Toward an ecological conception of timbre.

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Abstract

This paper is part of a series in which we had worked in the last 6 months, and, specifically, intend to investigate the notion of timbre through the ecological perspective proposed by James Gibson in his Theory of Direct Perception. First of all, we discussed the traditional approach to timbre, mainly as developed in acoustics and psychoacoustics. Later, we proposed a new conception of timbre that was born in concepts of ecological approach.

The ecological approach to perception proposed by Gibson (1966, 1979) presupposes a level of analysis of perceptual stimulated that includes, but is quite broader than the usual physical aspect. Gibson suggests as focus the relationship between the perceiver and his environment. At the core of this approach, is the notion of affordances, invariant combinations of properties at the ecological level, taken with reference to the anatomy and action systems of species or individual, and also with reference to its biological and social needs. Objects and events are understood as relates to a perceiving organism by the meaning of structured information, thus affording possibilities of action by the organism.
Event perception aims at identifying properties of events to specify changes of the environment that are relevant to the organism. The perception of form is understood as a special instance of event perception, which is the identity of an object depends on the nature of the events in which is involved and what remains invariant over time. From this perspective, perception is not in any sense created by the brain, but is a part of the world where information can be found. Consequently, an ecological approach represents a form of direct realism that opposes the indirect realist based on predominant approaches to perception borrowed from psychoacoustics and computational approach.

1. The physical parameters of sound.

When considering the physical parameters of sound, traditionally, one refers to pitch, loudness, duration and timbre. Usually, we admit that these parameters can be isolated and manipulated independently. With the development of computer music, such as an independent manipulation of each one of the parameter, became an usual practice by composers and technicians. In computational environments, is possible to treat each aspect of sound extrinsically and in a objective mode, but when the subject turns to recognition of timbre, or in instrumental execution situations, this physical independence became a very problematic and controversial issue. In some sense, seems that is not possible to deny certain independence of pitch, loudness and duration[1]. In the other hand, we believe that timbre have a kind of dependence of the former parameters, or of the relation of them.

The physical acoustics defines pitch as the frequency of a sound wave, and sound with determined pitch are measured in Hertz (cycles per second). Loudness or amplitude of a sound is a description related to the amount of propagation energy (in decibels). Duration is the time that a sound is heard, and should be measured in many ways (in seconds, milliseconds, beats per second, measure units etc.). Nevertheless, is pretty interesting to note that a system for a timbristic measurement is not too simple like the others, which have defined and patronized units, for example the systems used for pitch and duration in western music. Besides, certainly sounds weird one speaks about be measuring a timbre. We note and claim that there is a, at least conceptually, difficult to put the timbre's notion in the same category of the others physical parameters.

In general, timbre is regarded as the quality of sound that permits one to identify or recognize the sound sources and events. In other sense, timbre permits the recognition of two sounds with different pitches, loudness, durations as produced by the same source, like a musical instrument. This should involve a sort of perceptual-cultural learning, but is not from our business here. Let's see what Danhauser said about:

> "(…) the timbre is this particular quality of sound that makes two instruments dissimilar of each other, even if they produce a sound with the same pitch and loudness. The human ear, even the less trained one, distinguish easily the timbre of a violin to a trumpet or an oboe". (Danhauser In: Schaeffer, 1966.)

The organization, that means, the proportional relation of pitch and loudness of harmonic partials in sound spectrum is what makes the timbre, but we believe that just this is not sufficient to the recognition of any timbre. In fact, seems that timbristic perception is dependent of dynamical factors, such as pitch and loudness variation overtime. In this way, is reasonable to claim that timbre is dependent of the others parameters, and that the variation of the last changes the former. The dynamical variation of loudness, or pitch, or in some sense the microtemporal duration[2], isolated or not, affects the timbristic results of a sound. That can be easily checked by eletroacoustical or instrumental experiences. In this sense, being the timbre dependent to the other parameters, we seriously consider the possibility to put this notion in other category, different of the one that contains parameters like pitch, loudness and duration. The ecological approach seems to offer a conceptual system very interesting to the description of timbre, and allows a suitable classification of it as a high-order parameter, as we will see in the following sections.

1.1 A critical analysis of the computational approach to perception

Another aspect is, in our point of view, suitable with the direct perception theory which is fundamental to understand our perspective of timbre. It is the notion of temporal stream intrinsic to perception. To Gibson, there is no past and present separated by a limit to perception, such as to language or to the verb that one conjugates. "A perception, in fact, does not have an end. Perceives go on" (Gibson 1986, p. 253). Now, is clear that temporal stream plays a fundamental and essential role in perception, and when this stream is represented or described by discrete values, there is a significant lost of a kind of information that is only available in the temporal stream.

