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Music Cognition, Semiotics and the Experience of Time: Ontosemantical and Epistemological Claims

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Abstract

[441] This paper is about musical epistemology. It stresses the role of how a listener can have a unified coherent experience over time. Central questions involve the conceptual construction of time, the role of non-objectivist as against objectivist cognition, and the role of cognitive mediation and imagery in music cognition. In order to discuss these claims a conceptual framework is introduced that does justice to the dynamic ongoing characteristics of the sonorous unfolding in time, leaning on the theoretical work of Kant, Husserl, and Schütz. An attempt is finally made to provide a formal description of dealing with music that objectifies the temporal unfolding of sound under the guise of presentational immediacy and as a kind of synthetic activity of the mind, stressing both the sequential experience and the construction of relational continuity.

1. Introduction

The purpose of this paper is to discuss the experience of timefrom the point of view of semiotics and cognition. Both traditions hold different epistemological positions, as semiotics is oriented primarily to the symbolic approach to cognition while the cognitive approach is more grounded in empirical and scientific research. There is, however, a common ground if we consider the *signification process* to be the critical element in the construction of musical meaning.

In order to elaborate this point, I will concentrate on three major topics. These are: how can we have a unified coherent experience over time, how can we make sense out of the perceptual flux, and what is the role of signs and sign operations in this constructive process of sense-making? For this purpose, I introduce some conceptual tools from the domain of semiotics and philosophy which may be useful for a better understanding of the experience of time. They must allow a description of the ongoing dynamic characteristics of the outer flux of the sonorous unfolding as well as the perceptual and cognitive processes that enable the inner experience of time.

Several questions should be considered here. Is music, as a temporal art,

to be dealt with “in time” or “outside of time”? Can we speak of “perceptual bonding” with respect to cognitive events which are directly induced by stimulating a sense organ (*peripherally connected*) or should we conceive of equivalent corresponding sensory images which are evoked in the absence of such stimulation (*autonomous cognitive events*) (Langacker, 1987)? In addition, is dealing with music reducible to real-time mental processes which are causally related to the sonorous unfolding or can we go beyond the limitations of time-bound reactivity to the sound? Coping with music, in fact, is not merely a conservative process which presents direct reactivity to external stimulation. It is proactive and retroactive as well, allowing the music user to navigate through the sound by relying upon memory and imagination (Reybrouck, 2001b). At this internal level of processing, it is possible to transcend the arrow of time and to cope with sounds in a kind of virtual simultaneity. It is a way of dealing with music which entails a transition from *presentation* to *representation*, allowing the listener to deal with mental replicas of the sound rather than with their sounding qualities. Sounds, then, can be handled in a kind of symbolic play and time can be considered as a modality of the structure of the music. As such, we can deal with music at the level of virtuality, somewhat analogous to the act of composing. Composing takes place mostly out-of-time, as the composer is not dependent upon the sonorous unfolding over time. It involves mental processes [412] which are performed on mental replicas of the sounds rather than on the sounds themselves (Reybrouck, 2000).

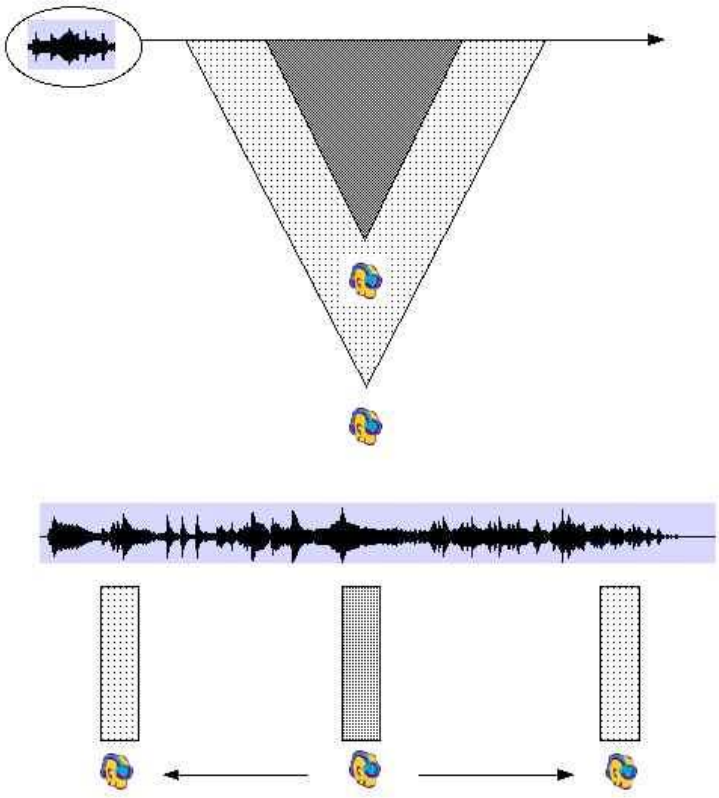

Fig. 1. Music as motion. The top figure depicts the listener (SoundJam icon) as a still spectator who can distance at will in order to recollect a small or bigger portion of the music. The lower part depicts the music in a kind of representational format, allowing the listener to navigate through the music and to inspect its unfolding in time through a small temporal window.

The experience of time, further, is related to the metaphor of music as motion. Two options are possible here: the music is the mover with the listener as a "still spectator", or the listener is moving while the music is fixed in a kind of representational format (see Fig. 1).

The distinction is important. It deals with *resolution* and *perspective* (Godøy, 1997). It is possible, in fact, to process music with high levels of resolution – as in "signal based" 44.1 KHz audio processing –, but it is equally possible to listen to music with a lower level of resolution which is "perception based." In order to illustrate this claim, I have depicted in Figure 2 the sonogram of the first measures of "Der Abschied" from Mahler's "Das Lied von der Erde." It is immediately clear that we can delimit four distinct segments with unit character, each of them having a duration of about 5 seconds. The first two segments are simple and distinct (tam-tam), the third and fourth are compound, allowing the listener to delimit distinctive parts (wood and brass instruments) which are components of the more encompassing sonorous event. It is up to the listener, however, to set the level of resolution and to select the elements which he or she considers to be discrete elements.

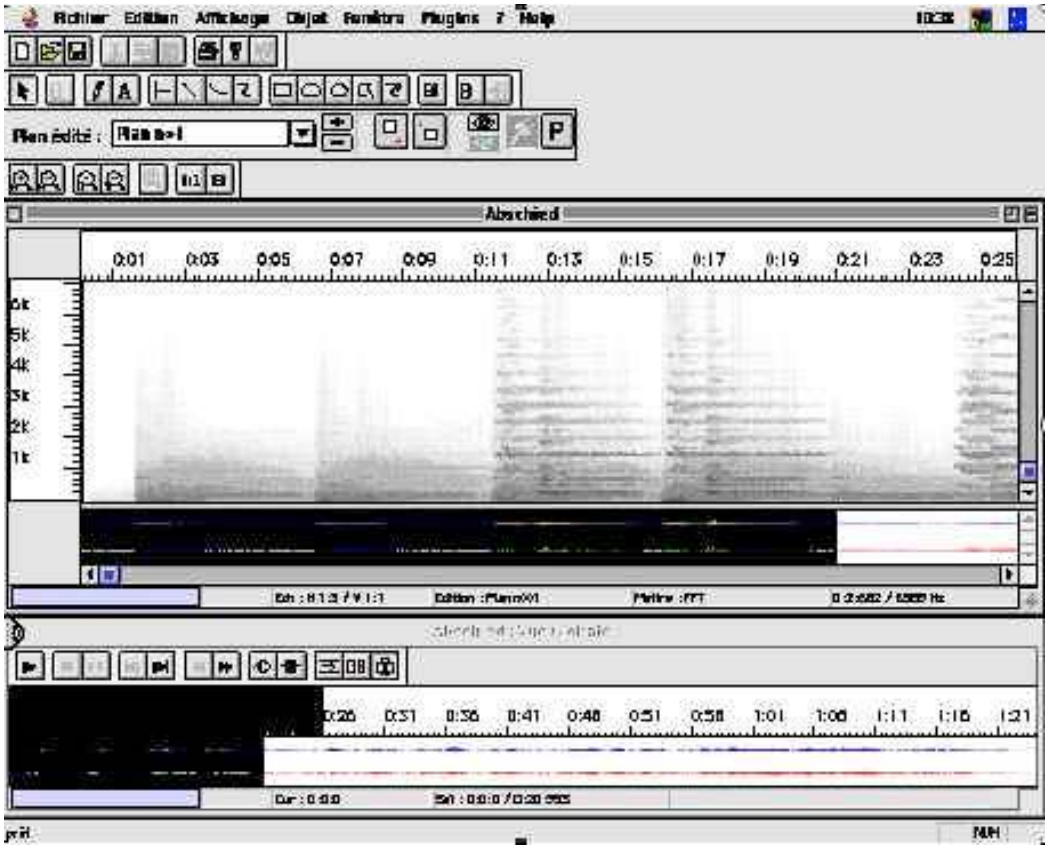

Fig. 2. Sonogram of the first measures of "Der Abschied" of G. Mahler (Das Lied von der Erde). The upper pane depicts a selected area (highlighted in black) of about 20 seconds in which four segments can be distinguished. The lower pane depicts a more global view of the same music in which the highlighted area is embedded as a waveform representation (realized with Acousmographe – INA/GRM).

