PERCEPTION, REPRESENTATION AND KNOWLEDGE : ACOUSTIC PHENOMENA BETWEEN NOISE AND SOUNDS

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ABSTRACT

Audition is a sense that has a long tradition of empirical research, may be not as long as for vision but in any case much longer than olfaction. As for vision, psychological research has mainly developed along the psychophysics tradition.

1. FROM PSYCHOACOUSTICS TO CATEGORIZATION FOR NOISES

Psycho-acoustics has established the "subjective evaluation" of stimuli which are analytically described within a multidimensional space given by physics. The psychological processes mainly concern subjective judgments of perceptive thresholds measured along intensity and frequency, and quantified in Db and Hz. Still relying on the "objective" conceptualizations of physics, the more recent cognitive science approach to audition has remained so far within the same experimental paradigm, focusing mainly on perception rather than on identification and semantic categories of "natural" sounds (as already noted by Castellengo, 1994). Attempts to evaluate the processes of identification of sounds can be found in musical acoustics, in particular in research on timbre (Grey 1977).

More recently "ecological psychology" has brought attention to environmental sounds (Vanderveer, 1979); Warren & Verbrugge, 1984; Ballas, 1993; for example). This last approach has pointed to the question of similarity in the identification and qualification of sounds, emphasizing their physical description (temporal structure of the noises, for ex), even if some alternative principle (such as the identity of the source) have been already suggested (Vanderveer, 1979; Handel, 1989). Similarly, the increasing problem of noise annoyance has pointed to the limits of the psychological measurement of noise along physical "dimensions" such as loudness (Bregman, 1990; Plomp, 1999), and suggested a more cognitive approach of noises as meaningful events[1].

In short, within the psychophysics paradigm:
- ✓ stimuli are described as dimensions and parameters **established by natural sciences**

[1] it can be noted that there is at a same time a change the vocabulary and object under investigation, shifting from sounds to noise, and that will be discussed below.

- ✓ answers are collected within «closed » procedures with ***a priori* categories** (those given par the natural sciences)
- ✓ "allowing" quantitative data analysis of qualitative judgements

*The analysis of **cognitive representations** of acoustic phenomena is conceived as the « subjective » (i.e. psychological) evaluation of objective measures, along an evident sequence that starts **from physics to psychology** through the **physiological** analysis of the receptors.*

Subjects are therefore conceived as imperfect measurement instruments in comparison to physical instruments, thus forgetting at the same time the specificity of psychological processes (Straus, 1935 (!); Bruner, 1990) and that the instruments themselves result from human **knowledge** (physics) and technological control on the world.

Our research on semantic categories is an attempt to contribute to the understanding of how psychological principles of categorization for acoustic phenomena lead to the elaboration of **concepts**, as building blocks of knowledge, including scientific concepts.

We will report first some results of free categorization experiments that elicited categorical structures for acoustic phenomena and their principles of organization, mainly relying on our cooperation with the LAM. Secondly, we will present the diversity of the linguistic devices involved in the description of the acoustic categories. It will allow to identify diverse cognitive concepts (mainly sounds **and** noises) for accounting of the "same" acoustic phenomenon, depending on the domain of practice (mainly common sense and every day life vs scientific ones).

2. SEMANTIC CATEGORIES IN ACOUSTICS : COGNITIVE CATEGORIES OF NOISES

The acoustic stimuli that were taken into consideration were acoustic recordings from complex everyday life objects that we encountered or manipulated (such as the production of familiar noises and recordings of urban soundscape), rather than *a priori* parametered sounds.

2.1. Categorization of domestic noises

One first set of experiments (Guyot, 1996) reproduced the paradigm that we already validated on visual and olfactory objects, by asking subjects (N = 15) to freely sort a set of 25 domestic noises (such as the striking of a match, the squeeking of a closet door, the ringing of an electric alarm clock, the clicking of a nail clipper, or the slicing of bread with a knife*…*).

The experiments showed that categories of noises could be identified at two levels: at a first level of aggregation, 8 classes could be observed, which, at a second level, clustered into two generic classes.