Almost all affirmations founded in cognitive literature relate the perceptual phenomena with the time in a discrete form. The events between organism and environment go separated in discrete samples, loosing the temporal stream. And we don't regard this stream as a snapshot sequence, but we are always considering it as a continuum. The samples, according with computationalism, must be stored in a sort of mechanism and place, and later be necessarily reconstructed in a temporal continuum. If we think in computational models, there is the necessity of an ordination process of these samples, of a

mechanism that stores the order of the samples to make the correct reconstruction. In this sense, Zampronha (2001a, p.100) claims that to the perceptual mechanism work by certain procedures among discrete elements, are necessary a buffer that stores such samples to the later spectral analysis, however this buffer does not exist in brain at all[3].

Van Gelder (1998) affirms that dynamical systems, working with parameters over the temporal stream, have essential features very different of discrete computational systems. The dynamical system model is proposed as an alternative to the computational model, and despite the fact that even today there is a lot of discussion about the limits of both models, is now clear that one can distinguish some aspects in this analysis. One of them is pointed by the fact of dynamical systems have numerical variables and qualitative properties of time and state. "(…) there can be distances between any two overall states of the system such that the behavior of the system depends on these distances (van Gelder 1998, p. 618)". Van Gelder considered dynamical systems as quantitative systems[4]. Thinking is this way, we can understand timbre in a different sense of the typical postulations of physics and psychophysics, once those approaches usually regard only static parameters, even when concerned with the temporal stream like a sequential samples order, fact that doesn't make the discretization effects softer.

The temporal stream is indispensable in a perceptual process, and does not seem to be very plausible, this analysis and synthesis of all the perceptual events, in a very cartesian way.

1.2 The perception of timbre

In agreement with our perspective that perception is continuous, we don't think that is pertinent a perceptual model of timbre based in discrete mathematical tools, like spectral analysis based in Fourier Fast Transforming (FFT), or the sum of static sinusoidal waves postulated by Helmholtz, or any other method or function in which takes discrete values. The combination of pitch and loudness of harmonic partials is a necessary aspect to the perception of timbre, but is not sufficient, we must claim. The sonic object viewed as a dynamical object involves parameters like the spectra's temporal evolution. As we said, the timbristic perception seems to be very often based in a sonic object's temporal behavior[5], and the discretization should at least masks important phenomena, in the better case some

of the important aspects of a sonic object will vanish. Analytical tools like FFT splits the temporal stream into analysis windows, which make a pondered sum in agreement with a curve, specified *a priore* (Hamming, Hanning, Gaussian etc.). Because that, again we can observe that transient properties of sonic object will be lost, or at least masked in such a mathematical operation.

The evolution of a sonic object over the time could be explained in some steps: attack, decay, sustain and release. Of course it is a discretization of the object, but we only use it to point out what we regard as transient properties that occurs in more or less specific parts of temporal evolution. In any sense, we are not proposing that such steps as being spliced in perceptual phenomena at all. The attack is the initial part of the sound (wave front), which is the major portion of information to the identification or recognition of a sound source or event, concentrated in a very short time period. The following parts (wave train), named the decay, sustain and release (for our proposes, we will refer to them only as sustain) shows the information spread out over a large quantity of time, and yet is much more stable than attack.

In that chase of sound, waves going through the air, Gibson classified two sorts of information, named as: *wave front* and *wave train*. He proposes also that every one of this sort of information is specifically referent to determined perceptual tasks, like spatial localization of sound source or recognition of sound pattern. Wave front is the information available that permits to organism a precise localization of sound sources in space, and by consequence, permits a kind of spatial orientation (Gibson 1966, p. 81).

Certainly, as demonstrated experimentally by Schaeffer (1966) and in agreement with Gibson (1966), the attack is the most important part in timbre's perception in the most of sounds sources and events. For example, registering a piano note over a magnetic tape (or computational support) one can manipulate the object changing its structure and features. In this way, we can cut off the sound's attack and let alone the rest. As Schaeffer show us in his work *"Quatre études de bruits"* (1948), specifically in the *"Etude Violette"* and *"Etude Noire"* movements, we don't recognize a piano sound as such, and besides, even with this suppression is possible to perceive the exact pitch and loudness – it looses only the timbristic properties. It does not mean that a sound with no attack does not have a timbre, but it has not its ordinary timbre that enables one to recognize or identify as such. Some

instruments produce sounds where the attack is pretty smooth (like the bowed strings), and in these cases, the detection of timbre depends more on the dynamical evolution than on the attack itself, as Schaeffer describes:

> "The importance of attack as an element of identification of a sound and its timbre is, thus, much more variable, in accordance with the nature of the objects produced by the instrument:
> - in sounds very briefs (*sons trés brefs*), the attack plays a role pretty decisive; its is characteristic of the timbre, as in percussion's sounds (and piano);
> - in sound a little stretched (*sons filés*), with middle duration, the importance of attack is diminished. The attention start to focus over the sound in evolution;
> - in sounds very longs (*sons entretemus*) with vibrato (as usual), the role of attack became almost unnecessary, one can think so that ear is before everything focused (or tuned) to the development of sound which at every instant appeal to attention".