The critical elements in this approach are the *distance* which the listener *window* through which he or she inspects the sonorous unfolding. This "inspector window" is limited by technological (temporal resolution), perceptual, ecological (event perception), and psychophysiological constraints (Reybrouck, 1998b, 2001c, 2004; Pöppel, 1997). It is possible to listen to the music with a small temporal window and to proceed simultaneously with its unfolding, but is possible also to recollect the data in a kind of working memory and to group them together in a hierarchically higher level of structuring. In order to do so, we must abstract from the level of "actuality" in favor of a level of "virtuality" at which we deal with mental replicas of the sounds rather than with the sounds themselves. This is a symbolic approach to music cognition which is related to the principle of *cognitive economy*. It is indeed much easier [413] to "recognize" a sounding event at a macroscopic level of resolution than to experience all the idiosyncrasies of its unfolding in time.

Symbolic labeling, further, involves a process of discretization, at least if we reduce the symbolization to the level of sounding phenomena. We may apply such a label to any given delimitation of events unfolding in time. Earlier I have proposed the generic term *sonorous denotatum* to be used in connection with any sounding things which can be "denoted" in an act of mental pointing (Reybrouck, 1995, 1998a, 1999, 2001c, 2003). These can be labeled symbolically as discrete things with "unit character", but they can have a continuous representation as well, to the extent that they reflect the temporal unfolding of the sound. As such we may conceive of a mixed discrete/analog approach to perception, stressing both the quantal aspect – the discrete unit – and the distributed substrate (Godøy, 1997). Every sounding event, in this conception, can be characterized as a discrete unit, while having at the same time a temporal extension that unfolds in time.

2. Empiricist claims: The sonorous articulation as a starting point

In order to make these claims more operational, we need a descriptive and explanatory vocabulary which provides conceptual tools for a better understanding of the sonorous unfolding in time. The concept of *articulation* is likely to be helpful here. Its primary meaning is related to the possibility of dividing something in discrete and distinct parts which can be joined together in

a flexible manner. The related term *sonorous articulation* has become common knowledge in music theory (Schaeffer,1966; Brelet,1949). It refers basically to music as a "temporal" and "sounding" art, which is characterized by its sonorous unfolding in time. The visual representations of sound as a wavelet or a sonogram are typical examples, but other translation algorithms which transform the audio signal into some kind of visual format can be considered as well.

The sonorous articulation can be continuous or discrete. It can be visualized as a curve with a beginning, a middle and an end, somewhat analogous to a point which traces a path and leaves a trail behind. A sequence of points, however, is one-dimensional. Other visualizations which rely on twoand three-dimensional representations are more promising, as is obvious from many special effects of several kinds of media players (iTunes for Mac, media player for Windows; see also Geslin, 2002, for an overview). A major problem with this kind of visualization is the acuity of the translation algorithms, which sometimes fail to provide a natural and causal relation between the visual effects [414] and the music which brings them about. They mostly provide continuous forms of visualization which do not do justice to the discrete character of the distinct sonorous denotata (the individual notes or sound configurations). They allow us, however, to conceive of the sonorous articulation through time in terms of topological transformations in which an original configuration is transformed into another (see Fig. 3). The transitions can be smooth or gradual, and even discontinuous, but the music can be invariably considered as an object in motion which passes through a series of distinct states. As such it can be objectified as the evolution of a configuration in time.

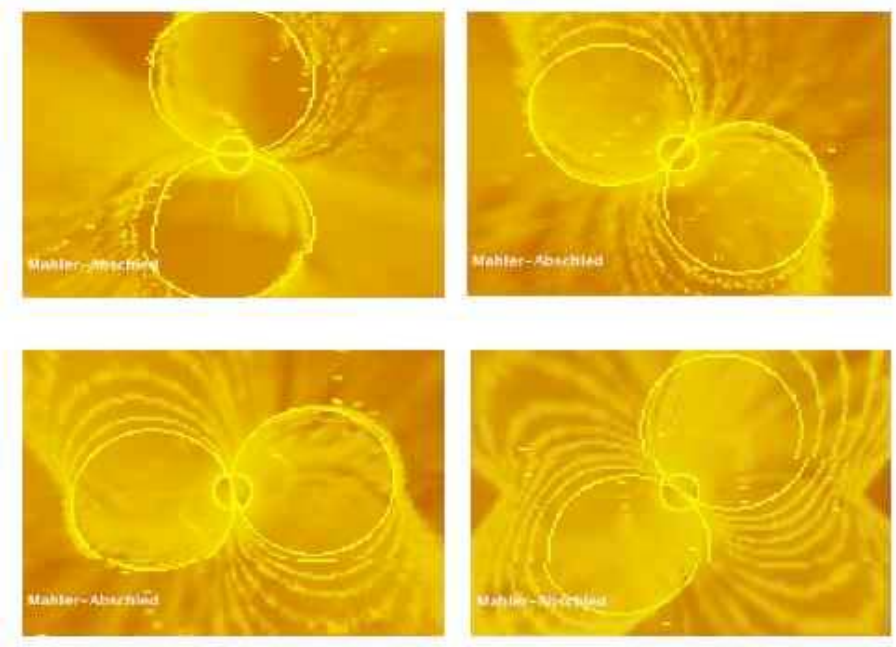

Fig. 3. Example of three-dimensional visualization of four distinct slices of the temporal unfolding of the first sound segment of Figure 2 (realized with iTunes for Mac).

The listener can keep pace with this unfolding and mentally trace the path the music – as a moving object – is following. The listening process, in this conception, is a function of the music. Or to put it in another way: the sounding qualities of the music are taken for granted in an attempt to provide means for portraying the continuous acoustic signal. It is an approach which fits in with the "objectivist" approach to knowledge acquisition which holds a *realist* epistemological position with strong *empiricist* claims. As such we can try to objectify the temporal unfolding of musical sounds and conceive of it as something which refers to a reality which is external to human experience.

Music cognition, however, is not reducible to "acoustic" or "auditory" listening as the only processing mechanism (Handel, 1989). What we hear is not music in its acoustic qualities, but music-as-heard. In order to make sense out of the perceptual flux, we must go beyond the mere acoustic description of the sound. We have to consider the role of "subjectivity" and "intentionality" and take into account the way in which human listeners structure the sonorous unfolding. What matters, then, is not merely the continuous flow of matter in the physical world, but the perceptual and cognitive processes of the knower.

The same holds true for making sense of music. It is the listener who selects at will in acts of deliberate attention. What he or she focuses on are not only the particularities of the sonorous unfolding but also the more general concepts or labels which are applied to them. Dealing with music, on this view, relies on "experience" and "conceptualization", and it is here that *semiotics* – as the science of signs – may be useful in providing conceptual tools that allow us to deal with music both at a concrete and abstract level of reference (Reybrouck, 1999). It is possible, in fact, to distinguish between the sign as a concept and the material sign vehicle in its sensory qualities.

