract 'cues' (or prominent features) which distinguish one part of the piece from another (Deliège, 2001a). The division into parts of a tonal piece largely depends, however, on formal (and cultural) rules (exposition, development, conclusion, coda, recapitulation, bridge, repetition, symmetry, etc.). Traces of these cultural rules may, in fact, persist in post-tonal music.

The GATM decided to focus its attention on the macroform of the piece, since it is basically the failure to perceive this aspect that may lead to confusion or tedium when listening to a post-tonal piece.

The experimental study

So far, the research has concentrated mainly on string quartets.[4] By working on such a homogeneous repertory, the number of variables is limited and it is therefore easier to formulate plausible and general hypotheses about the problems of listening to post-tonal music.

A comparison is made here between the macroformal analysis of the fifth movement of the String Quartet Op. 1, by G. Kurtág (Figure 1) carried out by seven professional music analysts from different Italian universities (members of the GATM) and those perceived by two groups of subjects, one made up of musicians and the other non-musicians, while listening to the piece in real time. The three macroforms selected for experimental study (see below) were the only ones to be proposed unanimously by all seven analysts after working independently on the basis of a pre-established analytical method.

For the reasons mentioned above regarding the differences between the analysts and listeners, we do not necessarily expect the three solutions proposed by the analysts to be predictive of the behaviour of the listeners. The aim of the study is rather to compare the two analytical procedures, that of the analysts and that of the listeners, in order to observe any elements they might share and the differences that separate them.

THE ANALYSTS' MACROFORM

The macroform analysis was largely based on Irène Deliège's theory of 'cue abstraction' (see above), and on the theory of 'domains' proposed by Christopher Hasty (1981). The model proposed by Deliège for the mental representation of tonal and post-tonal music listened to in real time attempts a systematic approach to these questions. Her hypothesis (see Deliège and Mélen, 1997; Deliège, 2001a, 2001b) sees music perception as a vast process of categorization, which begins with the rhythmic grouping and the arranging of groups based on the abstraction of 'cues', that is, the perception of similarity between motifs located at different places in a piece, and culminates in the organization of the traces left by the cues, the 'imprints'.

A 'domain', on the other hand, may be described as a microelement, a

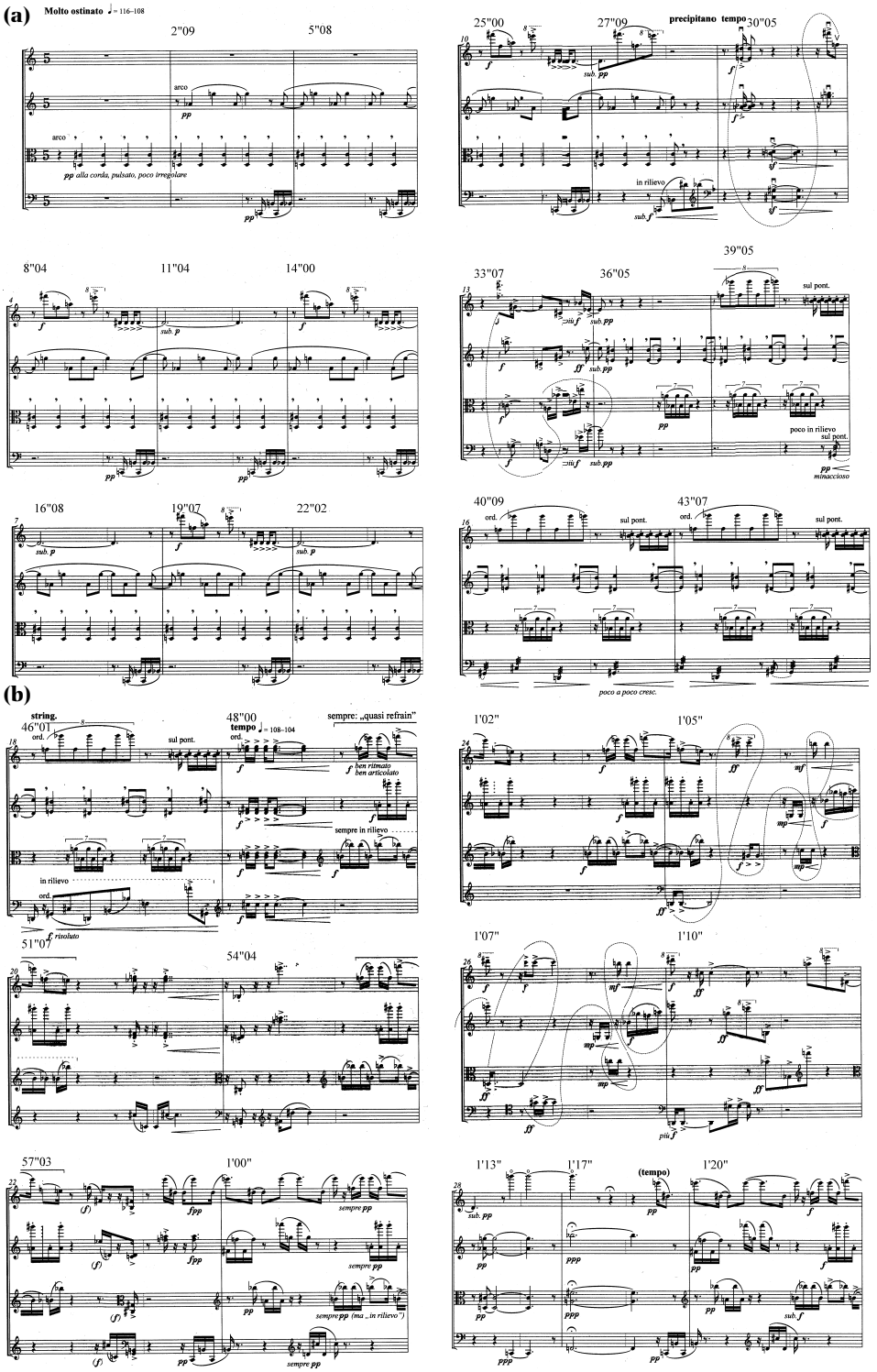
feature of the musical structure that presents constant values and unites discontinuous elements, thus enabling a single section to be identified. For example, in Hasty's analysis of Stefan Wolpe's (1969) string quartet (Hasty, 1981), the 'domain' is created in the first bar by the fact that the six notes are all introduced at regular eighth-note intervals, even though they present features of rhythmic, melodic and timbric discontinuity. However, since it may occur that they are located in a context characterized by other features or domains, some of them presenting analogous constant values, the analyst must in this case make a decision about which of them is the most important.