Even Schaeffer determining that attack is not always the main responsible to timbristic perception, depending on the kind of object produced by the instrument, he stress that "the musical listening as the musical praxis gives a predominant importance to the attack of sounds" (Schaeffer In: Menezes 1998, p. 41).

The Attack has a temporal development very characteristic that escape from an informational organization obvious and predictable. Often, it presents a behavior pattern almost chaotic. In this portion of sound, we can watch a large quantity of information and yet nowadays, there is not a definitive and exhaustive model of its properties. As we discussed, the analytical and mathematical tools that we have are not sufficient to elucidate totally what occurs in this initial phase of sound.

We will focus our ecological approach to the recognition of timbre on the temporal development of sonic objects, judging that is possible to demonstrate the information pick up by the detection of high-order informational patterns on the environment.

2 Basic concepts of an ecological acoustics.

Before we proceed specifically to an ecological approach of the timbre's notion, is necessary an introduction very important about concepts postulated by Gibson. The notion of potential stimulus is one of them (Gibson 1966, p. 79). Gibson arguments that is available in environment a kind of information to be picked up by a perceiver organism. Is pretty important consider, to this author, that information is a bi-directional arrow, with one

side pointing to the animal and the other to the environment; the ecological approach distingue *information-to* from *information-about*. In the following quotation, the authors describe the relation between some concepts: information-about, invariant and high-order parameter:

> "Much of the notion of information-about is expressed by the concept of invariant. From a psychological point of view, invariants are those high-order patterns of stimulation that underlie perceptual constancies (…)". (Michaels and Carello 1981, p. 40)

Therefore, information-about characterizes the environmental aspect that is being perceived, and information-to is a concept analyzing the information considering the animal, and is direct related to the notion of *affordance*[6]. Taking sound into account, this is what a determined sonic aspect of environment *affords* or even *immediately means*.

In accordance with Michaels and Carello (1981, p.40) much of the notion of information-about is expressed in the notion of *invariants*, that can be described as: "pattern of stimulations over time and/or space that are left unchanged by certain transformation". To the authors we have also to consider two kinds of invariants: structural and transformational invariants. The former stacked as a set of the properties that are maintained unchanged over time. And the last specifies a changing way that happens over some class of structures.

The second aspect of the gibsonian notion of information, called information-to, can be described as the notion of affordance. Gibson (1979) shows this notion as been a direct perception of meaning. Perceive something is perceives what this thing means, and consequently "affords". In this sense affordance can be understand as a set of action possibilities or restrictions created by the perception of an event. In Gibson's words: "the affordances of environment are what it offers the animal, what it provide or furnishes, either for good or ill." (Gibson, 1979 p. 127)

Now we can consider how we can describe the sonic information in accordance with such theory. The examples of affordances detection that Gibson (1979) uses, almost all are related to visual perception, but in analogy, we can purpose that sonic events affords some kind of behavior related to their meanings detected by a perceiver in a specific situation.

As an example of sonic affordance we can take the situation of a runner waiting for the sound of a shot to start moving. In this case the sound suggests that the runner should start run as fast as possible to achieve his goal, that means win the competition. In the other hand, if we hear the shot sound in an office or in a bank, or in a classroom, our behavior will be search for protection. That means that the same sonic pattern affords different behaviors in different contexts.

In the sense of describing of recognition of a sonic pattern, or identification of such patterns, as proposed by Gibson (1966, 1979), is really important that we can make a description of both the sonic invariants and affordances.

In accordance with Gibson, wave trains carries information that must be analyzed taking into account the time language. What physicists and psychophysicists do handling discrete and/or static values, with analysis like FFT? They ignore the time language, or at least, despise it. In this manner, the author shows us the notions of high-order parameters, distinguished form the low-order parameters. As we said, to Gibson, the traditional notions like FFT, don't take into account the time language, or the transients, and also understanding that complexity of a sound doesn't matters when analyzing with a simple combination of pure tone sensations (Gibson 1966, p.86).