Let us try to apply this to a musical example. In Figure 4 I have depicted the sonograms of the four sound segments of Figure 2. It is immediately clear that the first and second segment are mostly analogous. They can be labeled symbolically as the same sound configuration. A microscopic inspection, however, of the sonogram, reveals differences
[415] with respect to their sonorous articulation. It is a beautiful example of Morris' distinction between *indexical* and *characterizing signs* (1938/1975). Indexical signs denote only a single object (e.g., "this"), characterizing signs denote a plurality of things (e.g., "sound"). The combination of both (e.g., "this sound"), however, is very fruitful, as it unifies the definiteness of reference of the indexical sign ("this" sound) with the expectation which is implied in the characterizing sign (this "sound"). As such we can conceive of four segments in the beginning measures of Mahler's Abschied which can be labeled

symbolically as aabb. Most listeners will not distinguish between the a's. The b's, however, are more difficult to deal with, as there are minor differences in their sonorous articulation. It is up to the listener, then, to decide whether the second b is to be labeled as b or b'. The critical element, here, is not the sound itself, but the level of resolution and the distance the listener keeps with respect to the sounding event.

Another contribution from semiotics is related to the distinction between the sign as a concept and the material sign vehicle in its sensory qualities. It is the classical distinction of French structural linguistics, which stressed the difference between the material sign that signifies (the "signifier") and that which is referred to (the "signified"). This dyadic approach proved to be fruitful but insufficient because of its blindness concerning the role of the "sign user" – an aspect that has been emphasized within analytical philosophy,- action theory, general systems theory and the semiotic tradition of Morris and Peirce. Semiotics thus broadened its field from a "dyadic" to a "triadic" approach, to encompass the role of the interpreting mind. Basic in this approach is the process of *semiosis*, with its dynamic relationship between three levels of reference: the material "sign vehicle," the "object" it refers to, and the "final decoding by the interpreter" (Maser, 1977).

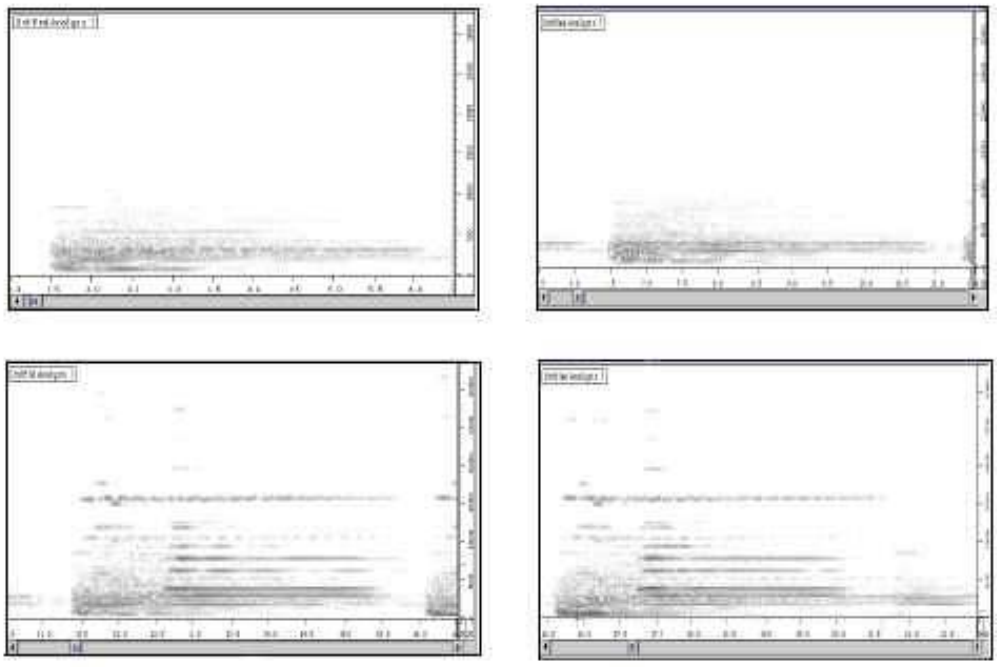

Fig. 4. Comparison of the sonograms of the selected sound segments of Figure 2. The first two sonograms are rather similar and the same holds true for the third and fourth segment (aabb). Microscopic inspection of the four segments, however, reveals minor differences with respect to their sonorous articulation (realized with Audiosculpt/IRCAM.

The application of these claims to music is rather tedious.What are, for instance, the material "sign vehicles," and what are the objects that are referred to? I have elsewhere proposed that we may conceive of the sounding material as the sign vehicle and consider music as being essentially selfreferential (Reybrouck, 1999, 2001c). This means that music refers primary to itself and that it is up to the listener to delimit the units he or she considers to be musical signs. It means further that the distinction between "sign vehicle" and "object" is gradual and not qualitative. Every sensory articulation which can be a possible object of *discrimination* and *identification* can be considered as an object. As such it acquires a repeatable character, which allows us to label it symbolically as a sign. The role of the listener, again, is of primary importance here.

[416] Let us return again to the sound example of Figure 2. The four initial segments are typical examples of possible delimitations of temporal unfolding which are distinct and discrete. At this level of resolution, there seems to be little ambiguity. At a higher level of resolution, however, the listener has more freedom. The third and fourth segment, e.g., contain component parts which call forth strategies of selection in order to give them perceptual weight (see Fig. 5). It is possible, in fact, to distinguish between wood instruments, brass instruments, and a whole gamut of percussion instruments, allowing the listener to set the level of resolution at will.

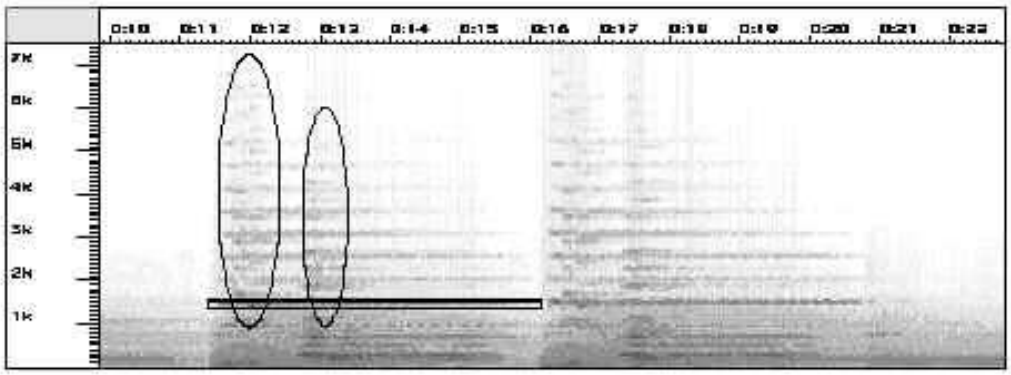

Fig. 5. Selection and delimitation of three component parts in the third sounding event of Figure 2. The most striking element is the melodic line in the wood instruments (horizontal rectangle), besides the percussive sounds of the tam-tam and brass instruments (vertical ellipses) (realized with Acousmographe – INA/GRM).

Dealing with music, in fact, is highly idiosyncratic. It involves strategies of *semanticity* which assign semantical weight to perceptual units (Reybrouck, 1999; Deliège, 1998, 1996; Deliège et al., 1996; Deliège & Mélen, 1997). As such we must relinquish the concept of music as a normalized and complete sign

system in favor of a system with elements which can be “delimited” and “denoted” at will (Reybrouck, 1995). It means, further, that we must start music analysis from the level of the sounding material, taking the sonorous articulation as a starting point, somewhat analogous to the extraction of types of auditory images from a given sound in auditory modeling (see Todd, 1994; Brown & Cooke, 1994; Toiviainen, 1996).

3. Imagery as connecting structure: from discrete succession to relational continuity

The delimitation of “sonorous denotata” is an analytical approach to music cognition. It involves acts of apprehension which are plainly episodic and have a position in a timeseries (Geach, 1981). As such they account for the succession of discrete units, but they fail to provide an overarching principle of unity. In order to meet this requirement we need a connecting structure which may instantiate the transition from “discrete succession” to “relational continuity.”

Such a connecting structure can be found in the schematizing function of the imagination. It is an old idea which was already stressed by Kant (1790; see also Johnson, 1987, p. 165) who claimed that imagination generates much of the connecting structure by which we have a coherent, significant experience over time. It organizes mental representations into meaningful units and orders them in time.

The role of conceptualization must be considered here, both with respect to the units and their relations. Perception, in fact, is not limited to a succession of discrete nowmoments. It calls forth relational continuity which is effectively experienced by us in our *stream of consciousness.* This idea, which was introduced by William James (1912/1976), has received much attention. Less known, however, is its elaboration in his doctrine of *radical empiricism*, which is an original epistemology that deals with the tension between *concept* and *percept*. It stresses the role of knowledge-byacquaintance – as the kind of knowledge which we have of a thing by its presentation to the senses – rather than conceptual knowledge. What really matters is the fulness of reality which we become aware of only in the perceptual flux (1911/1968). Conceptual knowledge is only needed in order to manage the information in a more economical way.

