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"Analysis beyond Notation in XXth and XXIst Century Music"
Alessandro Bratus and Marco Lutzu (Guest editors)

Beyond the Score: Timbre Analysis in Avant-garde Music

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Abstract

The article examines perceptual aspects of timbre within the context of avant-garde XX century music. An excerpt from a work by Luciano Berio was taken into account. We recorded it on 8 separate channels each of them devoted to small groups of homogeneous sounds, in order to obtain a global result that we could modify by subtracting one or more of the recorded groups. We prepared four different excerpts: one with the original version and three with modified versions. 50 participants (25 experts, 25 non-experts) were invited to fill in a semantic differential bipolar scale made of 12 adjectives, 6 concerning emotional and 6 sensorial aspects of perception. We interpreted the subjects' responses with the help of a spectrographic analysis and of studies on timbre verbalization. The main aim of our research was to explore the possibilities of timbre analysis, a field that so far has no solid scientific background. The research obtained promising responses from expert listeners, while non-experts manifested a sort of aesthetic refusal of this genre of music. Positive results were obtained also in the critical observations of possibilities and limits of spectrographic analysis and verbalizations of timbre. We hope that our initial data can be useful for future studies on timbre perception.

Keywords: Timbre, perception, emotion, avant-guard music, spectrogram

2

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Dossier / Dosier / Dossiê

M. Baroni, R. Caterina y F. Regazzi. Beyond the
score: Timbre Analysis in Avant-garde Music.

Mas allá de la partitura: análisis del timbre en la música de vanguardia

Resumen

Este artículo pretende examinar los aspectos perceptivos del timbre en el contexto de la música de vanguardia del siglo XX. En la investigación se ha utilizado un fragmento musical tomado de una composición de Luciano Berio. El fragmento ha sido grabado en ocho canales separados, cada uno contenía un pequeño grupo de sonidos homogéneos consiguiendo un resultado global que podía ser modificado eliminando uno o más de los grupos grabados. Se han elaborado cuatro grabaciones distintas, una con la versión original y las otras tres con una versión diferente. Han sido invitados 50 participantes (25 musicalmente expertos y 25 no expertos) y se los ha invitado a completar una escala bipolar de diferencial semántico constituida por 12 adjetivos, 6 pertenecientes a la percepción emocional y 6 a la percepción sensorial. La interpretación de las respuestas de los participantes se ha realizado con la ayuda del análisis espectrográfico y de los estudios sobre verbalización de las calidades tímbricas. El objetivo principal de nuestra investigación ha sido el de explorar cuáles podían ser las posibilidades del análisis del timbre, un campo que todavía no tiene a sus espaldas un solido bagaje científico. Las respuestas dadas por los oyentes expertos se han revelado prometedoras, al contrario los oyentes no expertos han manifestado una especie de rechazo de tipo estético frente a este tipo de música. Resultados positivos se han recogido también con respecto a las útiles observaciones críticas sobre las posibilidades y las limitaciones del análisis espectrográfico y de la verbalización. Tenemos la esperanza de que estos resultados iniciales puedan ser de utilidad para futuros estudios sobre la percepción del timbre.

Palabras clave: timbre, percepción, emoción, música de vanguardia, espectrograma

Para além da partitura: análise do timbre na música de vanguarda

Resumo

O presente artigo busca examinar os aspectos perceptíveis do timbre no contexto da música de vanguarda do século XX. A pesquisa utilizou um fragmento musical de uma composição de Luciano Berio. O trecho foi gravado em 8 canais separados, cada qual contendo um pequeno grupo de sons similares, a fim de se obter um resultado global que pudesse ser modificado eliminando um ou mais dos grupos gravados. Foram preparadas quatro gravações: uma com a versão original e três com uma versão diferente. Cinquenta participantes (25 especialistas em música e 25 não especialistas) foram convidados a preencher uma escala bipolar de diferencial semântico composta de 12 adjetivos: 6 relativos à percepção emocional e 6 relativos à percepção sensorial. A interpretação da resposta dos participantes foi realizada com a ajuda da análise espectrográfica, e dos estudos sobre a verbalização das qualidades do timbre. O objetivo principal da nossa pesquisa foi o de explorar as diversas possibilidades das análises de timbre; um campo que não possui ainda um sólido embasamento científico. As respostas obtidas através

3

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Dossier / Dosier / Dossiê

M. Baroni, R. Caterina y F. Regazzi. Beyond the
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dos ouvintes especialistas mostraram ser promissoras, enquanto as respostas dos não especialistas demonstraram uma rejeição de cunho estético em relação a esse tipo de música. Foram igualmente obtidos resultados positivos em relação às úteis observações críticas sobre as possibilidades e os limites da análise espectrográfica e da verbalização sobre o timbre. Esperamos que os nossos resultados iniciais possam ser utilizados nos estudos futuros sobre a percepção do timbre.

Palavras-chave: timbre, percepção, emoção, música de vanguarda, espectrograma

1. Introduction and aims of the research

About a thousand years ago some mediaeval monks, used to passing their life in the midst of immense collections of written books, started to think that music, just like verbal language, could perhaps be preserved in written form, if considered particularly important for social life, and tried to find technical ways of writing it. And what could be more important for social life than the preservation of the liturgical songs of the ancient Roman church? From that moment on, scores were gradually used in churches, then in aristocratic residences and now written music is present in vast collections of books and is part of our familiar everyday life. Today, however, at the turn of the second millennium, technological and political events have substantially changed the perspectives of human life worldwide and among them also the perspectives of music. In other words we are at the beginning of a new historical phase. As musicians and musicologists, we are now in an epoch of listening and "beyond the score". This is no great novelty and it was not really necessary to evoke centuries of European cultural life of which, moreover, we are all perfectly aware, but our intention was simply to underline that the title of our article is not exclusively linked to the activities of a minority of persons interested in the analysis of music. It has indeed wider bases: the idea of being now beyond the score can be really attractive for today's musicians, and recalling the origins and possible consequences of this idea can perhaps prove useful.

In the recent tradition of musical studies attention to the sounds of music (more than to its scores) has been widely present in psychoacoustic investigations: the books by James Beauchamp (2007) and Alexander Lerch (2012) are two significant examples. Other fields where acoustic experience has an important presence include the empirical research on cognitive perceptual and emotional interests, for example in the monumental collections of articles published by journals as *Music Perception*, *Musicae Scientiae*, and obviously *El oído pensante*. Computer research in music (in particular focusing on music performance) is another large area of interests, strictly linked to musical practice and based on sound results. We can cite, to give an important example, the Research Centre for the History and Analysis of Recorded Music (CHARM) in the University of London. Music analysis, however, is mostly based on scores. This is the reason why we would like to understand if we can go beyond the score, and the present article is devoted to this question.

Our proposal derives from a paper we presented in a session of the EuroMac VIII - European Music Analysis Conference, where other coordinated papers discussed about improvised music, jazz, traditional oral music, popular music: musical genres without a written tradition. In our paper we would like to talk about music that does have a written tradition. But what is written in a score, in our opinion, does not exhaust what we call "music" and what we are able to listen to in a live concert, in a broadcast or in a recording. A score does not have the function of being a sort of mirror of music: its main function is to allow the repetition of a piece of music by writing what a musician must do when playing his/her instrument (obviously excluding the integrations of his/her performing creativity). In a score, however, not only are the infinite aspects of subtleties and parametric nuances of creative performers structurally lacking:

when several players perform together, for example, the combined effects of their actions are not written and cannot be written. The result of their actions does not correspond to the sum of the written notes: something else, something beyond the score, is added when they play together. Performers know very well the art of obtaining sound effects like these and composers are able to include such possibilities in their scores without writing them, but both of them act intuitively without explicitly knowing the techniques they actually adopt in doing so.