The author propose a consideration of physical parameters of sound as ecological parameters, that means, beside other things, understand it and classified it as low-order or high-order, and also consider the meaning of sounds. A high-order parameter is the one that is subordinated to temporal flux, the one that can't be understand totally outside this stream[7]. Consequently, low-order parameters are those that the temporal dynamics are not fundamental, and can be discretely, analyzed and described. In this sense, as we can see on the following quotation, Gibson describes what he understands when considering physical parameters as ecological, inside the temporal language:

> "Meaningful sounds, however, vary in much more elaborated ways than merely in pitch, loudness, and duration. Instead of simple duration, they vary (…) in repetitiveness, (…) in regularity of rate, or rhythm (…). Instead of simple pitch, they vary in timbre, or tone quality, in combinations of tone quality, (…) and change of all this in time. Instead of simple loudness, they vary in direct change of loudness (…). In meaningful sounds, this variable can be combined to yielded high-order variables of staggering complexity". (Gibson 1966, p.87)

3 A new concept of timbre.

The understanding of timbre as a high-order parameter comes in agreement with the theories of Pierre Schaeffer, described in the beginning, and with what we propound here: regard timbre in a new category, apart from the one that contains pitch, loudness (and perhaps duration). We think the lasts should be taken as low-order, because they don't need the temporal stream necessarily (e.g. a pitch does not change if its duration is shifted, or the loudness of a sonic object does not change if its pitch or duration is altered). About timbre, the situation is completely different, it needs the time to be, it is a parameter totally underlined by dynamical changes over the time; the interruption or alteration of such a stream turns its recognition very difficult or even impossible.

In principle, seems to us that this is an alternative to the traditional understanding of physics and psychophysics in explaining timbre as stressed harmonic partials in a spectrum, or the harmonic series, and analyzing it with discrete tools. To the new conception, the timbre is dependent of how the sonic spectrum and other parameters behave inside the time. One can observe that is completely different than saying that timbre is just a physical aspect of sound like any other. The ecological approach gives us subsidies to regard timbre as a high-order pattern, which means, take it as occurring over time and inseparable from time.

Is also clear that timbre notion is more associated with wave train concept than wave front, since where is all the arrangement and structure of acoustical array resulting form the relation of various harmonic series involved over the temporal stream. It is not the matter of see timbre and wave trains as a synonym. What we are propounding is to consider the action of temporal flux as a influent element on timbre, making reference to features that Gibson calls wave train.

We are also stressing the relation of timbre with what Gibson characterizes as meaningful sounds. He yet had raised this relation, as in last quotation (see above). We observe this position as very related with Schaeffer's theories (1966). Schaeffer's concepts were and are source of a new paradigm in conception of sonic object's parameters. To conceive a new paradigm to sound parameters open uncountable perspectives to research on sonic manipulation techniques and consequently of musical composition (especially on computer-assisted composition).

Finally, we argument toward a new conception of timbre, an alternative to current proposes of acoustic and psychoacoustics area, based on statically discrete analysis tools. A new conception of timbre must be, at least ideally, conceive timbre as an ecological parameter with distinct nature of physical parameters as pitch, loudness and duration. This new conception must, also and always, consider the temporal stream to proceed analysis of sound patterns, or search for tools that yield a dynamical and ecological analysis to sound phenomena.

4 Final considerations.

After the discussions just initiated in this paper, we shall now, briefly point out our conclusions:

1) Timbre, like other parameters, should be understand as an ecological parameter despite as a physical parameter, in the study of perception;
2) As an ecological parameter, the timbre must be considered as being a high-order stimulus, inside a special category, apart from pitch, loudness and duration (low-order);
3) Such characterization of timbre as a high-order ecological parameter could drive us to new perceptual paradigms related to its recognition and processes and mechanisms involved.

New perceptual paradigms related to timbristic recognition could raise interesting technical and esthetical speculations in the field of contemporary musical composition, mainly in its computational branches. Surely, the ecological approach is now, even in a restricted way, used in compositional processes (for example, by Keller, Truax and Schafer). Our next goal in future papers, in this sense, is to propose, characterize, elucidate and evaluate this new (ecological) paradigm to timbristic recognition. In addition, we are really concerned with compositional experiments based on ecological concepts. We believe that such as a commitment could be fruitful spreading the real landscape (soundscape sounds better) of composition and scientific research.

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Notes

[1] We understand duration, in this situation, as the time that sound occurs. We shall denominate two opositte manners to view durations: macrotemporal and microtemporal. The former have reference to relations between sonic objects, the last is about relations related to frequencies of sound wave.

[2] In this sense, Stockhausen (1951) *A unidade do tempo musical*, In: Menezes (1996).

[3] See also Port, Cummings and McAuley (1998).

[4] "Roughly, a system is a quantitative when there are distancies in state or time so that distances matter to behavior "(van Gelder 1998, p. 618).

[5] Zampronha claims that perception of timbre doesn't work as a spectral analysis, but as a scale of behavior in accordance to the periodicity, being: periodic, semi-periodic, chaotic and a-periodic (noise).

[6] "Affordances are the acts or behaviors permitted by objects, places and events" (Michaels and Carello 1981, p.42).

[7] See Michaels and Carello 1981, p. 25