The claims are appealing. They are related to the problem of veridical representation of the sonorous unfolding in time. They bring together the *discrete-digital* and *analogouscontinuous* representation of sound (see also Krumhansl, 1992; Vecchione, 1987; Desain & Honing, 1992, 1995; Dannenberg, Desain, & Honing, 1997; Cariani, 1997, 2001; and Pattee, 1974, 1990 for a more general backdrop of the mixed analog-digital devices), and combine the flexibility of

[417] continuous knowledge representation with the discrete labeling of symbolic representation, with the experience of time being the mediating link between percepts and concepts, to quote Kant again.

The topic is somewhat related to Peirce's conception of continuity in consciousness, which states that thoughts involve a succession of sensations that flow through the mind. Thoughts are not immediately present to the mind. They must cover some portion of the past or future (1878/1965). Essential in this conception of continuity is the experience of *duration* and *transition*.

It is not difficult to apply this to the experience of musical unfolding in time. Koechlin (1926) e.g., stressed that musical time can be conceived as the memory of a great number of states of consciousness which are related through some duration, somewhat analogous to a path that is drawn between two points. Central in this claim is the focus on the path rather than on the discrete points of succession. The concept of a "melodic line" as a curvilinear trace of motion is a workable example here, but other examples can be given, as is obvious from experimental research in the domain of *apparent motion* and *motion perception* in the visual arts and music (Gjerdingen, 1994; Grossberg & Rudd, 1989).

What is meant, essentially, is an "organic" rather than a "mechanistic" conception of musical unfolding, a *path of becoming* rather than a static representation of a succession of discrete slices of time. The continuity, further, must be felt as a kind of *inner duration*, as advocated in the philosophical work of Bergson (1907/1969) and Deleuze (1983, 1985). Bergson's first thesis on movement, e.g., claims that movement should not be confounded with the space which is passed along. What really matters is the *act of passing* rather than the *passed space*, the latter being divisible and past, the former being indivisible and present. It is a conception which is somewhat related to Deleuze's concept of *image-movement* as exemplified in movies. Movies can be described analytically as a succession of slices of time, but they cannot be reduced to immobile slices with movement which is added to them. What they call forth is an irreducible unity of image and movement (Deleuze, 1983, p. 11).

4. The conceptual construction of time

Arguing on these lines, we may consider how we can come to have a conceptual construction of time. The problem has been sketched by von Glasersfeld (1996) who used the same frame metaphor of *cinematography,* in which the connections between separate frames are not given in advance. The frames are static. They need an active construction of the mind to supply a relational concept that goes beyond simple succession. The same holds true for listening to music, which is a process that invites the listener to go beyond the coincidence of mere immediacy. Music, in fact, is a temporal art which leans upon processes of attention, memory and expectation. In contrast to geometric figures which are

present at a glance, musical figures require a minimal unfolding in time before there can be an act of recognition as the result of the summation of the prior elements. This "integration of time" is dependent upon temporal unfolding. It draws the principal distinction between *time-oriented processes* and *spatialized structures* (Meyer-Eppler, 1952; see also Patel, 1998, for the related problem of temporal integration).

The temporal unfolding, further, can be conceived as a concatenation of discrete time-moments or as an indivisible whole. The latter conception was advocated by Bergson (1889/1961, 1911) who conceived of time as *pure duration* without distinction between the component parts. Time cannot be conceptualized as a spatial structure which is divisible and homogeneous. Its real characteristic is the dynamic and kinetic character of continuity and development, with past and present being intermingled in an organic unity. As such, we must consider the mental synthesis which provides the connecting structure rather than solidifying the sensations in a kind of geometric structure. It is the basic distinction between time-as-quality (*temps-qualité*) and time-as-quantity (*temps-quantité*). The latter allows us to conceive of duration as an extensive quantity which is the projection of a fuzzy multiplicity into a distinct multiplicity which is measurable and observable. It stresses the sensational aspect of time rather than the mental synthesis which puts the component parts together.

The claims are appealing. They are somewhat related to Kant's conception about the *synthesizing function of the mind* as an activity that goes through the manifold in order to put it together and to make knowledge of it. It links the separate impressions in an act of *apprehension* which combines knowledge a priori with empirical observation (Kant, 1787).

The synthesizing function of the mind has been elaborated further by Husserl (1928) who brought it in connection with the experience of duration. Starting from an idea of Brentano, which stated that the grasping of a succession of representations involves that they are treated as the simultaneous object of a single act of consciousness, he argued for a kind of knowledge which summarizes all of them in time. This summing up is not articulated through time, as a series of successive representations, but must be considered as the experience of a temporal space or distance between distinct time moments at different time points of their unfolding. It entails a relational consciousness which embraces at a glance a whole area of consciousness. It is a central claim of Husserl's phenomenology: each experience which has at least some pregnancy, is experienced as a unity of the inner consciousness which is primarily a consciousness of time and of experience. Such an experience, further, is to be conceived as a *time-constituting consciousness* which is directed to the past and to the future. It involves a tension to the past (*retention*) and to the future (*protention*), with listening to a tune as a typical example. Retention,

further, is an original consciousness, which substitutes a primary memory for actual experience (Husserl, 1928). It constitutes the lively horizon [418] of the now-moment and offers a consciousness of the immediate past which can be recalled as something which is there again. The consciousness of time, however, is not only oriented to the past, but also to the future. It is an intention which is directed to a series of possible fulfillments.

In order to make his claims more operational, Husserl (1928) has suggested a *phenomenological constitution of time* which combines "phenomenological" and "real" or "objective time." It can be depicted graphically by means of horizontal and oblique lines, as illustrated in Figure 6.

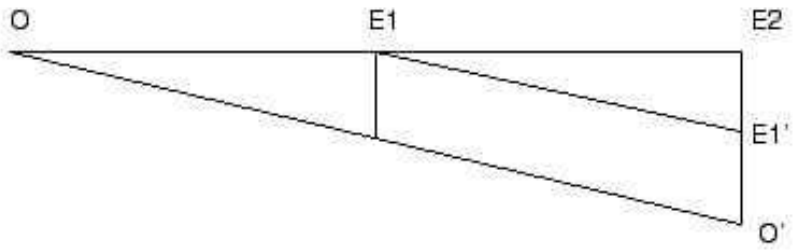

Fig. 6. The constitution of time (after Husserl, 1928). The horizontal line is a mere succession of now-moments. The oblique lines refer to the receding of these now-moments with a shift from actual perception to retential memory.

The horizontal line refers to the primal data of objective time (as a succession of now-moments); the oblique lines refer to the receding of these now-moments, with a shift from actual perception to retential memory. The actual sound E1, e.g., becomes a memory trace E1' at the new time-moment E2 and the first impression 0 has changed from perception at 0 to a memory trace at E1 and to a memory trace of a memory trace at 0', and so on. Every time-moment, further, can be grasped in a horizontal (causal-transitive) and a vertical (simultaneous) way, constituting a relational framework which goes beyond the mere description of temporal order, and which offers a time experience which deals with actual and virtual time simultaneously.

Husserl's construction is challenging. It brings together the synthesizing function of the mind and the actual articulation through time. The same holds true for his description of *time objects* as objects which are in time as well as objects which embrace a temporal extension in themselves (Husserl, 1928). Hearing a tune or even a simple pitch are typical examples: every pitch has a temporal extension, which is heard as a now at the beginning of its sounding, and as a new now at each successive moment of continued sounding. What we hear at every moment, however, is only the actual phase of sounding. To

objectify the whole duration of the pitch we need an act continuum which is constituted partly of memory, experience (only for a singular time moment) and expectation.

The topic is related to the distinction between theunchangeable but divisible "outer experience" of time and the indivisible stream of "inner experience." It has been elaborated by Schütz who recalls Bergson's "tensions of consciousness" and James' "stream of consciousness." Inner life, in Schütz's conception, is a stream of connected experiences, with the "now-moment" as the time of immediate experience, the past as a set of complete but indirect experiences which are available only through memory, and the future, which is available through anticipation. As such he calls forth the dimensions of inner time (see Fig. 7) with a major distinction between *reproduction*, *retention*, *the now moment*, *protention* and *anticipation* (Schütz, 1971, 1976).