The GATM group partly adapted Hasty's idea to its own objectives.[5] In a piece of music there are often sections where a given set of parameters (e.g. melodic intervals, characteristics of timbre, texture, dynamics, durations, etc.) behaves in a constant way. This persistence leads the listener to attribute an internal unity to that section of the piece, which distinguishes it from a successive section when some, or all, of the parameters change their behaviour. In other words, the characteristics of that particular parametric 'domain' act as 'cues' (Deliège, 2001a) for the perception of the division into parts. We should like to stress that, in our opinion, there is no conflict between the theories of Deliège and Hasty, since both of them attempt to identify the reasons why a fragment is heard as a unit containing musical continuity. While the analysts have time to seek out such points in the score and define them (referring to Hasty's theory), the listeners have no such time at their disposal and therefore depend more on the abstraction of 'cues' as proposed by Deliège.

In the piece by Kurtág, the above-mentioned analytical techniques had to take into account another important aspect: the presence of fragments characterized by an ostinato. This very evident feature may well be an example of the survival of certain aspects inherited from the tonal tradition (see, for example, the passacaglias of the 17th-century deriving from baroque usage). The division into parts of the quartet therefore appears to depend largely on the repetition of the ostinatos, following a principle that is quite similar to the one underlying classical structures, even though here we are dealing with ostinatos instead of themes. In this particular piece, then, the 'domains' (the constant features of the timbres, dynamic, texture, etc.) that make up the homogeneous content of the sections, coincide with the rhythmic-melodic ostinatos.

On the basis of the principle of the repetition of ostinatos and of the 'domains', the analysts of the GATM group independently worked out the following three possible macroforms (see Table 1 and Figure 1):

- *Macroform 1* – the analysts identified a first part, featuring a rhythmic-melodic ostinato that begins in bar 4 on the violin, although originating in the rhythmic-harmonic double-stopping of the viola in bar 1. This first ostinato is repeated four times until bar 11, where the analysts indicate


(a)
Molto ostinato
2"09
5"08
arco
pp alla corda, pulsato, poco irregolare
25"00
27"09
precipitano tempo
30"05
in rilievo
8"04
11"04
14"00
33"07
36"05
39"05
sul pont.
poco in rilievo
minaccioso
16"08
19"07
22"02
40"09
43"07
ord.
poco a poco cresc.
(b)
string.
46"01
48"00
tempo
sempre: „quasi refrain"
ben ritmato
ben articolato
sempre in rilievo
risoluto
1'02"
1'05"
51"07
54"04
1'07"
1'10"
più f
57"03
1'00"
sempre pp
sempre pp (ma „in rilievo")
1'13"
1'17"
(tempo)
1'20"