The first generic class aggregates noises produced by ***similar sources*** (« *le claquement ou la fermeture d'une porte* » 'slamming or shutting of a **door'**, « *bruit de moteur* », 'noises of an **engine'**) or having the same ***function*** (such as « *sonnerie d'avertisseur* » 'warning with bells', « *klaxon de voiture ou sonnette de bicyclette* », 'car or bicycle horns'...).

The second generic class clusters categories of noises along their similarity of **mouvement** or **action** generators of noises (« *percussion* » 'percussion', « *claquement* » 'clapping', « *grattement* » 'scraping', « *claquement* » 'crackling').

Within each category, the variable distances between objects suggest that typicality may structure the internal organization of the categories (« *le tic-tac d'un réveil* » 'the tic tac of an alarm clock' being more typical of alarms than the « *la sonnerie d'un téléphone occupé* » 'busy signal of a telephone', for example).

One critical point is that a "same" acoustic phenomenon could be classified according **either** to the **source** that produces it **or** to the **action** generating the noise (this is the case for instance for the squeeking of the door which can be categorized either among "noises of doors" *(« fermeture, claquement, ouverture d'une porte »* 'shutting, slamming, opening of a door'*…)* or with other instances of «*grincement* » 'squeeking' *(*of doors, of windows, or of steps*)* (cf. a similar finding in Handel,1989). This remark converges with differences observed in inter-individual attitudes towards acoustic phenomena. As it were, some subjects (acousticians, members of the laboratory) sorted the noises along their physical "objective" properties such as pitch or temporal evolution, while others (actually most of the subjects) sorted the noises according to the sources that produced the acoustic phenomena. Furthermore, this latter group could operate at different levels of abstraction as far as the sources were concerned, by taking into consideration either the physical properties of the sources (electric *vs* mecanical sources for example) or the actual type of object source (such as engines *vs* doors *vs* alarms). It confirms that the "intrinsic" characteristics of a physical event can be differently considered as defining or relevant features for **categorization depending on the subject's processing.**

2.2. Categorization of soundscapes

A second set of experiments involved soundscapes (recorded sounds of environmental urban noises) handled with the same procedures and data processing as the domestic noises (Maffiolo, 1999; Maffiolo & al., 1998). The soundscapes were selected from a list of recordings made in locations that a pre-experiment had identified as representative of noises of a city (Paris).

For example,16 sequences were involved in this experiment, each lasting from 15 to 20 seconds. There were 23 subjects for the free sorting task and the results were processed along the same algorithm as in the previous experiments.

The results show that the sequences are not clustered along an intensity dimension **alone**: not only the notion of average intensity for such complex acoustic stimuli is problematic, even from a physical point of view, but subjects cluster sequences of different mean intensities (sequence 9 (68,9 dBA) with sequence 10 (75,3 dBA), for example), and their comments refer mostly to characteristics other than intensity alone.

At a generic level, two main cognitive categories of sequences emerge:
- (a) **"event sequences"** i.e. sequences including specific events ('starting a car', 'breaking', 'giving a speech' ...),
- (b) **"amorphous sequences"**, such as 'background noises' in which no specific event could be isolated.

A finer grain categorization distinguishes categories of sequences within each of these two main categories. Event sequences subcategorize according to either:
- the type of **source** involved in the production of the noise (traffic noises like car, buses, motobikes *vs* engines, lawn-mower, warning signals (like horns *vs* human sounds (like steps, speech) or
- the qualitative evaluation of the noises as **pleasant** or **unpleasant** (boring, aggressive, unbearable or quiet).

Meanwhile, the amorphous sequences were subcategorized by either :
- on judgments of **pleasantness** or on
- on judgments related to **acoustic parameters** (intensity, low/high frequency, continuous *vs* discontinuous signal...).

In each case, the sequences are structured at different distances, suggesting once more that some sequences may be more representative than others as exemplars of the category. For example, among the different sequences of "very unpleasant" traffic soundscapes which include discontinuous noises of engines, one sequence seems to possess the greatest number of properties defining this category, and could therefore be considered as the most typical exemplar of this class. *(from Maffiolo et al., 1998)*