Fig. 7. The dimensions of inner experience of time (after Schütz, 1971, 1976).

The combined processes of memory and expectation embrace the totality of our experience of time. They are crucial in constituting an uninterrupted stream of consciousness. There is, however, a difference in ontological level between their constituent parts. Retention, e.g., is an experience in which the actual experience is still retained. It allows the listener to experience a sustained tone without interruption as a collection of successive now-moments.
This is not the case for reproduction which refers to a past which is not directly contiguous with the actual experience. The same holds true for the dimensions of the future, with an analogous distinction between protention and anticipation. Protentions are expectations with respect to the immediate future, anticipations are directed to a more distant future.

The claims provide operational means for dealing with music. They allow us to distinguish between several levels of processing of the sound. There is, first of all, the level of actuality, at which the listener listens to the music through a temporal window which is the combination of retention and now-moment. As soon as this temporal window is passed through, the processing of the music shifts from retentional memory to reproduction. And the same holds true for the level of protention which shifts to anticipation as soon as the representation is no longer contiguous with the actual unfolding. The whole

construction is depicted graphically in Figure 8, in which I have tried to suggest a possible implementation for visualizing the inner dimensions of the experience of time.

Starting from the sonogram it is possible to provide a simultaneous overview of a segment of the sonorous unfolding over time (middle pane). The navigation tools (forward, backward) allow the listener to move through the music and to listen to it through an inspector window which can be resized in order to select a scope of attention. This window can be considered as the actual sounding "now-moment" together with its retention and protention. The lower andupper panes provide an extension of the selected area with the level of reproduction (bottom) and anticipation (top). Resizing and rescaling of the pane allows the listener to have a smaller or more global overview.
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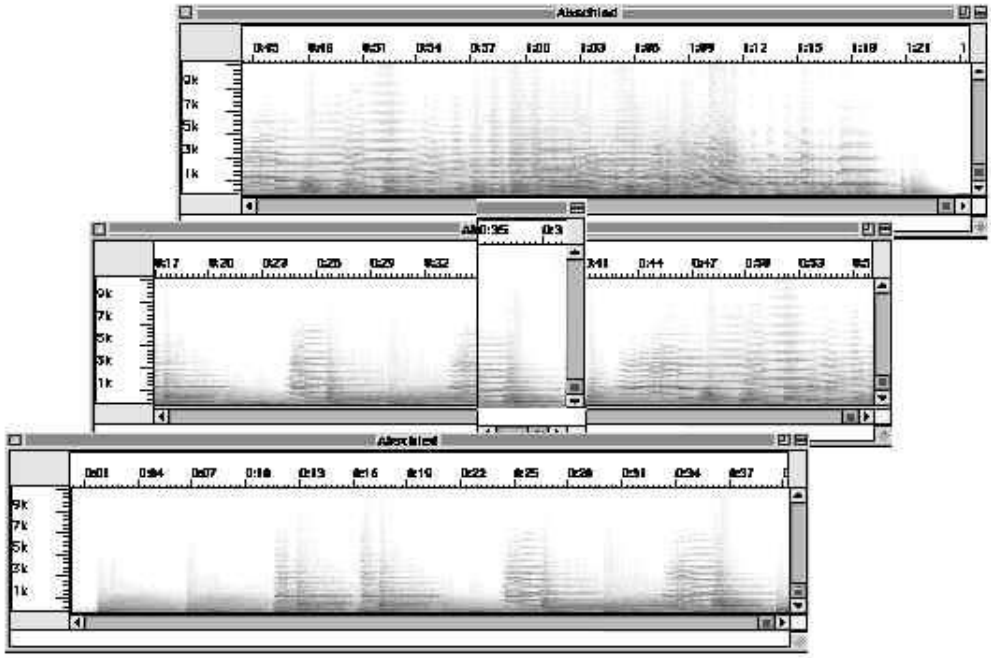

Fig. 8. Graphic depiction of the inner dimensions of time. The middle pane displays the level of actuality with the now-moment being selected through a temporal window which can be resized. The lower pane provides the level of reproduction and the upper pane the level of anticipation. It is possible to resize the scope of each window in order to provide a smaller or more global overview.

5. The delimitation of elements: time objects, temporal patterning and signs

The conceptual construction of time involves strategies of selection and semanticity. It is up to the listener to focus and select at will and to denote and delimit now-moments and segments of time with a certain temporal extension.

These delimitations can be described as "structural units" but it is possible also to treat them as *signs* if we conceive of them in semiotic terms. There are essentially three reasons for doing this: first of all, there is the "denotation" and "delimitation" of a set of elements; these elements can be considered as "signs" if they have at least some referential quality; and the signs, further, can be considered as static and discrete symbols, but it is possible also to conceive of them as variables with a temporal extension. They can thus be described as "functions of time" and treated formally as propositional functions.

The idea of time objects delimited by the listener and having a sign-like character presents a challenge for the field of music cognition: it unites the symbolic and empirical approaches and stresses the mutuality of experience and conceptualization. As such, it resumes the basic claims of William James' doctrine of radical empiricism which has not yet received much attention in music theory. Several questions, however, are still to be solved. What are, e.g., the elements that must be delimited? Can we rely on "ontological" categories and conceive of objective elements which are "out there", or must we conceive of "epistemological" categories which stress the role of the music user and his or her listening strategies?

The answer is not obvious, but the concept of *time object* is likely to be an interesting starting point. It is possible, in fact, to conceive of time objects as segments of time which can be handled as variables with a temporal extension that depends upon the listener's decoding strategies. The process of delimitation, therefore, is a constructive and intentional one. It is related to the idea of *figural synthesis* in artificial intelligence which considers mechanical pattern recognition to be a synthetic process which selects segments out of the perceptual flux, somewhat analogous to the recognition of characters in handwriting (Hofstadter, 1986). The basic mechanisms which are at issue here are *identification algorithms* and mechanisms of *pattern recognition* which deal with temporal patterns in an active way.

But how do we delimit the elements? An interesting approach to the problem is the concept of *temporal gestaltunit* (Tenney & Polansky, 1980) as a distinct span of time which is both "internally cohesive" and "externally segregated" from comparable time-spans immediately preceding and following it. The approach is related to the problem of *parsing*, *segmentation* and *perceptual grouping*. Yet, parsing can yield static products which are not relevant to the music as it is heard (Smoliar, 1995). More promising is an [420] adaptive model of perceptual categorization which requires the negotiation of the ongoing activities of *delimitation*, *discrimination* and *association* of objects (Edelman, 1987, 1989; and for a somewhat related musical analogy, Zbikowski, 1999) and which assigns temporal unfolding to a subset of time objects which are identifiable and recognizable as such.

The delimitation of temporal gestalts, further, leans upon pattern generating mechanisms which, in the case of temporal patterning, involve the

association between successive elements, and which allow the listener to build up a discrimination between a combination of stimuli (S1 + S2) and either of the components (S1 and S2) appearing separately (Berlyne, 1965). Crucial in this distinction is the grouping and integration of auditory stimuli in an act of categorization which is the outcome of prior associations between them. As such is it related to the economy of cognitive processing in reducing segments of temporal unfolding to known schemes or prototypes. It allows us to conceive of them as instances of classes and to treat them in a propositional way.

6. Towards a formal approach: the musical sign as a function of time

Knowledge can be defined as the product of active knowers who shape their thinking to fit the solicitations they experience. This is the "non-objectivist" position of *cognitive semantics* which stresses the role of the knower rather than the known things as objectified (Lakoff, 1988; Johnson, 1987; Jackendoff, 1988; Varela, Thompson, & Rosch, 1991). The claim is contrary to the "realist dogma" that there is an objective world "out there." It relinquishes the conception of knowledge as a representation of an independent reality in favor of an organism-dependent way of knowing which is relative to the organism's way of experiencing (von Glasersfeld, 1996; Reybrouck, 2001a).

The position is an "epistemological" one. It defines music cognition not merely as the understanding of music as an *ontological* category, but as a process of knowledge acquisition and the construction of meaning out of the perceptual flux. Essentially, this is a bottom-up approach which is datadriven, and which I take for granted as a starting point (see also Carroll-Phelan & Hampson, 1996). It means further that the signification process must be grafted on the sonorous unfolding.