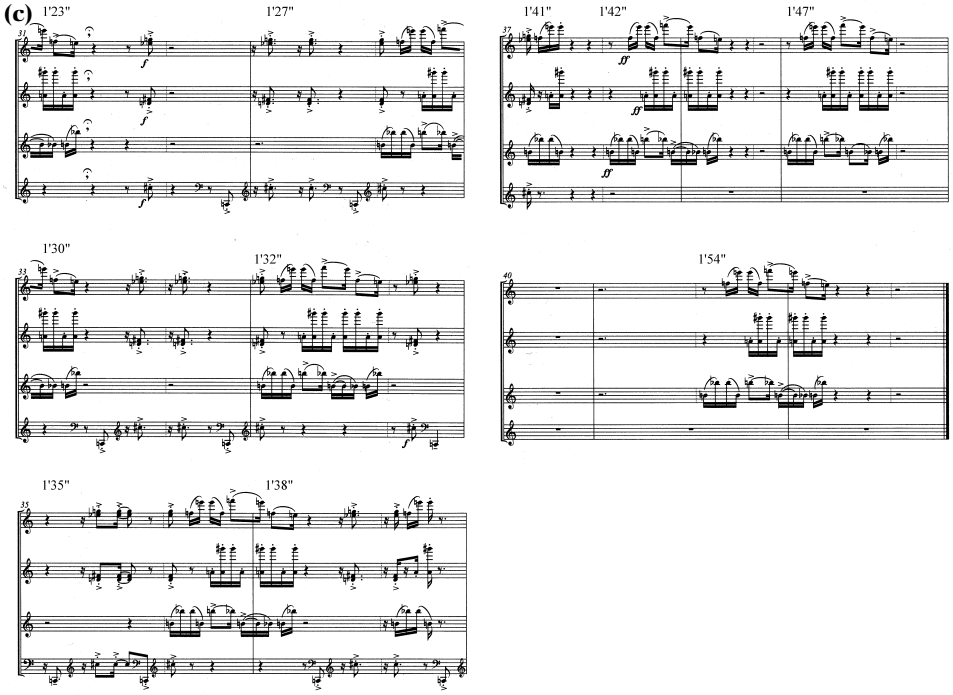


FIGURE 1 *György Kurtág, String Quartet Op. 1, fifth movement (© 1964 Edito Musica, Budapest, Z.4481, pp. 21–26). Reproduced by permission of the publisher.*

TABLE 1 *Analytical macroform hypotheses*

Macroform 1	
I part	bars 1–11 (sec. 000–27”/30”)
II part	bars 12–19 (3) (sec. 30”–50”)
III part	bars 19 (4)– 42 (sec. 50”– end)
Macroform 2	
I part	bars 1–11 (sec. 000–27”/30”)
II part	bars 12–19 (3) (sec. 30”–50”)
III part	
IIIa	bars 19 (4) – 29 (3) (sec. 50”–1’19”)
IIIb	bars 29 (4) – 42 (sec. 1’19”–end)
Macroform 3	
I part	bars 1–11 (sec. 000–27”/30”)
II part	bars 12–19 (3) (sec. 30”–50”)
III part	
IIIa	bars 19 (4) – 25 (1) (sec. 50”–1’7”)
IIIb	bars 25 (3) – 29 (3) (sec. 1’8”–1’19”)
IV part	bars 29 (4) – 42 (sec. 1’19”– end)

the end of the first part. The second part features the entry of a new set of ostinatos, introduced by the double-stopping in syncopation with the second violin, beginning at bar 14 and ending at bar 18 (the passage from bars 12 to 14 without the ostinato was considered a bridge passage on account of its brief duration). The third part begins at bar 19 with the entry of a new ostinato played by the cello and the two violins, which appears almost constantly until the end.

- *Macroform 2* – the second proposed macroform takes into account the fact that the features of the last part of the piece are not completely homogeneous; from bars 19 to 29, the ostinato motive characteristic of this part is only repeated four times (bars 19, 21, 23 and 24); the third time it is pianissimo and after the fourth time, the ostinato is followed by five bars (25 to 29) where it does not appear at all; on the other hand, from bars 30 to 42, it is repeated eight times, each time closer (bars 30 to 37) until finally being reduced in duration while being interspersed with long pauses (bars 37 to 42). The second macroform, therefore, proposes the division of the third part into two sections. The division between the two sections has been placed at bar 29, due to the long, pianissimo notes, which give the idea of closure.
- *Macroform 3* – the last part of the piece could also be divided into three sections, if the five previously mentioned bars (25 to 29) are considered as self-standing due to their not featuring any ostinatos. The third macroform, therefore, proposes the division of the movement into four distinct parts.

It is interesting to note how the proposals have taken into account the fact that the presence of the ostinatos is not totally consistent. There are, as we have seen, parts of the piece with no ostinatos. Moreover, the ostinatos themselves present irregularities, mainly in the last part of the piece. Finally, the fact that the three proposed macroforms are somewhat different from one another should not be cause for surprise or for any doubts about the correctness of the procedure. It is simply due to the structure of the piece itself, which contains certain ambiguities and may be interpreted in more than one way.

LISTENING TESTS

Subjects

Two groups of subjects aged 22 to 35 took part in the experiment: 25 non-musicians (university students whose only musical experience was what they had received at school between the age of 11 and 14 years) and 18 musicians (conservatory graduates – piano, violin, composition, and conservatory teachers – piano, composition, electronic music). Although the vast majority of the musicians (70.6%) had previous experience of post-tonal music, only a small group of non-musicians (21.4%) was familiar with the genre.