Knowing something more about techniques like these ought to be one of the tasks of today's music analysis. Probably we are not yet in a situation mature enough to expect satisfying results from research in this field. On the other hand, studies involving the collaboration between disciplines at the boundaries between scientific methods and human and aesthetic problems have not been rare in recent years and can encourage paths in this direction. For example *Music Analysis* recently published a large issue on "Music and Emotion" edited by Michael Spitzer (2010) where philosophers, musicologists and psychologists discussed the problem from different convergent points of view. Other prompts come from the idea of music "expressiveness" in which aspects of music communication not exclusively linked to the emotions are being explored: in Italy for example there are computer scientists in the University of Genoa that have developed interesting experiments on the relationships of musical performance with body movements (see Castellano et al 2008). In Bologna the Miror Project (Addessi 2014) studied the interactions between improvisations of girls and boys and a responding computer machine. In Belgium Marc Leman is going to publish for MIT Press a book on a neural theory of human communication applied to music (Leman, in press). Not to mention the studies edited by Stephen Malloch and Colwyn Trevarthen (2008) on the vocal and gestural relationships (they call "musical") between babies and mothers in the first phases of life.

In the present article our intentions are not so ambitious: we simply propose a tentative analysis of a short excerpt of twentieth century music mainly based on the timbre relationships between different sound producers, whose notes are written in the score, and whose sound effects are largely beyond the score. In order to develop an analysis like this, it was necessary to choose an excerpt where melody, harmony, rhythm, counterpoint, and so on, had a minimum of impact in order to leave only timbre a maximum of presence and of musical relevance. We chose an excerpt by Luciano Berio and proposed to groups of listeners a number of opposite adjectives organized in a differential semantic scale in order to detect what timbre aspects were better perceived and how they were interpreted from affective and sensorial points of view. We also tried to find possible correspondences between the preferred adjectives and a spectrographic analysis of the excerpt.

The main aims of our research were explorative, primarily they were devoted to pointing out the possibilities and the difficulties of the perception of musical timbre: a field where experience is still scarce in musicology. A more specific aim was to test the possibilities and the advantages of applying the psychological technique of differential semantic scale in this kind of inquiry. And a final important aim was to verify the limits of common listeners in correctly perceiving the structures of music partially independent from melody, harmony and counterpoint traditions.

2. Method

2.1 The musical excerpt

The musical excerpt we analyze in our paper is written according to the traditional graphic conventions, but its structures, when they are listened to, tend to exclude or almost to reduce, clear aspects linked to melody, counterpoint or harmony (single pitches, durations and meters). Due to the absence of structures like these, the attention of the listeners tends to focus more on timbre. The title of the work is *Laborintus II*. Its verbal text, written or selected by the poet Edoardo Sanguineti (1956), is inspired by passages from Dante Alighieri's "Inferno" in the *Divina Commedia*, and include excerpts also taken from Dante's *Vita Nova* and allusions to or quotations from other poets: for example Ezra Pound and Thomas S. Eliot. In the dramatic narrative of the work, contrasting phases evoke the disorienting labyrinth that characterizes modern life: violent vs. grotesque episodes, tragic vs. ironic, dynamic vs. contemplative. For our experiment we used a short excerpt (about 30") from an episode named "Canzonetta". Its verbal text is the following:

Dolcissima, dolcissima morte, vieni a me	(Sweet , o sweet death, come unto me
Io porto già lo tuo colore	I already wear your colors)

Example 1. Excerpt from "Canzonetta" (*Laborintus II*, Universal Edition 1965).

As we can see from the score in example 1, the voices are organized by triads in which the global duration of consonant superposition is predominant compared to dissonant intervals; the pronunciation of the words is traditionally isorhythmic, while the melodies proceed by adjacent degrees. Stylistic choices like these, totally opposite to those of avant-garde music, can be considered as a sort of neo-renaissance allusion to an Italian *canzonetta*, strongly different from the aggressive expressions of the majority of the other episodes of the work. The only plausible explanation for this apparently strange choice could be that Berio imagined the *canzonetta* in connection with the meanings of the words. There is, however, a difference between an ancient *canzonetta* whose words speak of love of a young man for a young woman and the present *canzonetta* whose words speak of the attraction of the author for the image of death. We think that the presence of dissonances and other aspects of modern music in Berio's version can perhaps allude to the difference between the two love situations. The instruments are functional to the voices: harp 1 and cellos double the vocal parts, harp 2, clarinets and wa-wa trumpets prolong the voices with different "echo" effects, small percussion instruments tend to reinforce the harps. Only a few other instruments (particularly the flute and the trombones) have independent parts.

2.2 The texture

An analysis of the excerpt could include textural aspects, conceiving the word "texture" as the complex sound resulting from the superposition of more or less dense or loose musical sequences. We prefer to avoid, for the moment, the problems linked to the analysis of texture, for two reasons: first of all the concept of texture, though frequently used in musicological literature, is not a well defined one. See for example the article written by Jonathan Dunsby (2002) on this topic. Secondly, the psychoacoustic literature, in recent formulations, tends to go beyond the idea of timbre conceived as the sound produced by a single instrument, as, for example, in the multidimensional analyses of John Grey (1977). According to Sophie Donnadieu (2007: 273) the term can be referred to many different notions: "timbre can be described in terms of (1) a set of sounds of an instrument and also of the specific timbre of each sound of a particular instrument, (2) an isolated sound, (3) a combination of different instruments, (4) the composition of a complex sound structure, or (5) in the case of timbres produced by analysis/re-synthesis, hybrid timbres or chimeras, sounds never heard before, which can be associated with no known natural source". So, in our article we prefer to speak of timbre as in the third quoted proposal, even if in our example the combinations conceived by Berio are "sounds never heard before".

2.3 The recording

Since our research concerned the analysis of the sonorities of the excerpt, we decided to propose more than one version to our listeners by changing some of the instrumental components and modifying its sound perception in order to discover possible different functions of different instrumental timbres. An ensemble of the Conservatory of Parma under the direction

of prof. Danilo Grassi recorded a particular performance of the *Canzonetta*[1]. It was recorded in separate channels in order to allow manipulations of its timbres. Eight separate channels were considered: harps, clarinets, flute, percussions, trumpets, trombones, cellos with double-bass, and voices. Four versions of the same excerpt of *Canzonetta* were prepared for our experimental task:

I. A version with no voices and their instrumental doublings: this version included a flute, percussions, trumpets and trombones.

II. A version without percussive effects: the instruments of this version were a flute, clarinets, trumpets, trombones and voices.

III. The original version with 8 instrumental traces.

IV. A version without echo effects: only a flute, percussions, cellos with a double-bass, trombones, and voices[2].

The full version with 8-tracks was mixed with particular attention to the sounds of the original performance conducted by L. Berio (1969, *Ensemble Musique Vivante*, Harmonia Mundi) in order to obtain a version as close as possible to the composer's intentions.

2.4 Participants

50 participants (25 experts, 25 non-experts) were invited to take part in our experiment. Expert participants were musicians and music analysts used to the modern classical music repertoire. Non-experts were university students with no musical experience either in classical music or in avant-garde repertoires.

2.5 The bipolar semantic differential scale

The Bipolar Semantic Differential Scale is a well-known technique used in psychological researches. It proves to be useful in describing an item or an object according to some opposite qualities generally expressed by a pair of adjectives. The aim of this technique is just to give a coordinated picture of individual reactions to an object or to an event according to some evaluation qualities. Our semantic differential scale was made of 12 pairs of opposite adjectives, chosen on the basis of their emotional value (the 6 pairs unpleasant-pleasant, tense-relaxed, aggressive-mild, mortal-vital, alarming-reassuring, and depressed-serene) or sensorial meaning (the 6 pairs rough-sweet, obscure-clear, opaque-transparent, cold-warm, hard-soft, and dull-bright). They were organized according to well-known representations of emotions in the scientific literature (Plutchick 1980, Russel 1980, Sacharin et. al. 2012, Scherer 2005).

Participants were asked to judge the music excerpts according to a bipolar 7-point Likert scale: 3 points next to an adjective if it fits (very much, much, only partially) the target item, 3 points next to the opposite adjective plus a neutral point between the two adjectives. (For example: Warm 1/2/3 /4/ 3/2/1 Cold).

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[1] We are grateful to the Conservatory of Parma and in particular to Danilo Grassi for their invaluable collaboration.
[2] In the following examples and in our comments on the excerpts we have maintained the order of the presentations adopted in the experiment, where the original form (8 channels) was in third position.