It is up to the listener, however, to select the sounding events which present themselves on the basis of *functional signification* and *perceptual pregnancy* and to raise them to the status of "signs," rather than assuming musical "objects" to exist independently of the human knower.

Arguing on these lines, we should be critical of *naïve realism* and *naturalistic conceptions* of musical epistemology which argue for a causal relation between the sounding substrate and the signification process by the listener (for an overview, see Leman, 1999). The problem is rather tedious as the mind is both an *organized* and an *organizing* machine (Paillard, 1994). It is possible, in fact, to treat the signification process at low levels of cognitive functioning, as a kind of time-bound reactivity to the stimuli of the external environment. This is a basic claim of ecological perception which states that the perceiver recognizes perceptual data as "real things" without conscious intervention of the mind (Gibson, 1966, 1979, 1982). The newer paradigms in

neuroscience, however, transcend this reductionistic conception of the brain as a *reactive machinery* (Paillard, 1977, 1990, 1994; Berthoz, 1997) in favor of the introduction of mental operations which are interposed between the perception of the stimulus and the triggering of the action (Paillard, 1994).

The role of *cognitive mediation* is a central issue here. Hence my emphasis on the role of "signs" as epistemological tools for conceiving of sounds in symbolic and representational terms rather than in terms of their sounding qualities. They allow top-down processing as conceptual-driven support for dealing with the sensory material. Signs, and also musical signs, however, can be so general that they do not represent the idiosyncrasies of the sonorous unfolding. To solve this problem, we must combine the discrete-symbolic character of the sign with an analog-continuous description of the sound (see also Brown & Cooke, 1994).

Let us take an example of a clarinet player who produces a single sound. This sound can be considered as a discrete unit. It can be treated symbolically as a sign and can be represented graphically as a single note. The symbolic representation, however, is working at high levels of abstraction, as it leaves out all particulars of the sounding. We only need a *proposition* (denoted by one of the letters p, q, m . . .) which assigns a *predicate variable* (a, b, c . . .) to an *object variable* (x, y, z . . .), and which can be formally represented also as a "one-place predicate" ("ax": x has the quality a, or in this case: this sound has the quality of the sound of a clarinet). Digital signal processing of the same sound, on the contrary, offers an acoustic analysis which enables an analog and continuous description of the sound as it really sounds. The mathematical description, which allows a transition from a "qualitative" to a "quantitative" description of the sound, however, is very costly as to memory requirements (44.1kHz processing). The qualitative description is more economical. It allows propositional thinking and symbolic labeling which need only one allocation point in memory. The quantitative description allows exactitude and flexibility, as well as continuous knowledge representation, but it needs much more memory requirements.

It is possible, however, to combine the two approaches, if we conceive of musical signs as *continuous functions of time* (see Dannenberg, Desain, & Honing, 1997). In order to do so I take as a starting point Dirichlet's definition of a function: "*a function of a variable x is every quantity which has only one value, which is dependent upon x and which can be constructed in some way*" (quoted in Colerus, 1937, p. 330). The definition is appealing but it raises two questions: how to find the rule of construction and how to formulate restrictions on the infinity of possible functions? There are, in fact,
[421] perceptual and cultural constraints which limit the number of possible functions that can be perceived, as the psychological space of perception is only a subspace of the more encompassing sonic universe (Reybrouck, 1998b). It is tempting, therefore, to broaden Dirichlet's mathematical concept of function, as

a *denotative function*, which "denotes" a particular value of y, to the logical concept of *propositional function*, as advocated by Whitehead and Russell: "*Let* ϕ*x be a statement containing a variable and such that it becomes a proposition when x is given any fixed determined meaning. The* ϕ*x is called a 'propositional function', it is not a proposition, since owing to the ambiguity of x it really makes no assertion at all* " (1968, p. 14).

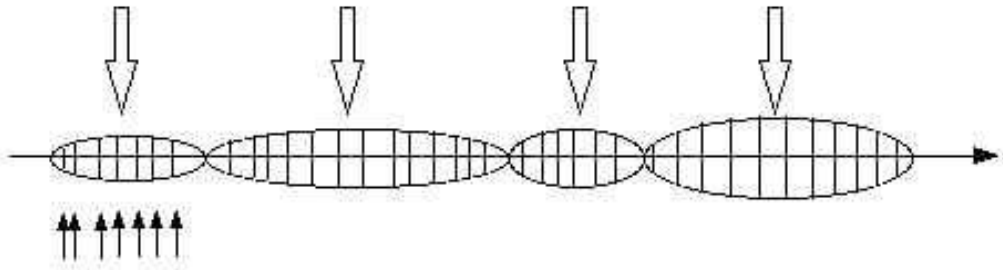

Fig. 9. Schematic diagram of the levels of representation. The lowest level displays the unfolding of time (horizontal arrow) and can be considered as an independent variable of the first order. At a higher level the listener assigns propositions to this unfolding (small black arrows), which can be considered as predications of the first order and independent variables of the second order. The next higher level links the separate propositions together (big white arrows) in order to provide predication processes of the second order.

The introduction of propositional functions has many advantages. Firstly, it allows a transition from general knowledge to a particular predicate in substituting "propositions" (ϕa) for "propositional functions" (ϕx). It really makes a difference whether we speak of "the" sound of a clarinet (ϕx) as against saying that "this" particular and actual sounding sound sounds like a clarinet (ϕa). Propositions, further, can be treated as basic building blocks, but it is possible also to consider them in terms of *subject* and *predicate,* with the copula (the verb form that connects a subject and a complement) as their connecting element. The subject-predicate construction, however, has proved to be inadequate as evidenced by the shortcomings of categorical grammars (Levelt, 1974) and the existence of languages without copula. Yet, it is possible to enlarge the categories of subject and predicate to other categories (argument and predicate, operandum and operator, and argument and functor) which can be treated formally as *variables*. Both the argument (x or a) and the function (ϕ) can be filled in deliberately, since the listener can select and focus at will in delimiting the argument to which he or she assigns a function.

In an attempt to make these claims more operational I have displayed in Figure 9 a hierarchical model of interrelationships in which I try to show the difference in *levels of predication* which are involved in assigning propositions

to the sonorous unfolding in time. At the lowest level there is the unfolding of time, which I consider to be an independent variable of the first order. This is displayed as a horizontal arrow with a direction from left to right. At a higher level the listener comes in with predication processes which assign propositions to temporal events which are selected by a process of delimitation and denotation. These propositions are displayed by small black arrows which indicate their discrete character and quasi-focal allocation on the temporal axis. I conceive of this level as a *predication process of the first order* and an *independent variable of the second order*. The next higher level shows the grouping and synthesizing function of imagery that links the separate propositions together in a *predication process of the second order.*

The dependent variables, as we may conceive of them, are dependent upon the lower level variable (the independent variable). Dependent variables at lower hierarchical levels, in turn, can be considered to be independent variables for higher levels. As such we can speak of independent variables of the first (to be expressed in objective time), second (predication processes, propositional) and third order (interpropositional). The lower levels of predication, further, are linked directly with the unfolding in time, the higher levels, on the contrary, can transcend the inexorable character of time.

The distinction is important. It allows us to deal with music at several levels of abstraction. The predication process of the first order is coperceptual. It entails a direct linkage between the propositions and the acoustic signal. The predication process of the second order, in turn, relates the propositions to each other (interpropositional) without direct linkage with the sounding entities. As such there is a difference in hierarchical level as well as in the ontological status (actuality vs. virtuality) of the units which are involved. The propositions, however, are the critical elements in our descriptive vocabulary. They have a mediating function between the sensory level (the sounding material) and the mental operations they trigger and allow us to treat the music in terms of a propositional calculus.

Conceiving of music in terms of "propositions" involves a shift from *ontosemantical* (music cognition as a direct representation of real sounding objects) to *epistemological claims* (Reybrouck, 1999, 2001c). It stresses the recognition and the labeling of the sounds rather than the experience proper of their acoustic qualities. As such it meets the requirements of a general semantic theory which must elevate individual entities to the status of "things that can be [422] referred to" (Jackendoff, 1988) but at the cost of actual experience. It is a basic problem of semiotic methodology: signs are signs only to the extent that they exhibit at least some level of generality, but generality relinquishes the idiosyncrasies of the sonorous unfolding.