Materials
The material used was G. Kurtág's String Quartet Op. 1, fifth movement (1959), duration two minutes and two seconds, performed by the Arditti String Quartet (CD WDR Auvidis Montagne MO 789007).

Apparatus
A special computer program called EPM (Experiments on the Perception of Music) was used, which was devised at the University of Padua. This program allows each subject to listen to a piece through headphones and indicate the segmentations perceived while listening in real time by clicking the mouse. Every time the mouse is clicked a red square on the screen in front of the subject turns yellow. The program records the subject's selection in hundredths of seconds, making it possible to compare the results with the score (Figure 1).

Procedure
Each subject was allocated a computer and given a questionnaire which, in addition to the written answers, involved three tasks to be carried out using the EPM program. The questionnaire also contained details of how to use the program. The experiment took place in a room containing 30 computers. The subjects were called in two sessions of mixed groups (musicians and non-musicians) of 20 and 23. An operator read out the instructions for the use of the computers and the program. Two assistants were available to resolve individual problems, if needed. Each test began only when all subjects had finished the previous task.

The experiment lasted approximately 45 minutes and involved various steps and tasks. After an initial listening to become familiar with the piece and with the program (task 1), the subjects were given two segmentation tests: they had to listen to the piece twice and indicate during each listening the segmentations they perceived, using the computer and the EPM program (tasks 2 and 3).[6] This was followed by two tasks involving the perception and memorization of the macroform (tasks 4 and 5): the subjects had to listen to the piece three times and identify the main sections; after the first listening they were instructed to mark the perceived sections along a line on a sheet of paper (task 4); in the next two listenings they had to indicate the sections on the computer using the EPM program; that is, they were asked to indicate on the computer what they remembered of the macroform of the piece (task 5). For the purposes of statistics, only the answers given for the last listening (the sixth listening) were considered.

In the next two tasks the subjects had to write the answers to questions that tried to identify the criteria they had used in formulating their solutions (tasks 6 and 7).

The results discussed in this article are based on the answers given in tasks 5, 6 and 7, as they are directly concerned with the analysis of the macroform.[7]

TABLE 2 *Macroforms given by subjects and macroforms given by music analysts*

Seconds	1–7	8–13	14–25	26	27–34	35	36–41	42–46	47–54	55–56	57–65*	66–72	73–82	83–92	93–100	101	102–108	109–113	114–end
Bars	1–3	4–5	6–10(3)	10(4)	11–13(3)	13(4)	14–16(3)	16(4)–18(3)	18(4)–20	21	22–25*	25(2)–27	28–30	31–33	34–36	37(1)–37(3)	37(4)–39	40–41(3)	41(4)–42
Musicians																			
1		**X**			**X**		**X**						**X**				**X**		
2					X				X		X		X	X			X		
3		**X**			**X**		**X**						**X**				**X**		
4		X	X		X		X		X	X	X			X	X		X	X	X
5					X						X		X				X		
6					X						X		X						
7							X						X						
8					X								X				X		
9					X		X		X		X		X				X		
10					X				X				X	X					
11					X		X		X				X						
12	X	X			X		X		X										
13					X														
14																			
15					X									X					
16	X	X			X				X				X	X			X	X	X
17	X				X		X		X		X		X						
18							X				X		X						
Non-musicians																			
1			X						X					X				X	
2		X			X		X		X	X			X						
3					**X**				**X**				**X**						
4					X										X				
5					X								X					X	
6					X		X				X		X				X		

7		X			X						X						
8						X					X						
9					X						X				X		
10					X	X					X					X	
11		X			X		X				X	X				X	X
12					X	X					X	X					
13					X			X							X		
14					**X**			**X**			**X**						
15					X	X		X			X				X		
15			X		X	X											
17		X			X			X			X	X	X			X	X
18						X					X				X		
19					X			X			X				X		X
20					X	X					X	X					
21		X	X		X				X		X				X	X	X
22		X	X		X	X					X				X	X	X
23			X		X			X	X		X	X	X		X	X	X
24	X				X			X			X						
25					X			X					X				
Analysts' macroforms																	
Macroform 1					**bar 12**			**bar 19(4)**									
Macroform 2					**bar 12**			**bar 19(4)**			**bar 29 (3)**						
Macroform 3					**bar 12**			**bar 19(4)**		**bar 25(2)**	**bar 29 (3)**						

Difference musicians/non-musicians $p < .05$.

The subjects' replies are marked with the letter 'X'. Bold **X** indicates the replies of the subjects that gave the identical macroform (musicians nn. 1 and 3; non-musicians nn. 3 and 14).

The answers given in test 5 have been grouped into 19 ranges corresponding to the areas where the subjects identified the points of division. The ranges are shown in the columns, with the seconds and bar numbers. In the last three lines, the bar numbers are given corresponding to the points where the analysts indicated divisions in their three macroform proposals. It is thus possible to see the macroform given by each subject (horizontally) and the extent to which they coincide with the solutions proposed by the analysts (vertically).