The adjectives of the scale were in Italian with reference to the original English words quoted in the scientific literature. In order to avoid any order effect the adjectives' polarities (negative-positive) were randomly distributed.

2.6 Task procedures

Participants were asked first to listen carefully to the four excerpts and to consider all the excerpts, in order to have an idea of the totality of the proposed listening tests, to have a look at the pairs of adjectives which could describe the different excerpts and to think of a preliminary possibility of comparative judgements. They then listened to the single excerpts, one by one, and they were asked to judge each one –after having heard it– according to all the adjectives of our semantic differential scale.

2.7 Sound structures and subjects' responses

It is important to observe that voices and instruments, excluding the flute, are never used as autonomous parts in the excerpt from the *Canzonetta* (and in its three variants). The composer always conceived them as aggregations of quite homogeneous groups which, even though well distinguishable in perception, were always used in different combinations, producing different varieties. Note that the ever changing sound blends of this piece only rarely corresponded to well known instrumental timbres. The proposed adjectives did not ask for responses to particular timbres or groups of timbres, but for a response according to general aspects of the excerpt that each subject considered predominant or more typical in his/her listening experience. Moreover, we should add that one of the secondary, almost implicit, aims of our research was to understand if the emotional responses of the subjects had something to do with the meanings of the sung words (with the "color of death"), according to the hypothesis, we discussed in the final part of point 2.1. We stress, on this matter, that our listeners had no information about *Laborintus II*, or about the text of the words. We proposed them simply to say what their reactions were in listening to four pieces of music.

2.8 Spectrographic analysis

The spectrographic analysis as we shall show in the following sections of the article, had the principal aim of helping the task of finding possible motivations for the responses of our subjects. Obviously our analysis assigned particular privilege to the adjectives linked to the "sensorial" differential qualities. Spectrographic aspects, however, were sometimes considered also a possible predictor of particular aspects of emotional orientations in groups of listeners.

3. Results

3.1. Data analysis

Data coming from the bipolar differential scale were organized in order to obtain a more readable version: all the adjectives were presented as referring to a unipolar 7 point scale, low values being linked with the positive adjective of the pair, high values with the negative one. In the case, for example, of the pair pleasant-unpleasant, low values (1, 2, 3) express that the

stimulus has been judged as pleasant, while high values (5, 6, 7) indicate that the stimulus has been judged as unpleasant.

We compared pairs of the four excerpts: values of version 3 (8 channels) with 1 (without voices), with 2 (without percussive effects) and with 4 (without echo effects). The pairs 1-2, 1-4 and 2-4 were not comparable: for example excerpt 2 and 4 had in common only the flute and trombones, all the other instruments being different. In situations like these we could not know to which instruments we could assign the motivations for the different responses. The non-parametric statistic test of Wilcoxon was used to investigate whether the differences among the three compared pairs were or were not statistically significant. Comparisons were made either considering all 50 participants, or groups of 25 participants (experts and non-experts), and we also analyzed if there were statistically significant differences between expert and non-expert participants. The non-parametric statistic test of Mann Whitney was used for this purpose.
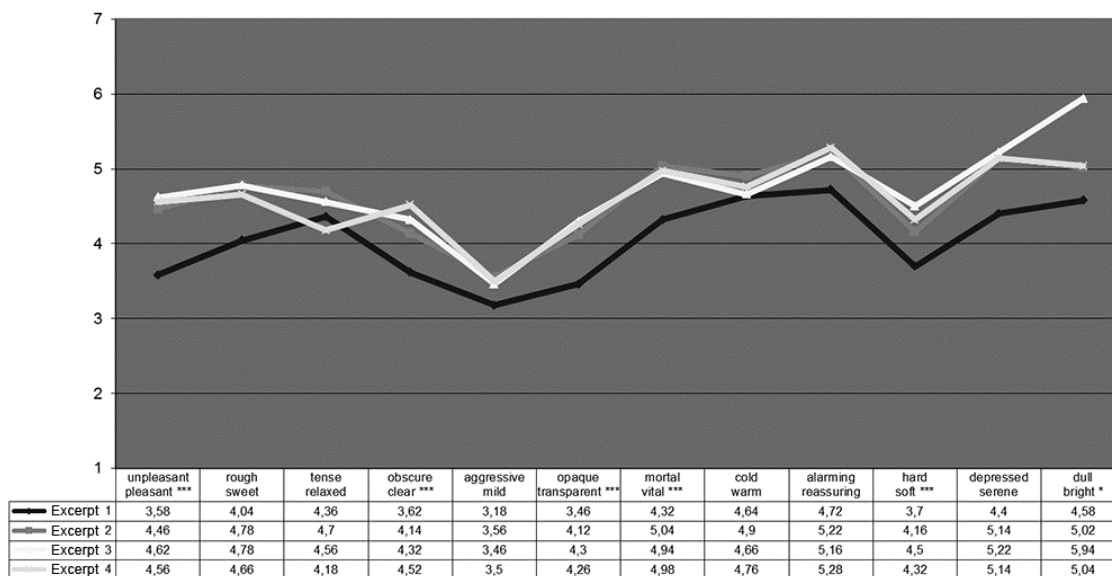
Finally, we considered the distributions of judgements in the semantic differential scale according to particular "cut points". Cut point definition is important to select groups of subjects whose answers to a test are clearly above or below some critical scores: for example in a test concerning anxiety we can consider people anxious if they had a score higher than a given cut point. By analogy in our case we considered score 4 as a neutral result, being equidistant from 1 and from 7, and we fixed as critical points scores >0.4 above the neutral point for the negative polarities and below the neutral point for positive polarities.

3.2. Global results

In considering all the participants we found significant differences between excerpt 1 and the other excerpts for 7 of the 12 pairs of adjectives, as can be seen in note 3. Excerpt 1 (without voices) was judged by means of adjectives with less negative polarities in comparison with the other excerpts[3].

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[3] Significance according to Wilcoxson test.

PAIRS	Excerpts 1-2	Excerpts 1-3	Excerpts 1-4
unpleasant-pleasant	Z -3,214 sig. .001	Z -3,823 sig. < .001	Z -3,330 sig. .001
obscure-clear	Z -3,330 sig. .001	Z -2,248 sig. .022	Z -2,732 sig. .006
opaque-transparent	Z -3,101 sig .002	Z -3,315 sig. .001	Z -3,315 sig. .001
mortal-vital	Z -2,943 sig. .003	Z -2,579 sig. .010	Z -2,601 sig. .009
hard-soft	.n.s.	Z -2,824 sig. .005	Z -2,426 sig. .015
depressed-serene	Z -3,059 sig. .002	Z -3,069 sig. .002	Z -2,482 sig. .013
dull-bright	Z -2,184 sig. .029		

	unpleasant pleasant ***	rough sweet	tense relaxed	obscure clear ***	aggressive mild	opaque transparent ***	mortal vital ***	cold warm	alarming reassuring	hard soft ***	depressed serene	dull bright *
Excerpt 1	3,58	4,04	4,36	3,62	3,18	3,46	4,32	4,64	4,72	3,7	4,4	4,58
Excerpt 2	4,46	4,78	4,7	4,14	3,56	4,12	5,04	4,9	5,22	4,16	5,14	5,02
Excerpt 3	4,62	4,78	4,56	4,32	3,46	4,3	4,94	4,66	5,16	4,5	5,22	5,94
Excerpt 4	4,56	4,66	4,18	4,52	3,5	4,26	4,98	4,76	5,28	4,32	5,14	5,04