The solution I propose is a combined discrete-analog approach to music cognition, with the listener operating on mental entities (propositions) which are grafted upon the sonorous articulation through time. It is a basic semiotic

claim, which conceives of signs as functions of the material sign vehicles – in this case the sound – (Bense, 1971; Maser, 1977). The signs, then, are not to be considered as static and discrete entities. They refer to a dynamic unfolding, somewhat analogous to "motor encodings." Movements, in fact, can be stored as action schemes with unit character but which are variable in their actual manifestation. As such, they can have a *propositional* and *analogous* representation (Reybrouck, 1999, 2001).

In an attempt to develop this claim, we can draw upon the scientific analysis of sound as proposed in the seminal work of Schaeffer (1976, 1966). It was one of his central claims that all sounding events can be defined and classified as *sonorous objects*, which led him to the elaboration of a morphology and typology of sonorous objects on the basis of the criteria of *sustaining* and *articulation* of the energy. The sonogram has proved to be useful for meeting some of these requirements (for a discussion, see Helmuth, 1996; Ungvary & Waters, 1990). The spectrographic description of the sound as a function of time; however, is likely to be more interesting (Dannenberg, Desain, & Honing, 1997; Cogan, 1984; Cogan & Escott, 1976; Reybrouck, 1998a) as exemplified in Cogan's conception of spectral morphology. And the same holds true for Smalley's (1976, 1997) approach to *spectromorphology* and for the concept of *acousmatic morphology* in general (see Desantos, 1997).

The morphological way of thinking is challenging. It allows a description of typical patterns of temporal unfolding as well as a description of their sensory articulation. As such it genuinely combines the discrete and propositional with the analogous description of the sound. Furthermore, it has received impetus from other areas of research, to mention only Petitot (1983, 1985, 1989) and Thom (1972, 1980) who proposed "morphological" and "morphodynamical procedures" for delimitating a morphological lexicon. Such a lexicon consists basically of elements which are defined as being dependent upon an interplay between stability and instability in order to deliver the fundamental perceptual effects of *invariance* and *discretization* (for an application to the domain of music, see McAdams, 1989; Dufourt, 1989).

7. Dynamics of representation

Music, as a temporal art, unfolds in time. This is *inexorable* or *linear time* which is characterized by contiguity and irreversibility. But time can be *represented time* as well, with the imagination as the connecting structure. Imagination, however, works in an "achronous" way, allowing us to grasp simultaneously the succession of temporal unfolding and to navigate through time as in a kind of symbolic space. This is exemplified by the many possibilities of visual representation of sounding music, with the waveform representation and the spectrogram as typical examples (see Fig. 10). Visual representations, in fact,

are not constrained by temporal unfolding. They present their content at a glance, providing a synoptic overview of the structure of the music.

Time, in this conception, is a critical factor, which instantiates the transition from virtuality to actuality. This is immediately clear if we press a play button in order to let the music sound. What we hear, then, are actual sounds which are "out there" and which are characterized by temporal contiguity that proceeds in real time.

The concept of virtual simultaneity, further, calls forth two mental operations: the transformation of a perceptual flux to a kind of object and the conception of much-at-once. According to Godøy, there is the possibility of "*thinking a musical object in different temporal representations, from 'real time' versions to extremely compressed, i.e., 'instantaneous'or 'synoptic' kinds of representations, which have also been called 'outside time'* " (Godøy, 1997, p. 11). As such, we must conceive of different representations of musical objects, allowing a dynamics of representation.

Temporality, in Godøy's conception, is a modality of the music. It is "*a quality of the 'sonic image' in our reflection. The speed of unfolding and the agility of focus are . . . not limited by the actual unfolding of the 'primary perception'* "(Godøy, 1997, p. 66). There is, on the contrary, a "*multiplicity of velocities in representations of musical objects*" (p. 66), and each of them can provide a different kind of perspective and knowledge of the musical substance. Time, then, mustbe accepted as a morphological dimension of the musical object.

This conception of temporality as a "morphological" dimension allows us further to conceive of temporal succession as virtual simultaneity. As such, it is related to the distinction which Kramer (1988) has drawn between the *linear* or *active* and the *non-linear* or *still-spectator* mode of listening (see also Jones, 1976, 1987, 1992; Jones & Bolz, 1989). The critical element in this distinction is the contiguity of the discrete particulars and their perceptual bonding. It is possible, in fact, to deal with the sonorous unfolding at the level of *concrete operations* which means that we can perform mental operations on concrete things which are presented to the senses. But is also possible to do this at the level of *formal operations*. It is a basic distinction that was suggested by Piaget, and which he elaborated formally in his description of the mathematical concepts of *group* and the less known notion of *grouping* [groupement] (Piaget, 1949).

In order to provide a workable example, I have depicted in Figure 11 a visual representation of the beginning of Mahler's Abschied. The spectrogram (upper pane) combines the linearity of the unfolding in time with a synoptic [423] overview that freezes the sonorous articulation in a static graphic representation. It entails a translation from the "sounding" to the "visual" mode of representation which has the advantage of plasticity. In the visual mode it is possible to gaze at will and to direct attention to selected areas in the

spectrogram. It allows the listener to move around in spectrotemporal space – to borrow Merker's term (2002) – and to transcend the inexorability of the unfolding of time. This is exemplified in the middle pane which provides a kind of workspace in which the selected areas can be dragged. It is possible to perform these dragging operations – which are concrete operations – on the computer screen, but is also possible to keep distance with respect to the concrete material and to conceive of the selected areas in terms of their formal equivalents in the listener's mind. It allows the listener to perform mental operations such as selecting, delimiting, comparing and classifying. What matters here is a shift from "concrete" to "formal" operations, which are so typical of the logico-mathematical operations, which were described by Piaget (1968). The basic operations that are involved in this approach are relations of "order" and of "equivalence" (lower pane), and the corresponding operations of "classification," "seriation," "bringing in correspondence" and "combining." Conceiving of the temporal order as a relation of order, e.g., makes it possible to conceive of the music as a linear string of elements (seriation), but it is possible also to compare these elements and to classify identical events as being part of the same class (classification).

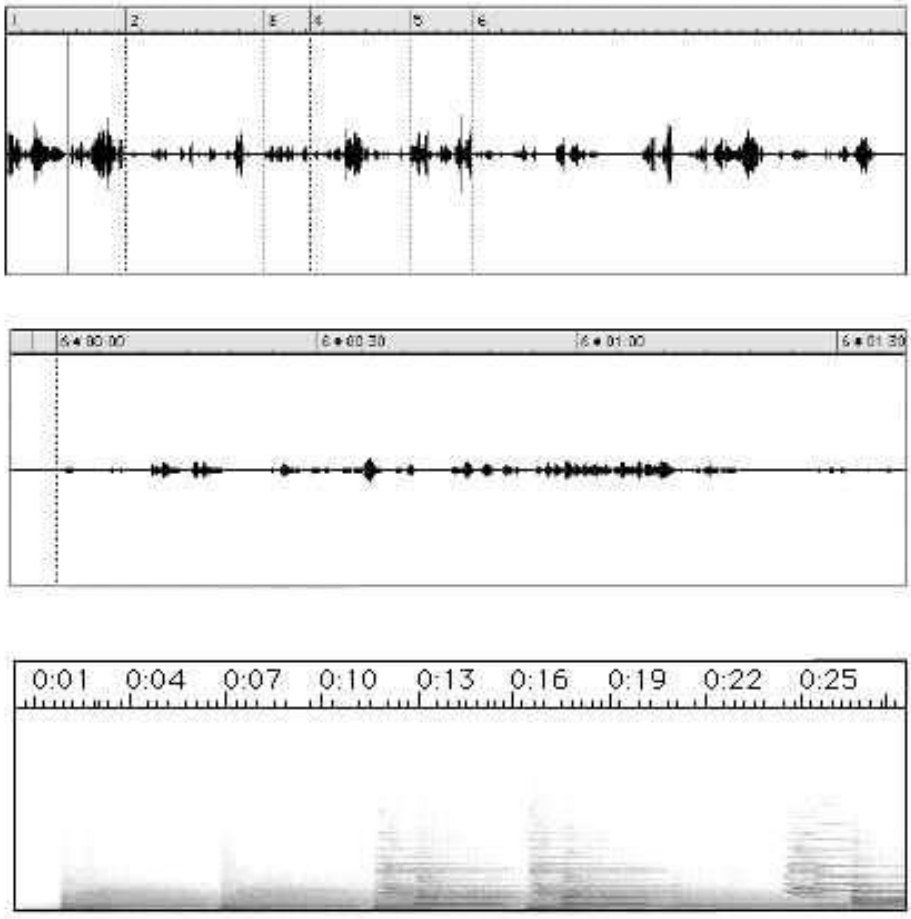

Fig. 10. Dynamics of representation. The upper pane displays a highly compressed waveform representation of Mahler's "Das Lied von der Erde." It provides a synoptic overview which displays at a glance the global structure of the music. The middle pane displays the first 90 seconds of the sixth movement (Abschied) of this piece. Here it is possible to keep pace with the unfolding in time. The lower pane displays the sonogram of the first 25 seconds. The higher resolution of this representation allows a kind of microscopic listening, which makes it possible to follow exactly the sonorous articulation through time.