Results

TASK 5

Generally speaking, the results show that the subjects' perceptions of macroforms were extremely heterogeneous. Most of the subjects, whether musicians or non-musicians, indicated more divisions than those hypothesized by the analysts. The number of divisions indicated by each subject is extremely variable, ranging from 0 to 16. This makes any comparison between subjects and between groups (musicians, non-musicians) somewhat problematic.

The answers given in task 5 have been grouped into 19 ranges (see Table 2) corresponding to the areas where the subjects identified the points of division of the piece. It should be born in mind that Table 2 does not show precise points, but rather the number of seconds and the range of positions in the bar. The ranges therefore show the space of time where a set of answers is grouped.

In the data analysis, the dependent variables were the different ranges in which the answers are clustered and the independent variable was the musical education of the subjects. A non-parametric test (Mann-Whitney) was used to check the difference between musicians and non-musicians within the given ranges: only in the range 57–65 seconds, bars 22–25, do we find a difference that is statistically significant (Mann-Whitney $U = 163$, $p < .05$; see Table 2).

In order to observe the relationship between the perceived macroforms and the three macroforms of the analysts, it is necessary to analyse the data subject by subject (see Table 2).

- *Musicians* – none of the musicians perceived a macroform which coincides perfectly with any of the three macroforms proposed by the analysts. Only two subjects (numbers 1 and 3, see bold 'X' in Table 2) gave identical answers; that is, they perceived the same macroform.
- *Non-musicians* – we can see that there are two subjects (numbers 3 and 14, see bold 'X' in Table 2) who perceived the same macroform. In this case, the macroform actually coincides with the analysts' M2.

It is nevertheless possible to observe a general tendency confirming the points of division indicated by the analysts (see Table 2). The subjects thus confirmed the analytical hypotheses, but with some variations. The division most frequently perceived (27–34 seconds, bars 11–13; musicians: 84.2%, non-musicians: 88.0%) coincides with the first point of division in the analysts' macroforms. The second most frequently perceived division (73–82 seconds, bars 28–30; musicians: 72.2%, non-musicians: 80.8%) only appears in M2 and M3. The other division in the analysts' macroforms, namely the one in bar 19(4) within the 47–54 seconds range, was less frequently indicated by the subjects (musicians: 44.4%; non-musicians: 46.2%). Finally, the point of division in bar 25(2) within the 66–72 seconds range, which had been indicated in M3, is completely absent in our subjects' answers.

We developed an empirical index to check how near or far the macroforms perceived by the subjects were from those proposed by the analysts. All the points of division given for each perceived macroform were recorded and compared with those of the analysts' macroforms. In order to make this comparison, the following formula was applied: I =(c*100)/A, where c is the number of points coinciding with the points in analysts' macroforms and A is the number of all the points of division indicated by the subjects. If A is smaller than the proposed points in the analysts' macroforms then I is not computed.

It can be seen from Table 3 that M2 (I = 48.15 musicians; I = 52.41 non-musicians) is the closest to the macroforms perceived by both musicians and non-musicians. The results for M3 are slightly lower (I = 47.85 musicians; I = 43.25 non-musicians), while M1 is clearly the furthest from the perceived macroforms (I = 28.96 musicians; I = 32.40 non-musicians). The results obtained for M1 can be explained by the fact that many subjects did not indicate the range 47–54 seconds as a point of division.

There are no significant differences in the I values between musicians and non-musicians according to the Mann-Whitney test.

TABLE 3 *Correspondence between macroforms proposed by musical analysts and macroforms perceived by the subjects*

Subjects		*n*	Mean index of correspondence* (%)	Standard deviation (%)
Musicians	Macroform 1	16	28.96	15.79
	Macroform 2	14	48.15	18.33
	Macroform 3	12	47.85	18.59
Non-musicians	Macroform 1	25	32.40	19.90
	Macroform 2	23	52.41	22.65
	Macroform 3	14	43.25	17.17

*Index of correspondence is an empirical measure that we have adopted obtained by the number of points coincident with macroforms (1, 2 and 3) multiplied by 100 and divided by the number of all the points given by the subjects to define their macroforms. Reproduced by permission of the publisher.

TASKS 6 AND 7

In tasks 6 and 7, the subjects were asked to express the reasons for their macroformal choices. This was achieved by asking them to indicate, from a list of suggested items, the elements which had elicited their division of the musical piece into a certain number of parts; that is, they were asked to specify the differences they had perceived between the various parts of their macroforms. The following categories were considered:

1. variation in intensity;
2. timbre variation;
3. acceleration, deceleration or change in rhythm;
4. thickening or thinning of the sound;
5. introduction, repetition;
6. elements concluding or suspending;
7. pause.

In task 6, subjects were asked to indicate all the elements they took into consideration. In task 7, subjects were asked to give a hierarchic order of the indicated elements (from the most important to the least important).

If we look at the results in Table 4, we can see that all the suggested categories were used by our subjects to explain their segmentations. Some significant differences ($p < .05$), according to the Mann-Whitney test, can be found between musicians and non-musicians: musicians in comparison with non-musicians seem to indicate the category 'thickening or thinning of the sound' to explain segmentation in a larger number of cases; on the other hand the category 'acceleration, deceleration or change in rhythm' is significantly more used by non-musicians.