Figure 1. Test for all participants (50ss). Differences between positive and negative adjectives in excerpt 1 compared to the other excerpts. High values correspond to negative adjectives.
Significant differences between Excerpt 1 and other Excerpts.
* = <.05 (probability of differences due to random are less than 5%) ***= <.01 (probability of differences due to random are less than 1%).
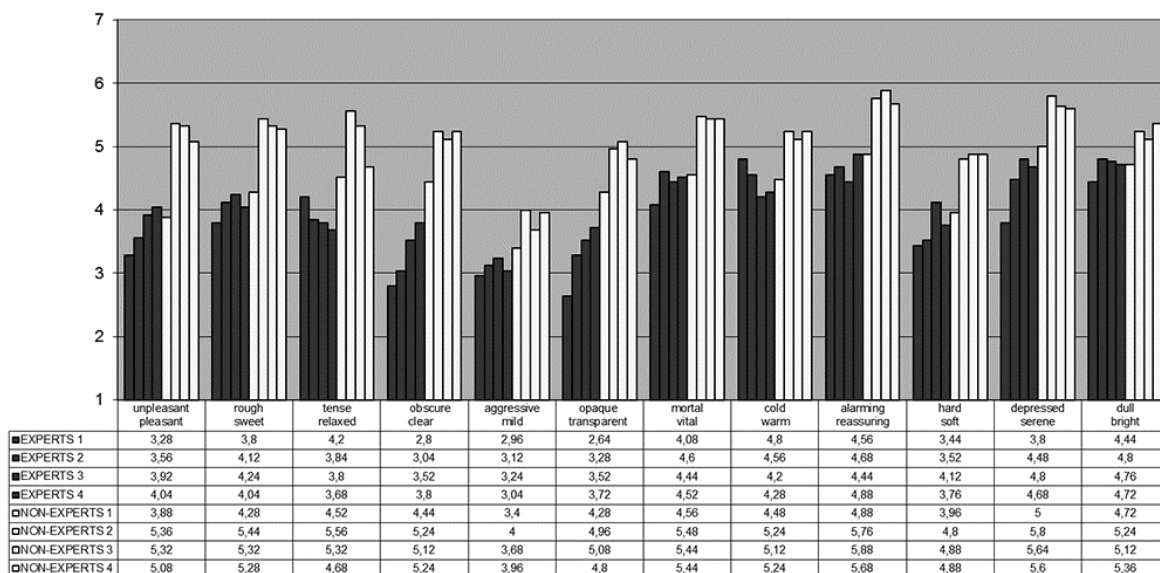For detailed results of the Wilcoxon test see note 3.

3.3. Results according to the expert vs. non-experts groups

In considering the two groups (experts and non-experts) you can see from figure 2 how different their profiles are according to the single pairs of adjectives and the four excerpts. Non-expert judgments are almost always much more negative than expert judgments[4].

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[4] Significant differences between experts and non-experts in the single excerpts according to the Mann-Whitney U test.

PAIRS	Expert vs Non Experts Exc. 1	Experts vs Non Expert Exc. 2	Experts vs Non Expert Exc. 3	Experts vs Non Expert Exc. 4
unpleasant-pleasant	n.s.	U 118,5, Z -3,837, sig. <.001	U 170,5, Z -2,810, sig. .005	U 197,5, Z -2,280, sig. .023
rough-sweet	n.s.	U 145, Z -3,362, sig. .001	U 180,5, Z -2,633, sig. .008	U 188,5, Z -2,480, sig. .013
tense-relaxed	n.s.	U 134, Z -3,567, sig.< .001	U 152, Z -3,3191, sig. .001	n.s.
obscure-clear	U 143,5, Z -3,366, sig. .001	U 82,5, Z -4,582, sig. <.001	U 161, Z -2,989, sig. .003	U 153, Z -3,166, sig. .002
aggressive-mild	n.s.	n.s.	n.s.	U 183,5, Z -2,568, sig. .010
opaque-transparent	U 143,5, Z -3,366, sig. .001	U 129,5, Z -3,633, sig. <.001	U 154,5, Z -3,129, sig. .002	U 196, Z -2,322, sig. .020

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Dossier / Dosier / Dossiê

12

M. Baroni, R. Caterina y F. Regazzi. Beyond the
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	unpleasant pleasant	rough sweet	tense relaxed	obscure clear	aggressive mild	opaque transparent	mortal vital	cold warm	alarming reassuring	hard soft	depressed serene	dull bright
■EXPERTS 1	3,28	3,8	4,2	2,8	2,96	2,64	4,08	4,8	4,56	3,44	3,8	4,44
■EXPERTS 2	3,56	4,12	3,84	3,04	3,12	3,28	4,6	4,56	4,68	3,52	4,48	4,8
■EXPERTS 3	3,92	4,24	3,8	3,52	3,24	3,52	4,44	4,2	4,44	4,12	4,8	4,76
■EXPERTS 4	4,04	4,04	3,68	3,8	3,04	3,72	4,52	4,28	4,88	3,76	4,68	4,72
□NON-EXPERTS 1	3,88	4,28	4,52	4,44	3,4	4,28	4,56	4,48	4,88	3,96	5	4,72
□NON-EXPERTS 2	5,36	5,44	5,56	5,24	4	4,96	5,48	5,24	5,76	4,8	5,8	5,24
□NON-EXPERTS 3	5,32	5,32	5,32	5,12	3,68	5,08	5,44	5,12	5,88	4,88	5,64	5,12
□NON-EXPERTS 4	5,08	5,28	4,68	5,24	3,96	4,8	5,44	5,24	5,68	4,88	5,6	5,36

Figure 2. Experts (25 ss) – Non-experts (25 ss) according to the single excerpts. High values correspond to negative adjectives. For detailed results of the Mann-Whitney U test see note 4.

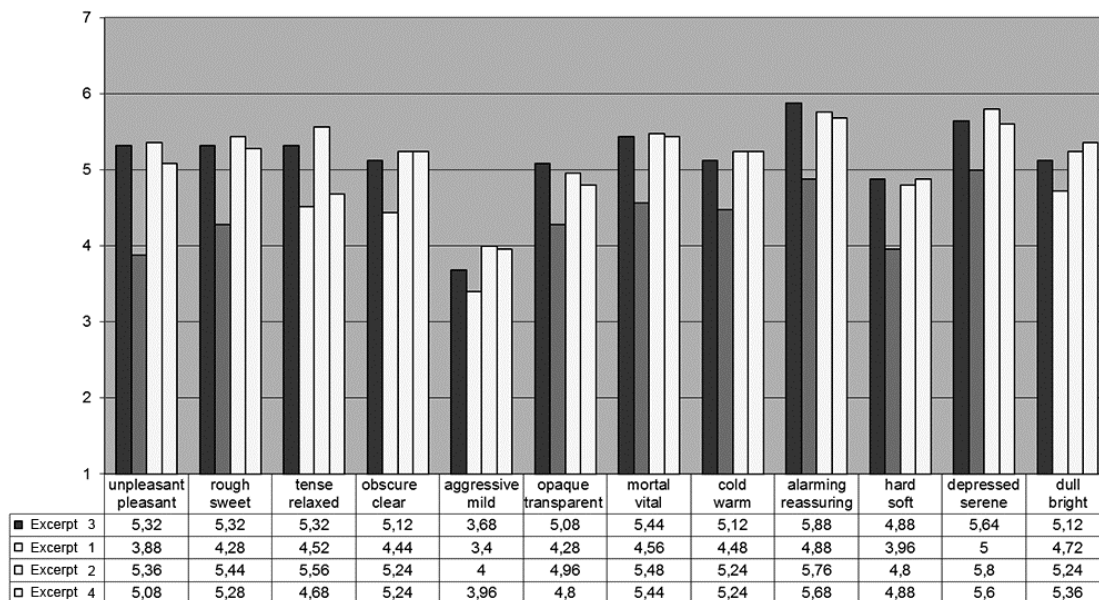3.4. Results regarding the comparison between excerpt 3 (all 8 channels) vs. the other excerpts

In considering the comparison between excerpt 3 and the other excerpts in the two groups of expert participants and non-expert participants (graphs 3 and 4) we can make some considerations. While for non-expert participants the significant differences concern exclusively the comparison between excerpt 3 and excerpt 1 in a great deal of the adjective pairs presented[5],

mortal-vital	n.s.	U 208, Z -2,109, sig. .035	U 166, Z -2,929, sig. .003	U 186,5, Z -2,514, sig. .012
cold-warm	n.s		U 209, Z -2,057, sig. .040	n.s.
alarming-reassuring	n.s.		U 147, Z -3,290, sig. .001	n.s.
hard-soft	n.s	U 139,5, Z -3,431, sig. .001	U 199, Z -2,265, sig. .024	U 185, Z -2,529, sig. .011
depressed-serene	U 181, Z -2,619, sig. .009	U 154, Z -3,162, sig. .002	U 192,5, Z -2,409, sig. .016	U 212,5, Z -1,996, sig. .046
dull-bright	n.s	n.s.	n.s	n.s.