In summary, free categorization tasks provided us with two suggestive main results:
- First, the noises under investigation can hardly be reduced to a set of expected physical parameters. In particular, intensity (or even loudness) is **not** the only nor the most important criterion involved in noise categorization. Such a conclusion is consonant with results obtained by engineers involved in ecology and noise reduction as well as by acousticians of the scientific

community (Guski, 1999). Intensity (as a cognitive representation) is more a **property** than a **dimension,** which variations are not psychologically monotonous when correlated with other characteristics of noises, such as hedonic characteristics, identification of the source, or meaning of the event (warning, ...).
- Second, the stimuli can be processed either as **part of a meaningful event** or, in a more analytic manner, along **physical parameters, when** the process of identification of the source fails. As part of an event, they are processed as **noise**s and may therefore be considered as **effects** of the world onto the subject (as is the case for odors, see Dubois, 2000); when no source or meaningful event can be identified and related to it, the stimuli are rather processed as **sounds**, which can be characterized by a "dimensions" as described by physics.

Therefore, in comparison to physical (i.e. physically described) concepts, a cognitive representation of acoustic phenomena is characterized by the following properties:

- ✓ *As a subjective representation, it is* ***individual*** *and* ***non-observable***
- ✓ *It i**s global** and **multimodal*** (visual***,*** auditory, kinaesthetic, vestibular, …),
- ✓ *Always experienced in* ***context*** *and in practices; therefore may not be unique*
- ✓ *"made of"* ***memory****: it includes perceptions* ***and responses*** *given to "inputs"*
- ✓ *Therefore, it is both individual (sensory experience) and* ***collective*** *(as everyone giving responses relevant to his/her membership to different communities*
- ✓ *It involves* ***interpretations*** *(meaning production and not simply "pre-existing information processing")*
- ✓ *It is connected to, constructed by* ***linguistic*** *expressions*
- ✓ *therefore is* ***shared and accessible*** *through verbal and symbolic* ***public representations***.

The specificity of cognitive objects

3. Linguistic devices for noise(s) and sound(s)

In order to explore further the different cognitive representations of acoustic phenomena, we performed linguistic analyses of the diversity of devices available and used (in French) to describe them.

The linguistic data come from different elicitation procedures:
- one consists of comments produced during the previously reported categorization tasks of **actually perceived noises**,
- the other of definitions and type of « noises » and « sounds » collected through questionnaires in the lack of any stimulation (therefore referring to subjects' **representations in memory**) (David, 1997) (see also Mzali, 2002, Guastavino, 2003 and below, for a comparison of these different procedures)

One major result is that there are few single words on which people agree to describe the noises. In both of the sorting tasks we presented above, subjects used complex words or phrasing to describe the categories. A large variety of linguistic devices were observed, with some preference of certain linguistic constructions for a certain type of category comforting the relevance of the distinction between noises *vs* sounds.

For the denomination of categories of **noises**, subjects used the greatest variety of linguistic categories, given below:

(a) **nouns** referring to different types of sources (*door, traffic, cars*, ...) in the same phrasal construction of the denomination of odors, **N de N** 'N of N', where the head noun is the generic term (*« bruit, sirène, alarme »' noise, sirene, alarm'*), and the second N is part of a prepositional phrase which refers to a source (… *« de voiture » 'of car'* … *« de pompier » 'of fireman'*).

(b) **deverbal nominalizations** (suffixed noun derived from verbs) of two kinds:
- regular and frequent suffixation of *- ment: « claquement », « craquement», «frottement », « grincement », « roulement ».* This verbal suffixation refers to a mecanical action on (or of) an object, such as *« claquer »* 'slam, burst', *« craquer »* 'creek', *« frotter »* 'rub', *« grincer »* 'squeek', and the source appears as complement of the SN and the grammatical subject of the

verb, as in *« claquement de porte »* 'slamming of door', *« grincement de frein »* 'squeeking of brakes'. The verbs refer to the mode of production of the sound.
- rarer suffixations of *-age*: *« démarrage de bus »* 'starting of a bus', *« freinage de voiture »* 'breaking of a car', were noted and which linguistic interpretation remains to be worked on.

(c) **deverbal adjectives** (adjectives derived from verbs): *« plaisant »* 'pleasant', *« insupportable »* 'unbearable', *« gênant »* 'annoying' etc, which refer mostly to an “hedonic” scale, suggesting (as for odors) that noises are also **effects** of an event of the world on the subject.