The whole approach is closely related to the mathematical distinction between "group" and "grouping." Mathematical *groups* are logico-mathematical structures which belong to the class of algebraic structures. They are essentially collections of finitary operations on a set with as basic characteristics the possibility of returning to the starting point (inverse operation) and of obtaining the same goal in different ways (associativity) (Piaget, 1968). The concept of "*grouping*," on the contrary, is a mathematical structure which is less elaborate. It refers to the concrete operations as illustrated by the logic of the child with actions which arecoordinated sufficiently to be conceived as an encompassing [424] structure. The operations, however, are concrete as they are fulfilled in the presence of the concrete material.

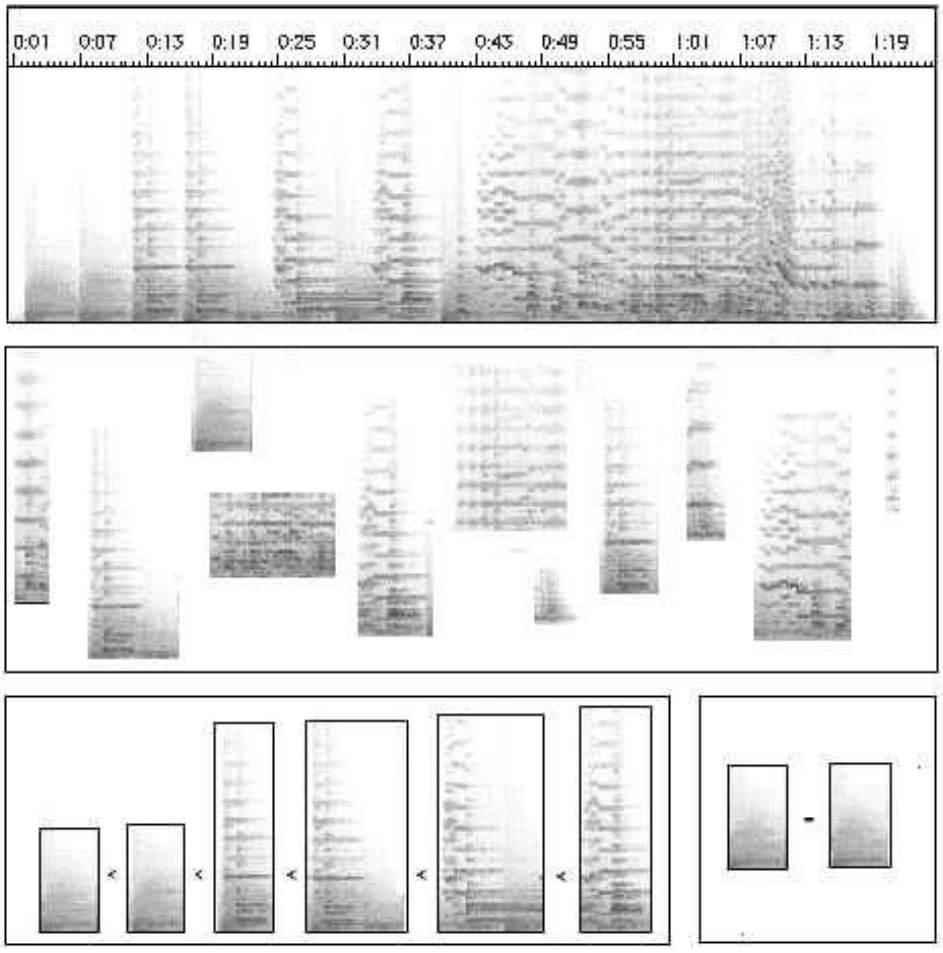

Fig. 11. Concrete and formal operations. The upper pane depicts the beginning of Mahler's "Abschied" as a spectrogram. It combines the linear unfolding of the sonorous articulation and the simultaneity of the global overview. The middle pane acts as a kind of work space in which selected areas of the upper pane can be dragged and move around in a kind of symbolic play. The lower pane illustrates the operations of seriation (left) and classification (right).

The mathematical structure of a "grouping" can be formally described as a quadruple <E, +, -, < > with E referring to a limited collection of objects (a set) which are partially ordered (the relation <) and on which two binary operations (+ and -) are defined with the following properties: (1) the operation "+" is limited to certain elements of E, in the sense that they can be performed only on contiguous elements of a series; (2) the operation "+" is associative, (3) the operation "-" is the inverse operation of "+", and is submitted to the same restrictions, (4) there is a neutral element (0), (5) the operation "+" is idempotent ($x + x = x$), and the operation "+" is such that, if $x \leq y$, then $x + y = y$.

The formal description of a "grouping" is mathematically and psychologically less satisfiable than the concept of group. Both concepts, however, are useful, as they allow a transition from a concrete linkage with the actual sonorous unfolding (grouping) to a more abstract representation of the sound (group) which goes beyond the non-commutative character of the unfolding. The difference between "grouping" and group, in fact, is basically a matter of abstraction, with the time-bound linkage to the sonorous unfolding as the critical distinction.

Applying group theory to music is not obvious. It is possible, however, to consider the role of listening experience. The first confrontation with music proceeds in an inexorable way and can be formalized in terms of grouping. The listener, in this case, is likely to be tied to such representations of the musical happenings in which only successive temporal objects are, as it were, "accessible" from each other. All the elements which are mentally pointed at (denotation and delimitation) are contiguous as they unfold in time. Listening repeatedly to the same music, however, allows him or her to conceptualize the elements in achronous terms as well. A formalization in terms of a mathematical group is likely to be more suited here. Our imagination, in fact, is able to summarize all actual and virtual impressions as conceptualizations which may be dependent upon the unfolding in time (coperceptual) but which can go beyond this temporal unfolding as well. Or to put it in other terms: the perceptual judgments at the propositional level (first order predicates) [425] can be combined and interrelated (second order predicates), abandoning the linear character of their realization at successive time-moments. As such, we can conceive of a *conceptual construction* of time which allows us to collect the sounding events in memory as they unfold in time, and having them at our disposal for retrieval, comparison and anticipation. It allows us to conceive of

time as a set of actual and virtual elements which allow multiple connections in a kind of symbolic play.

8. Conclusion and perspectives

Listening to music involves dynamics of representation. The real experience is dependent upon articulation through time (Reybrouck, 1999). Predication processes however can go beyond the idiosyncrasies of the sonorous unfolding. Crucial in this respect is the experience of time for which two options are possible: the first involves a continuous decoding by the listener as a kind of time-locked reactivity to the solicitations of the sonorous articulation; the second involves distancing and polarization between the listener and the music. In the latter case the listener is reacting intermittently rather than continuously, and draws upon grouping and segmenting in order to reduce the perceptual flux to focal points or temporal windows. The role of attention and conceptualization must be considered here, as there is no causal relation between the acoustic signal and its meaning for the listener. The signification process, however, is not arbitrary, as there are biological, psychophysiological and cultural constraints which reduce the possible numbers of perceptual units which we can delimit. It is a workable hypothesis, therefore, to argue for the construction of a thesaurus of continuous functions of time which allow both discrimination and identification and which can be subjected to relations and operations in order to construct a relational framework. This claim offers perspectives for modeling the listening behavior as an expert system which draws upon a knowledge base and which has adaptive qualities as well. The system, in fact, can learn if it is trained to focus on variable functions of time which receive perceptual weight as a function of emergence and reactivation of the same or similar patterns. It is likely that a combination of spectromorphological description of the sound and the whole domain of topological transformations is suited for this task.

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