[5] Significant differences between Excerpt 3 and Excerpt 1 in non-expert participants, according to Wilcoxon's test.

PAIRS	Excerpts 3-1
unpleasant-pleasant	Z -3,505, sig. <.001
rough-sweet	Z -2,086, sig. .042
opaque-transparent	Z -1,438, sig. .015
mortal-vital	Z -2,178, sig. .018

for expert participants significant differences between excerpts are less undifferentiated and concern not only the relationship excerpt 3 vs. excerpt 1[6]. Non-expert judgments are undifferentiated and may simply express their lack of interest towards the modern classical music repertoire. Expert judgments on the contrary are much more balanced.
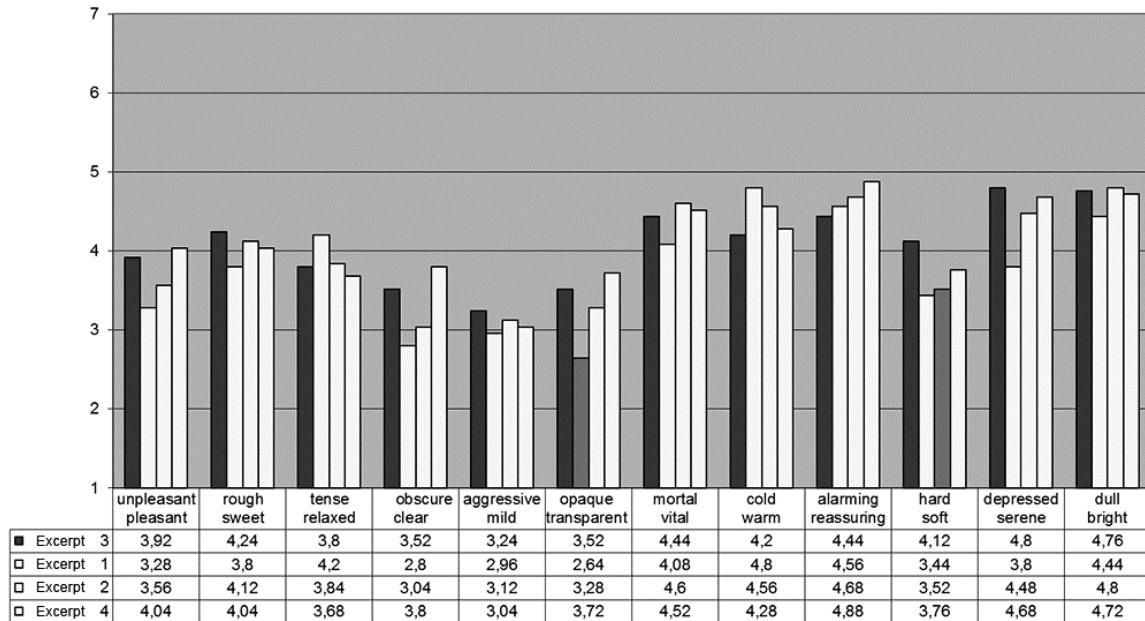

	unpleasant pleasant	rough sweet	tense relaxed	obscure clear	aggressive mild	opaque transparent	mortal vital	cold warm	alarming reassuring	hard soft	depressed serene	dull bright
■ Excerpt 3	5,32	5,32	5,32	5,12	3,68	5,08	5,44	5,12	5,88	4,88	5,64	5,12
□ Excerpt 1	3,88	4,28	4,52	4,44	3,4	4,28	4,56	4,48	4,88	3,96	5	4,72
□ Excerpt 2	5,36	5,44	5,56	5,24	4	4,96	5,48	5,24	5,76	4,8	5,8	5,24
□ Excerpt 4	5,08	5,28	4,68	5,24	3,96	4,8	5,44	5,24	5,68	4,88	5,6	5,36

Figure 3. Excerpt 3 versus other excerpts in non-expert participants. Significant differences are indicated by dark grey histograms. For detailed results of the Wicoxon test see note 5.

cold-warm	Z -2,495, sig. .035
alarming-reassuring	Z -1,753 sig. .014
hard-soft	Z -2,293, sig. 010
depressed-serene	Z -1,715, sig. .046

[6] Significant differences between Excerpt 3 and the other excerpts in expert participants, according to Wilcoxon's test.

PAIRS	Excerpts 3-1	Excerpts 3-2	Excerpts 3-4
opaque-transparent	Z -2,281, sig. .023	n.s.	n.s.
alarming-reassuring	n.s.	n.s.	Z -2,308 sig. .021
hard-soft	n.s.	Z -2,071, sig. 038	n.s.
depressed-serene	Z -2,376, sig. .017	n.s.	n.s

14

	unpleasant pleasant	rough sweet	tense relaxed	obscure clear	aggressive mild	opaque transparent	mortal vital	cold warm	alarming reassuring	hard soft	depressed serene	dull bright
■ Excerpt 3	3,92	4,24	3,8	3,52	3,24	3,52	4,44	4,2	4,44	4,12	4,8	4,76
▢ Excerpt 1	3,28	3,8	4,2	2,8	2,96	2,64	4,08	4,8	4,56	3,44	3,8	4,44
▢ Excerpt 2	3,56	4,12	3,84	3,04	3,12	3,28	4,6	4,56	4,68	3,52	4,48	4,8
▢ Excerpt 4	4,04	4,04	3,68	3,8	3,04	3,72	4,52	4,28	4,88	3,76	4,68	4,72

Figure 4. Excerpt 3 versus other excerpts in expert participants. Significant differences are indicated by dark grey histograms. For detailed results of the Wicoxon test see note 6.

3.5. The main features of the excerpts according to the expert participants

As we shall discuss later, the non-expert results are rather incongruous, undifferentiated, not really in touch with the required tasks. Therefore we decided to look more closely at the expert results.

Besides the calculation of significant differences between the judgments of the adjectives given to the single excerpts, we can see how each excerpt could be described by the expert participants insofar as the mean values chosen are close or far from the neutral point equidistant from 1 and 7.

Using a procedure somewhat similar to that used to fix the "cut points", we indicate in Tab. 1 (an elaboration of fig. 4) how distant the judgments of our expert participants were from the "neutral" point (point 4) in the Semantic Differential Scale. Critical point distance values were selected according to 3 categories:

X: we conventionally fixed the first judgment category at a distance between 0.40 and 0.69 from 4, the "neutral" point (a minimal distance). This means that in figure 3 (expert judgments) the first category of "positive" judgments includes scores between 3.60 and 3.31 and that of "negative" ones, scores between 4.40 and 4.69.

XX: for the second category the distance was conventionally fixed between values of 0.70 and 0.99 (the mean judgments being either between 3.30 and 3.01 in the case of "positive" judgments, and between 4.70 and 4.99 in the case of "negative" ones).

XXX: in the third category (the maximum of distance from the neutral point) the distance was conventionally fixed as greater than 1.00 (the mean judgments being of 3.00 and lower values in the case of "positive" judgments or 5.0 and higher values in the case of "negative"

ones).

Observing the table, an interesting result is immediately evident: the symbols + and − are always common to all the excerpts for each adjective pair: for example you can see that all the excerpts have been judged as dull and alarming, or clear and transparent, and so on. In some cases you have neutral judgments associated with some excerpts while the others have been described as negative or positive, as in the case of pleasant-unpleasant. On the whole the 4 excerpts have been defined on the positive side as pleasant, clear, mild, transparent and soft (5 pairs of adjectives), on the negative side as mortal, cold, alarming, depressed and dull (5 pairs of adjectives): two pairs of adjectives (sweet-rough and relaxed-tense) resulted neutral in all 4 excerpts.

Taking a look at the single excerpts, considering the X levels and neutral judgments, we can describe different profiles. For example, Excerpt 3 (concerning all 8 channels) has been described as clear, mild, transparent on the positive side, while as mortal, alarming, and particularly depressed and dull on the negative side. Excerpt 1 (no voices) has been seen as pleasant, clear, mild, transparent and soft on the positive side and as cold, alarming and dull on the negative side, and so on and so forth. Some quantitative aspects are important as well: for example, excerpt 2 has been described as pleasant, clear, mild, transparent etc., and the same qualities are present in excerpt 1, but in excerpt 1 the distance from the neutral point 4 is higher in comparison with excerpt 2. Finally in excerpt 4 (no echoes) alarming qualities are more present in comparison with the other excerpts.