TABLE 4 *Closed answers: categories chosen to explain segmentation for the two groups of subjects (musicians = M, non-musicians = N).*

Categories chosen to explain segmentation	M (%)	N (%)
1. Variation in intensity	66.7	78.6
2. Timbre variation	72.2	57.1
3. Acceleration, deceleration or change in rhythm	44.4*	75.0*
4. Thickening or thinning of the sound	77.8*	50.0*
5. Introduction, repetition	61.1	39.3
6. Elements concluding or suspending	66.7	57.7
7. Pause	50.0	71.4

*$p < .05$; **$p < .01$.

If we consider the first categories chosen to explain segmentation (Table 5) we can see that it is the 'timbre variation' category which is the most frequently used by musicians, while 'variation in intensity' is the category most frequently adopted by non-musicians. According to the Mann-Whitney test, a significant difference ($p < .05$) can be found between musicians and non-musicians in the choice of the 'timbre variation' category, whereas there is no significant difference between musicians and non-musicians in the choice of the 'variation in intensity' category.

These results suggest that there may be some differences in the way musicians and non-musicians construct macroforms and that certain elements are stressed more than others.

TABLE 5 *Closed answers: first categories chosen to explain segmentation for the two groups of subjects (musicians = M, non-musicians = N).*

First categories chosen to explain segmentation	M (%)	N (%)
1. Variation in intensity	9.1	36.4
2. Timbre variation	36.4*	4.5*
3. Acceleration, deceleration or change in rhythm	9.1	18.2
4. Thickening or thinning of the sound	9.1	13.7
5. Introduction, repetition	18.1	4.5
6. Elements concluding or suspending	9.1	4.5
7. Pause	9.1	18.2

*$p < .05$; **$p < .01$.

Discussion

Several interesting points concerning the perception of macroforms arise from Table 2, above all in relation to the results that are clearly very different from the analysts' solutions. For example, one of the points of division chosen by many subjects, involving the passage from bars 12 to 14, was not considered suitable by the analysts, who, on account of its brevity, considered it as a bridge passage lacking in independence. The subjects, on the other hand, perceived bars 12 to 14 (where the ostinato is suspended) as an independent section. The results show that the internal characteristics of the sections, and therefore their homogeneity, seem to be more important for the listener than the duration of each section: the listeners seem to have been able to memorize not the presence of the ostinato, but rather its absence, and interpreted this feature as a section. This finding coincides with the experience of Deliège and El Ahmadi (1990): the listeners do not appear to have been influenced by the duration of the parts, unlike the analysts, who are aware of the theoretical principles of symmetry and formal balance. The question of experience of elapsed duration in musical listening is, in fact, a very complicated and controversial issue which often depends on the structure of the events involved, as suggested by Jones (1990). The absence of the ostinato in bars 11–13 would therefore seem to have acted as a 'cue', but it is nevertheless very likely, as the analysis of the closed answers suggest (tasks 6 and 7, Tables 4 and 5), that the listeners were also influenced by the concomitant changes in other parameters, such as the intensity, the rhythm, the texture and the density of the sound. At bar 11(3), not only is there an interruption of the rhythmic-melodic ostinato, but there is also an evident change in various other parameters (in particular an increase in the intensity and a change in texture), while at bar 14, the start of a new ostinato is accompanied by a marked decrease in both the intensity and density of the sound, and a greater regularity in the organization of the durations.

A similar occurrence can be observed in bar 25(2), where M3 proposes the beginning of a new section (bars 25(2) to 29), characterized by the suspension of the ostinato. Interestingly, in this case too about a third of the listeners perceive a brief section and indicate a point of division in bars 22–25. The point of division indicated by the analysts is more precise, being based on the score, and is situated on the second beat of bar 25. Nevertheless, the indications given by the listeners in bars 22–23 lead us to hypothesize that the distinct change in intensity on the last beat of bar 22 may explain why the listeners decided to segment here, even though the ostinato, which began in bar 19, does not stop until bar 25. As in the previous case, then, it would appear that the listeners were not only influenced by the ostinato, but also by other parameters such as the intensity. And it is at this point that we find the only significant difference between the musicians and the non-musicians (see Table 2): it is the non-musicians in particular that indicate a division here, showing a greater accordance with the analysts.

Both M2 and M3 give the beginning of a new section at the end of bar 29, where an ostinato returns. Many of the listeners, however, marked the beginning of a new section at bars 31–33, perhaps wanting to be sure the new ostinato was actually beginning, as they only registered the division after it had been repeated twice. A similar situation was observed even more frequently in the previous listening tasks dealing with segmentation (not discussed in this article), and this leads us to conclude that most of the subjects are able to anticipate the beginning of the section at bar 29 only after several listenings (6). This phenomenon has been studied by Deliège and El Ahmadi, who described this lapse of time between the end of the section and the segmentation as 'tiling' zones ('the limits of the end of sections [. . .] and the segmentations', 1990: 25).