(d) **prepositional phrases,** referring to the development of the noise in time (without variation in volume) or complex forms with multiple complements which include the mention of places and contexts, as in *« à la Bastille le samedi soir »* 'at Bastille on saturday night' which integrates location, time, and activity (Maffiolo, 1997; 1999).

(e) **relative clauses** attached to the source N of the prepositional phrase, such as *« le bruit d'un verre qui casse »* 'the noise of a glass that is breaking', *« le bruit d'une porte qui claque »* 'the noise of a door that is slamming'.

When acoustic phenomena are described as **sounds** (i.e. sets of physical properties), the most frequent linguistic forms are **adjectives**, either simple adjectives borrowed from physical sciences (*high/low frequency, loudness, continuity),* or derived adjectives of the denominal ('*noisy*'), or deverbal ('*pleasant'*) types.

4. LANGUAGE AS AN ACCESS TO COGNITIVE CONCEPTUALIZATION OF SOUNDS AND NOISES: METHODOLOGICAL CONSEQUENCES ON EXPERIMENTAL SETTINGS

Within such a theoretical framework, the ecological validity of experimental (analytic) procedures has to be evaluated according to this diversity of **subjects’** conceptualizations (rather than to *a priori* parameters borrowed from the analytic conception of physics) and may therefore vary according to the goal of the research.

Such an assertion has been demonstrated by Catherine Guastavino (Guastavino, 2003). From a free categorization task, it could be noted once more that acoustic stimulation can produce two different types of cognitive objects, as previously found by of Maffiolo (1998). In this case, two main categories of low frequency environments could be distinguished.

1. Categories of Source events, characterized in wordings by *Identified source (80%) and Effects on subjects (83%)*
expressed in a high frequency of deverbal adjectives (92%) (*annoying, jarring*)

2. Categories of Background noise
with **no specific event** mentioned but a high proportion of words denoting *Physical properties (73%)* by means of simple adjectives (63%) (*continuous, permanent)*
and by complex phrasings : **spatial** and **temporal** complements (*All around me, always there*).

The next question was to proceed to an experimental investigation in order to control and identify the physical parameters correlated to these two different objects. However, within our theoretical framework, we can wonder whether any experimental devices are equivalent regarding those two cognitive representations?
We thus compared verbal data collected with the same open questionnaire in two laboratory conditions, involving 2 **reproduction conditions**: **frontal stereophony vs multichannel Ambisonics**, in comparison to data collected in real-life situation (42 interviews in actual outdoors environments as a reference study).

The results show
- **similar descriptions of the source events** based on source identification and labeling. But
- **different descriptions of the background noise** which imply spatial attributes and the implication of the subject.

In other words, we got linguistic descriptions of different conceptualizations depending on the **quality of the sound reproduction**: the **spatial immersion** suggested by the **multichannel Ambisonic restitution** contributes to the recognition of cognitive the **spatial properties of background noise**. In contrast, the **stereophonic restitution** drives the cognitive processes on the **identification of source events**.

In short, the empirical issue is that the experimental protocol should be adapted to the purpose of the study and to the type of properties under consideration (Vogel et al, 1997. Guastavino & Cheminée, 2003). Inferences regarding common life processing (ecological processing) should take into account to allow subjects to process the stimuli through cognitive processes elaborated in real-life situation.

5. THE CHALLENGE OF A "REVERSE" PARADIGM: FROM PSYCHOPHYSICS TO SEMIOPHYSICS

*Sensory conceptualization is therefore conceived as the **objectivation (through language as public and shared descriptions)** of cognitive (i.e. individual and subjective) representations and processing, and the descriptions of natural sciences are to be considered as **one of these** public representations.*

When the subjects and subjects' conceptualizations are the specific objects of investigation, **subjects' conceptualizations** have to be studied **first** and the physical descriptions come afterwards as **correlated descriptions** which do not exhaust the full description of the cognitive object.

We therefore need to further elaborate :

- ✓ a theory of mental representations (non observable representations) (*psychology*)
- ✓ a descriptive theory of linguistic resources available to native speakers (*linguistics*)
- ✓ an explicit theory of the relations between language and cognition in order to make relevant inferences regarding subjective judgements from linguistic data, allowing to use language as an overt, observable, public representation of mental representations *(psycholinguistics and cognitive linguistics).*

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