Adjectives	Exc. n. 1 No voices	Exc. n. 2 No percussions	Exc. n. 3 8 channels	Exc. n. 4 No echoes
Pleasant- Unpleasant	– XX	– X		
*Sweet- Rough				
Relaxed- Tense				
*Clear- Obscure	–XXX	– XX	– X	
Mild- Aggressive	– XXX	– XX	– XX	– XX
*Transparent- Opaque	– XXX	– XX	– X	
Vital- Mortal		+ X	+ X	+ X
*Warm- Cold	+ XX	+X		
Reassuring- Alarming	+ X	+X	+ X	+XX
*Soft- Hard	– X	– X		– X
Serene- Depressed		+X	+ XX	+ X
*Bright- Dull	+ X	+XX	+ XX	+XX

Table 1. Critical points distance values (X =+/- 0.4; XX= +/- 0.7; XXX= +/- 1.00) from the neutral area (4.00) of the semantic differential scale in expert participants. Positive adjectives have lower values (-), negative adjectives have higher values (+). The symbol * indicates the "sensorial pairs".

3.6. Spectrographic analyses

We think that the emerging choices of our subjects may be determined or at least influenced by the sonorities of the musical excerpts. Obviously we did not have at our disposal the results of their perceptions: the spectrogram only refers to the audible sound structures of the

performance. It is a visual graphic representation of the distribution of energy in the acoustic spectral dimension and in its temporal modifications. It shows the global loudness of each moment but also the loudness of the single harmonic frequencies that are present in that moment, and of its non harmonic, that is noisy, components.

Psychoacoustic studies often underline that the visual representation of a musical excerpt cannot be directly mapped on its auditory representation. However, such studies also discussed a number of interesting aspects of musical timbre that, if carefully interpreted with the necessary caution, can give useful hints to partial explanations for some of the responses of our subjects.

4. Comments

4.1. Differences between experts and non-experts

One of the main hypotheses coming from our results is that timbre perception may be linked to the listeners' familiarity with a specific repertoire: non-expert participants are not familiar with avant-garde classical music and therefore simply reject it. Negative judgments are the rule: in excerpts 2, 3 and 4, the majority of adjective pairs (8 out of 12) always have scores higher than 5 (decidedly towards the negative side); in excerpt 1 there is only one positive judgment in the pair mild-aggressive, probably due to the absence of explicit aggressiveness (unanimously shared by all listeners) more than the presence of mild aspects. Maybe in non-experts judgments the dynamic components prevail (familiar not only in music), which can explain, for example, why excerpt 1, always played *pp* by the instruments, has been more positively evaluated. These results, however, concern timbre, not other structural aspects of music. It is well known that non musicians can recognize a correct intonation, the profile of a melody and can anticipate musical endings, as highlighted in many examples of cognitive research. David Huron (2006: 145 ff) for example, speaks of statistical learning to explain the concept of "familiarity": it corresponds to the exposure to music, that is, to the hours of listening to a particular kind. It is plausible to think that our non-expert listeners did not have too many hours of exposure to avant-garde music. These, obviously, are only speculations, hypotheses that could be tested in future studies. Such results go beyond other findings (Addessi and Caterina 2000) where post tonal hearing even in non-expert participants did not influence their ability to find the most important points of segmentation and of tension-relaxation. In that case, however, as in other cases of experiments on contemporary music listening (Deliège and El Ahmadi 1990, Imberty 1987), the musical context was not exclusively linked to timbre: the attention of the listeners was principally oriented on segmentation, a feature that is common also to more traditional music, and this probably avoided the absolute rejection we witnessed in the present case.

4.2. Comments to Table 1

Observing Table 1, where we consider the listening of expert subjects, one result becomes particularly evident and even surprising. The symbols + and − have exactly the same presence: 5 pairs have been considered positive, 5 negative and two neutral (that is, in position 4). If we add that this result is common to all four excerpts (minus and plus symbols are always coherent in

|7 El oído pensante, vol. 4, n°1 (2016) ISSN 2250-7116
Dossier / Dosier / Dossiê

M. Baroni, R. Caterina y F. Regazzi. Beyond the
score: Timbre Analysis in Avant-garde Music.

each line of the table) we can assert as a clear result that, while non-expert judgments are absolutely negative, those of experts are ambiguous: half negative and half positive. At this point we can pose a question: how can we interpret such ambiguity? As a sign of an uncertain decision or as a clear assertion that, from an emotional point of view, the piece has been felt as explicitly ambiguous? It is difficult to take a decision on this point, but a hypothesis can be perhaps taken into account. We have previously said that Berio's music is probably linked with the words of Sanguineti (the word sung by the voices) where an oxymoron is present (sweet death). Nothing is more ambiguous than an oxymoron, and the music itself has aspects of ambiguity: a neo-Renaissance structure within an explicit avant-garde context. We exclude the possibility that our listeners have understood and clearly interpreted the presence of the poetic oxymoron. We may think however, that they may have intuitively caught the contradiction between Renaissance memories and avant-garde tendencies, even if none of them knew the piece (as ascertained in short interviews made after the listening). In conclusion we cannot exclude that the ambiguous results of Table 1 can have something to do with the musical affective ambiguity of the piece itself. Again this is another mere speculation: in order to become scientifically proven, the hypothesis needs to be supported by more robust elements, but it is right that some aspects of its plausibility could be taken into consideration.

Apart from this aspect, Table 1 manifests an evident perceptual and emotional preference by our listeners for excerpt 1 (without voices) over the others. Its general lightness (as we have already observed) may have motivated their preference, and other spectral conditions, as we shall explain, could have induced our subjects to appreciate the changing variety of its mild and intimate sonorities. Other results are more difficult to interpret: for example the reason why Excerpt 3 (8 channels) was deemed more depressed than the others and the reason why excerpt 4 (without wa-wa echoes) was sensed as more alarming. We must note that in Table 1 there are 32 responses near to the neutral score (4), out of a total of 48, and this suggests that our listeners (even though "experts") had difficulty in perceiving too subtle perceptual differences among the proposed examples, a condition which could explain the presence of not clearly defined (if not apparently odd) responses. For some of them we could resort to the interesting concept of micro-emotions (Huron 2008), but for this hypothesis too we must wait for further more specific research. Finally we should not forget that the questions the listeners were asked referred to a general idea of the example: in its 30" many things happened and we do not know which of them attracted the attention of our listeners and for what reasons.

4.3. Spectral analysis

The spectral analysis is based on the techniques used in scientific psychophysical literature and on its results (Fastl and Zwicker 2007). The aim of such research is to find mathematically calculated sound physics parameters which could correspond to the perceptual responses of the subjects, deriving from the empirical procedures of the cognitive sciences. The intentions of our spectral analysis was not to discuss or to go more deeply into the methodological problems of psychoacoustics, but simply to take into consideration some of its results in order to try to confirm (or to exclude) hypotheses connected with the responses of our expert subjects. For our

aims we were particularly interested in the perception of phenomena such as roughness (Vassilakis and Kendall 2010, Lerch 2012) and brightness (Lerch 2012), resulting from analytical techniques such as Spectral centroid (Wu *et al*. 2014), Spectral flux, Spectral Rolloff, and RMS Energy (Lerch 2012). For the graphic renderings of our examples we used the Software Sonic Visualizer, developed at the Centre for Digital Music, Queen Mary, University of London, and some low-level feature extraction plug-ins from the Mazurka Project (CHARM) and from BBC Research and Development.

Only some of the responses listed in Table 1 can be pertinent to the results of spectrographic analysis. For example, the majority of the emotional responses don't have a physical parameter directly observable in a spectrogram. The emotional responses can probably be linked less to timbre components than to other musical parameters (rhythm, loudness and so on) which are also present, albeit in subordinate ways, in Berio's example. This is the reason why we based our analysis merely on the sensorial pairs indicated with an asterisk in Table 1. But not all 6 sensorial pairs we used in our test seem to have significant relationships with the spectrographic theory. In 4 of them, however, some aspect proved to be useful: sweet/rough, clear/obscure, soft/hard and bright/dull.