It is also interesting to note that the division marked by the analysts at this point coincides exactly with the start of the ostinato (bar 29(3)). Many of the listeners, on the other hand, indicate the beginning of the new section at bar 28, where we find a 'sub. pp', together with harmonics and long notes: a moment of calm contrasting with the convulsive density of the previous passage. Once again we see that for some of the listeners the macroform is not established by a thematic criterion (the rhythmic-melodic ostinato), but rather by the change in intensity, speed and density of sound (tasks 6 and 7, Tables 4 and 5).

Finally, another difference between the macroforms of the analysts and those of the listeners can be found in the sections indicated in the final bars (37(4) until the end), where a large number of subjects indicated a division not proposed by the analysts. The presence of the pauses certainly creates a strong case for contrast between one repetition and another in the same ostinato, a situation similar to the one described by Deliège in her studies on the relationship between the principle of difference (pause) and the principle of similarity (repetition of the same ostinato) (Deliège and Mélen, 1997). One

may wonder, however, if the pauses alone are enough to create these sections, or whether their rhetorical function of bringing the piece to a close is in some way involved.

Final remarks

In the present study, the results show that the distance between the analytic and listening procedures was not particularly great in the case of a score analysis based on explicit criteria taken from theories dealing with perceptual aspects of sound: in our study we referred to the theory of cue abstraction (Deliège, 2001a and 2001b) and that of domains (Hasty, 1981). It has already been noted that, despite appearances, certain common patterns can clearly be identified. While not going so far as to say that the analysts' solutions were predictive of the behaviour of the listeners, we can nevertheless observe that the three macroforms proposed by the analysts do, to some extent, appear to have represented the basic framework for those perceived by the listeners: the second macroform, in particular, represented a kind of a prototype that was perceived, with certain variations, by all listeners. The absence or repetition of the ostinatos acted as 'cues', as in the theoretical model of Deliège.

One of the most interesting results is that it is clearly possible to render explicit the sense of continuity in a given part of a piece. It appears evident that the inner and predominantly unconscious intuition of elements of similarity, which give unity to a part, can actually be defined analytically by means of the presence of a set of domains. The listener, of course, does not always have enough time to pick up such subtle structural aspects. On the other hand, certain structural devices, such as the ostinatos, are both well defined analytically and easily perceived in listening. The notable presence of ostinatos in Kurtág's quartet is, in fact, one of the reasons why the difference between the macroform analyses and listening responses was not so remarkable. Over and above the rhythmic-melodic parameter provided by the ostinato, however, other types of parameter also appear to have influenced the listeners: changes in the intensity and density of the sound, in the speed, and in the rhythm.

The differences between the analysts' macroforms and those perceived by the subjects of the experiment could in some ways be attributed to the different nature of the two types of analysis: the analysts referred to the musical score and so were able to make use of the visual aspect and go backwards and forwards to check their definition of the points of division and the homogeneity of the various parts, enabling them in particular to pinpoint the exact points where an ostinato began and finished. The predominant criterion used by the analysts was, then, the rhythmic-melodic aspect, and the use of the score clearly facilitated this task. The subjects, on the other hand, performed their listening in real time and were thus subjected to the temporal cognitive

structures and were not influenced by the visual aspect. As a result their solutions were, as mentioned above, often determined by reference to other parameters apart from the ostinato. A further important difference seems to be that the analysts make much greater use of formal criteria transmitted culturally through their musical knowledge (e.g. symmetry and formal balance, use of structural criteria such as the bridge passage).

Finally, it is interesting to note that the subjects who were actually musicians did not generally seem to draw on their musical experience and this represents an unresolved problem worthy of further investigation. The differences between the two groups of subjects, musicians and non-musicians, were not, apart from one exceptional case, statistically significant. This finding would therefore seem to support the hypothesis that, at some levels of analysis, the competence possessed by musicians does not neccessarily affect the perception of the macroform of a piece, at least in the case of post-tonal music. The fact that most of the musicians had some familiarity with post-tonal music makes this aspect of our results all the more noteworthy.

In conclusion, the results obtained would to some extent seem to sustain our initial assumption: when the analysis of a written score is based on 'grammars' inferred from the 'grammatical competence' of listeners, it is possible to produce analytical models that are fundamentally in line with a perceptual analysis whose cognitive mechanisms are described by theories of psychology.