Sweet / rough

According to traditional Western theory, dissonance is formed by the beats produced by intervals such as seconds (particularly minor) and sevenths (particularly major), and this is perceived as a rough sonority. This obviously refers to the fundamentals (the written notes). In our case, however, our interest is not focused on the fundamentals, but on the harmonic spectrum of the excerpt. It is possible to surmise that the stronger sonority of excerpt 3, with voices and instruments that produce beats throughout the spectrum and inter-modulation sounds among the harmonic partials, can emphasize its roughness. This phenomenon can be observed in the Spectral Power, which is a measure of the average power of each spectral frame. In the envelope profile of figure 5 the profile, referred to excerpt 1 without voices, has an evident difference compared to that of the other excerpts, due to the presence of fewer instruments and a sound texture made mainly from mid and high frequencies.
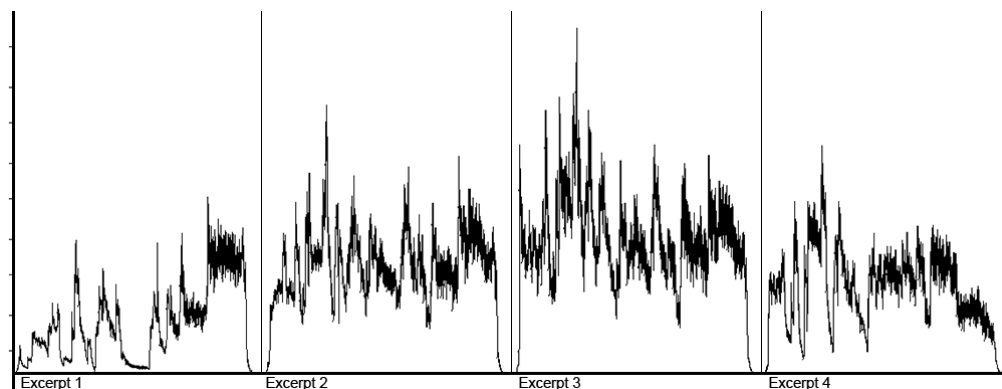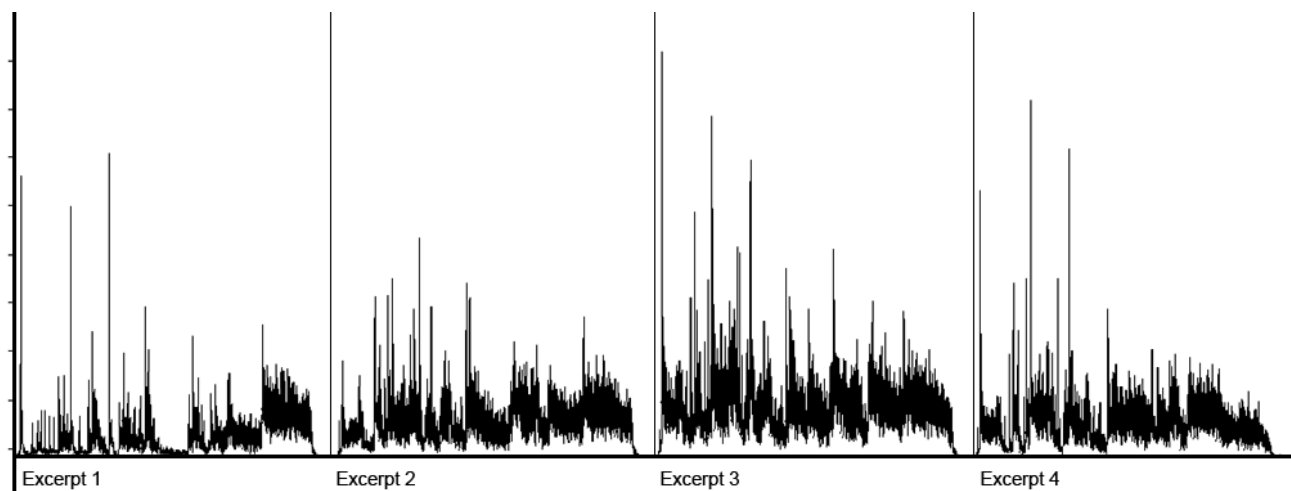

Figure 5. Spectral power: from excerpt 1 to 4, this curve represents the average power of each spectral frame over time. Low curve means low power and low loudness.

El oído pensante, vol. 4, n°1 (2016) ISSN 2250-7116
Dossier / Dosier / Dossiê

M. Baroni, R. Caterina y F. Regazzi. Beyond the
score: Timbre Analysis in Avant-garde Music.

19

In another psychoacoustic technique (Spectral Flux, which is a measure of the amount of local spectral changes), according to Hugo Fastl and Eberhard Zwickler (2007) roughness is measured with different procedures, but the results are quite similar: in Excerpt 3 the profile is oriented toward higher values than others (especially than Excerpt 1) indicating a fast change of the spectral components.

A short comment can be added about the perceptual sensation of roughness: this word can evidently assume slightly different meanings depending on slightly different points of view: for example we don't know if, from a perceptual point of view, Spectral Power and Spectral Flux measure exactly the same thing. If we add other considerations coming from an aesthetic point of view, obviously linked to cultural and not physiological or physical perspectives, the word "roughness" can assume other different meanings: in the ideas of composers like Berio or listeners to their music, the amount of dissonance (and roughness) derives from several models shared in modern music styles and from possible comparisons among them.

This means that in the present context the results of the spectral analysis must be integrated with other aspects coming from the analysis of its verbalization. These will be dealt with in the following section, obviously extending the comments so far devoted to sweet/rough to the other pairs.


Figure 6. Spectral Flux: from excerpt 1 to 4, this curve represents how quickly the spectral components change. Low curve means steady state or relatively few spectral changes.

Clear / obscure and hard / soft

According to other aspects of perceptive research which will be mentioned in the following section, the idea of clear is linked to the predominance of high frequencies and vice-versa. Figure 7 shows the scarcity of components in the mid-low regions of Excerpt 1 compared to those of the other excerpts, and this could help to explain the predominance of "clear" in Table 1 (three XXX) vs. less clear responses in the other excerpts.

As regards the pair hard/soft, the idea of hard is ordinarily linked to the presence of short and steep transient attacks. Stephen McAdams and Bruno Giordano (2009: 73) mention the attack time that distinguishes continuant instruments from impulsive ones. Impulsion is not the

same thing as hardness, but this difference pertains to verbalization more than to sound analysis. In our spectrograms we did not observe the presence of particularly evident transient attacks, and this corresponds to the absence of "normal" percussion instruments in the score: there are only small, light instruments and harps used in a percussive fashion, whose presence is observable in the spectrogram but does not yield evident results in perception because (as is clear from the score, and as we previously mentioned) these instruments are always played piano or pianissimo. This could help to explain the predominance of "soft" in the majority of the responses of Table 1.
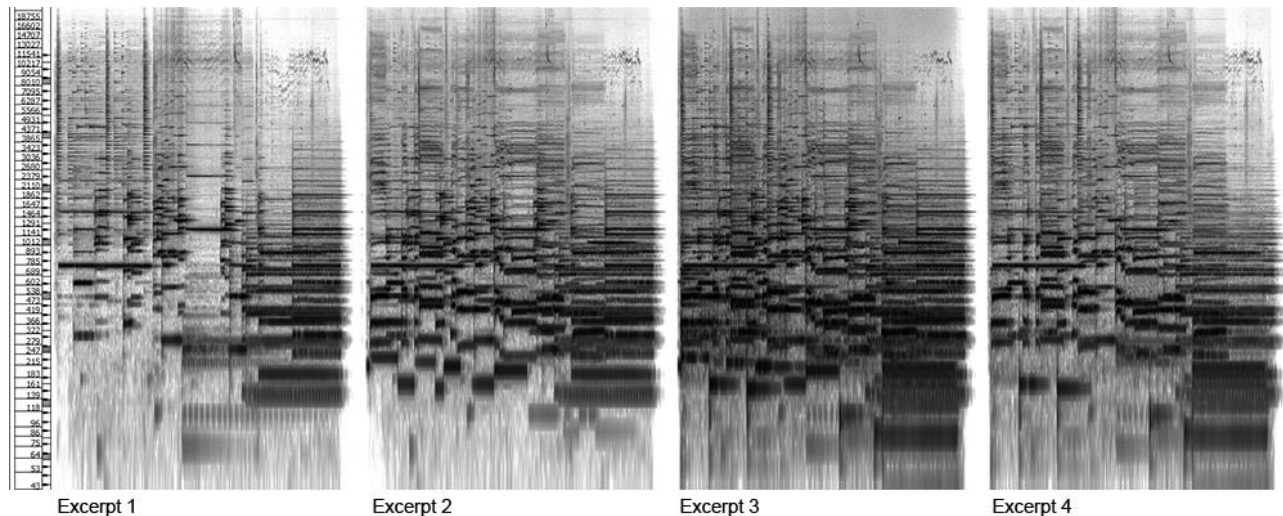
Figure 7. Spectrogram: from excerpt 1 to 4 this is a visual representation in a logarithmic scale of the spectrum of frequencies as they vary with time.

It shows not only the loudness of each moment (more black, more loudness) but also the frequency of the harmonic components. In this way you can see exactly where each sound event begins.

Brilliant / dull

The term "brilliant" is widely present in psychoacoustic literature. For example McAdams and Giordano (2009: 73) speak of spectral centroid "representing the relative weights of high and low frequencies and corresponding to timbral brightness". More exactly, the individual centroid of a spectral frame is normally defined (Lerch 2012) as the average frequency weighted by amplitudes, divided by the sum of the amplitudes. The higher the centroid, the "brighter" the sound. We, however, did not find, in our examples, spectral results which could explain the total absence of preferences for the term "brilliant" in the responses of our subjects (see Table 1). We do not know if bright and brilliant have exactly the same meaning. In any case we must again consider the possible difference which similar words can assume in the minds of the listeners with respect to the meaning conventions of psychoacoustics.

4.4. Verbalization

A particular section of psychoacoustic studies is devoted to problems of verbalization. Elena Samoylenko and collaborators (1996) observe that on this topic there exists a long tradition of proposals initially based on more or less acceptable individual opinions, and gradually on more systematic studies. In order to analyze the mental procedures of listeners they adopted a "free verbalization" approach: they asked them to describe in the most detailed way possible the mental procedures they used in comparing pairs of instrumental timbres. From their responses they deduced a number of linguistic and thinking mechanisms. For another example of the importance of verbalization in timbre listening we also quote an article (Zacharachis *et al.* 2014) whose authors try to shed light on the different uses and semantic connotations of analogous words present in the Greek and English languages. In verbalization studies we encountered large lists of words more or less frequently used, but so far we have not found a systematic approach to the problem of the connection between verbal terms and aspects of sound spectral entities. Probably this is due to the impossibility to obtain an organized definition of well distinct timbral units as if they were the entries in a dictionary. This however is a limit of spectrographic analysis applied to the perception of timbre.

For our purposes, though, we can also obtain useful suggestions from a sub-discipline of linguistics, which is phonetic symbolism (e.g. Dogana 1983), where the connections between meanings of the words and aspects of sound structure are systematically studied. This discipline has common aspects with prosody and with music even if it does not coincide with either of them: they nevertheless have in common the use of vocal timbres, of height profiles, of accents and, moreover, of their connections with expressive communicative intentions. Statistic analyses on lexicon of different languages can give scientific documentations to phonosymbolic research (Dogana 1983: 141). In this article we cannot enter into particular topics. We limit ourselves to observing that adjectives such as high, low, percussive, clear, obscure, hard, soft, smooth and rough, commonly used in them, are common to those of timbre perception in the discipline of music. And we add that the motivations of the relationships between vowel pronunciation and musical performance are quite similar: for example a high vowel such as "i" is normally associated with light, brightness and brilliance, while a low vowel such as "u" is normally associated with obscurity (Dogana 1983: 186). Occlusive consonants (p, t, k) are associated in different languages with percussions, explosions and so on (Ibid: 156), while smoothness is linked to particular types of phonemes: in particular the lateral "l", some nasal sounds and labial-dental fricatives, with long and not explosive attacks (Dogana 1983: 199).

5. Conclusions

First of all we wish to reiterate that our listening test on timbre is a rather unprecedented experiment. For this reason our initial idea was to explore the field in order to decide whether a more thorough research was worthwhile. The semantic differential technique confirmed by spectrographic and verbalization analyses obtained interesting results: on some occasions expert subjects had difficulties in listening because of the too subtle perceptual comparisons we proposed to them, but on other occasions they gave responses which showed a good competence

in the perception of timbral nuances. In other words, our research confirmed that the analysis of timbre perception is possible even though it requires attention and accuracy.

Some theoretical weak points emerged on different occasions, and it is useful to point them out in view of further research. There are for example uncertain perspectives in psychoacoustics itself. See for example Donnadieu (2014), where the author indicates uncertainties on the mental representation of timbres. One concerns the actual concept of timbre: sometimes research refers to the internal components of isolated instrumental timbres, in other cases of complex timbres of superposed instruments. We wonder, then, whether the two kinds of analysis could reach the same results. The second problem concerns the aims and methods of timbre research. There is an area traditionally named Timbre Space, which studies the individual spectral-temporal components processed by the sensory system according to more dimensional parameters graphically organized in a multidimensional space. Another viewpoint, named Ecological Theory, sees timbre perception as a direct function of the physical properties of the sound object: these studies describe the physical parameters that are perceptually relevant to the vibrating object. Research into psychoacoustics will obviously develop, but its application to music analysis can raise problems if there are still theoretical principles not clearly solved. Further research must be aware of this aspect.

Other important weak points exist in music and musicology. In the practice of score composition the presence of intuitive choices is absolutely dominant, and this aspect has evident consequences on musicological knowledge, which traditionally lacks information and analysis on this subject. In computer composition this aspect is less evident, but to translate compositional methods from one practice to the other is not an easy task, even if examples can sometimes be found in the literature.

Similar weaknesses are present in verbalization systems. Zacharachis and colleagues (2014), for example, speak of three possible timbre dimensions arisen from verbalization studies: a tactile dimension, a light dimension and a mass dimension The authors say that this three-dimensional theory is only a rough hypothesis which requires further work before being better assessed. This is also a reason why we have tried to suggest the contribution of the linguistic theories of phonetic symbolism.

Finally we would like to add a comment about our experience on the division between expert and non-expert participants. In psychological research this division is accepted and often gives significant results. This happens probably because cognitive research is normally based on tonal or traditional repertoires well known, in terms of listening exposure, also to non-expert listeners. In our case when we used contemporary music and asked for timbre perception, the traditional division lost much of its usefulness.

These are the main outcomes of our explorative intentions. We should also consider that expert listeners intuitively felt in the timbre of the piece the presence of expressive intentions of the composer and of narrative contents of the episode: this surprising aspect solicited our attention as a premise for future research.

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Biography / Biografía / Biografia

Mario Baroni has been full professor, and former director in the Department of Musicology of the University of Bologna. At present he is retired. In 1990 he founded the Italian Association for the Analysis and Theory of Music (Gruppo Analisi e Teoria Musicale). He was one of the promoters of the foundation of ESCOM (European Society for the Study of Cognitive aspects of Music). He published works on music analysis, emotional aspects of music experience, social impact of music, methodology of music education, and historical topics, particularly concerning 20th century music.

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25 El oído pensante, vol. 4, n°1 (2016) ISSN 2250-7116
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M. Baroni, R. Caterina y F. Regazzi. Beyond the
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Fabio Regazzi obtained degrees in piano, electronic music and composition. At present he works as a technician expert on sound analysis and computer music in the Department of the Arts of the University of Bologna. He is also the author of software for cataloguing of tapes and documents in a number of Italian theatres. In the last five years he collaborated with professors Caterina and Baroni in research projects presented in international conferences and took part in the European project *Miror* on the use of technology in music education.

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