NOTES

1. Some of the data pertaining to this paper were presented at the Sixth International Conference on Music Perception and Cognition, Keele, UK, 5–10 August 2000.
2. There are undoubtedly many theoretical and analytical differences between these authors, and between these authors and ourselves, to the extent that a whole article could be dedicated to this issue alone. For this reason, we have decided to refer the reader to the literature and to mention here only the points that will help clarify the contents of this article.
3. '*Schéma de structuration* du temps, c'est-à-dire mise en ordre *a priori* d'événements sonores, selon des règles issues des mécanismes perceptifs qui permettent le repérage des changements dans le continu sonore' (Imberty, 1981: 90).
4. A. Webern, String Quartet Op. 5; D. Milhaud, String Quartet No. 7; B. Maderna, String Quartet 1942 (alledged date) and Quartetto per archi in due tempi, 1955 (Addessi and Caterina, 2000, 2002).
5. The theory of domains has also been the subject of a process of formalization by computer, but this will not be considered in this article (see D'Ambrosio et al., 1999).
6. This procedure was suggested by the experiment reported by Deliège and El Ahmadi (1990), and Deliège (1998). In our case there were three aims: to compare the segmentations of the listeners in real time with those of the analysts using the score; to observe any changes between the first and second segmentation (as in Deliège and El Ahmadi, 1990); to compare the results of the

segmentations with those of the division into parts (we should remember that in this article the two terms are used with different meanings). The results of these two tests will not, however, be discussed in this article, but are briefly mentioned in note 7.

7. The answers given in tasks 2 and 3 were analysed by taking into account the single seconds of the musical piece where our participants decided to indicate a segmentation point. As the number of individual differences was very high (some participants indicated a large number of segmentation points, while other participants indicated only a very small number), we could not apply any global measure, but had to limit ourselves to observing the differences between the answers participants gave to single categories (i.e. seconds).

   In any case, if we consider the mean number of segmentation points indicated in tasks 2 and 3, we find that in task 2 the musicians indicated 15.72 segmentation points, while the non-musicians indicated 16.83 points; in task 3, the figures are respectively 16.8 points (musicians) and 16.48 points (non-musicians). None of these differences are significant according to the Mann-Whitney test. However, using the same test, significant differences were found between musicians and non-musicians in several segmentation points (12 points) of task 2 and only in two points of task 3. In detail, the majority of non-musicians' answers in task 2 appear on seconds 31 ($p < .05$), 64 ($p < .05$), 85 ($p < .05$), 103 ($p < .05$) and 117 ($p < .05$). On the other hand, most of the musicians' answers fall on seconds 3 ($p < .05$) and 5 ($p < .05$), and on seconds 52 ($p < .05$), 54 ($< .01$), 66 ($p < .05$) and 84 ($p < .05$).

   In task 3, the differences between musicians and non-musicians almost disappear. Significant differences only remain in two segmentation points: on seconds 37 ($p < .05$) and 76 ($p < .05$). Neither second 37, nor second 76 scored a significant difference in task 2.

   In task 3, the strongest segmentation points indicated by the non-musicians coincided with the long pauses before the end of the piece (bar 40, second 109). The strongest segmentation for the musicians, on the other hand, was on bar 14 (second 37), a point characterized not only by several pauses, but also by a change in texture and leading voice. It would appear that musicians pay more attention to structural elements of compositions, whereas non-musicians seem to be interested in surface elements (such as pauses). This may explain the significant difference found between the two groups on bar 14 (second 37).

   We also present in the Table 6 the results deriving from the comparison between the segmentations given during task 2 and those given during task 3, by musicians as well as by non-musicians.

   If the coinciding segmentation points in tasks 2 and 3 are considered, it can be seen that the correspondences between the two tasks expressed by musicians and non-musicians are somewhat different. Only for seconds 84 and 116 do both groups express a concordance percentage which is above 60 percent. Percentages of concordance are meant to indicate how coincident the segmentation points are in tasks 2 and 3 and in the groups of musicians and non-musicians.

   However, a certain correspondence between the answers given in task 2 and those given in task 3 can be seen for both musicians and non-musicians: if we consider the means of the percentages of correspondences between the segmentation points of tasks 2 and 3, the mean for the musicians is 22.60, while for the non-musicians it is 21.22. The difference between the means is not significant according to the Mann-Whitney test.

   We can also observe that the answers given during the third listening are more

TABLE 6 *Coinciding points of segmentation in task 2 and in task 3 within the groups of musicians (18 subjects) and non-musicians (25 subjects)*

Seconds	Musicians (%)	Non-musicians (%)
11	66.67	
25	85.71	
26		60.00
36		61.54
46	100.00	
53	66.67	
57		66.67
60		100.00
84	61.54	75.00
93		66.67
109	72.73	
116	66.67	66.67

Percentage values = >60
Values have been calculated for each category (seconds) according to the following formula: Cp/(((Sp T2 + Sp T3)/2)*100) where Cp are the coinciding points of segmentation in tasks 2 and 3, Sp T2 are the segmentation points in task 2 and Sp T3 are the segmentation points in task 3.

hierarchized in comparison with the previous one: briefer sections are grouped into ampler sections, where important points of segmentation are singled out. During the third listening, the segmentation becomes more precise, anticipating the points of segmentation where the arrival of the change is already known: for example, in the musicians' group the point of segmentation shifts from 52–54 seconds during the second listening to 50 seconds during the third listening and the segmentation on second 105, at the long pause before the end (bar 38), almost disappears in the third listening, as its rhetorical effect has already been memorized and it no longer has any value as a segmentation.

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