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Applying Cognitive Psychology to Urban Soundscapes: From Semantic Categories to Narratives

by
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Abstract: In the second half of the 1990s, the Laboratoire d'Acoustique Musicale at Pierre et Marie Curie University in Paris started a series of investigations on Urban Sound. Initiated at the request of the French Ministry of Environment, these investigations took into account from their very onset the ecological approach to auditory perception, following the footsteps of J.J. Gibson. Care was taken that sound reproduction was ecologically valid, and a whole methodology, based on E. Rosch's psychological principles of categorization, was developed with the help of psycholinguists in order to evaluate this ecological validity. We called it *semio-acoustics*. The presentation reviews the theoretical background, the methodology and the main results from a series of 5 doctoral theses on how human subjects talk about and describe soundscapes. It includes examples of free categories, semantic categories, prototypical categories, and graphic categories. More recently, we develop the methodology one step further with the help of semiotics, in order to take into account the imaginaries of the human subjects: we obtained full narratives of ideal urban ambiances. We are presently applying the methodology to Urban Soundscapes.

1. Introduction

Cognitive psychology is the study of mental processes. It refers to *cognition*, defined in the dictionary, for example the Webster (1989), as "the act or fact of coming to know or of knowing; perception; knowledge". It also refers to *psychology*, defined in the same dictionary as "the science of the mind or of mental states and process". In fact, perception itself refers to the mind: perception is "the act or faculty of apprehending by means of the senses or the mind". Thus, the link between perception and psychology is obvious for the dictionary: they are linked by a common reference to the mind.

What is the mind? Looking at the same dictionary provides us with another definition: "in a human or other conscious behind, the mind is the element, part, substance, or process that reasons, feels, wills, perceives, judges, etc." Thus, the dictionary does not take position in the philosophical debate whether the mind is spiritual or material. The debate is also beyond the scope of this paper, but we mention it for two reasons: first, it is philosophical, or rather metaphysical, that is, speculative in nature; second, considering the mind as material is an underlying assumption in the major approach to perception within psychology: psychophysics.

In this paper, we look at what semantics can tell us about psychological processes. Semantics is the study of meaning, in languages but also in other forms. Far-fetched as it may appear, the link between psychology, perception and semantics does exist. It is mediated on one side by the mind, which is a specificity of human being according to its definition, and on the other side by language, defined by the dictionary as: a) characteristic of human being; b) related to

meaning. Thus the link between psychology, perception and semantics is their relevance for human beings. This is the central hypothesis of the present paper, which investigates how language reveals the structural organisation of perception in the mind, a process that we call mental representation and that is intimately related to meaning. The main argument is that this organisation is based on experimental realism and its definition of categories

The present paper aims at studying the relation between meaning and perception.

2. The concepts

a. Psychophysics

Psychophysics, and more generally scientific psychology, was the first attempt in the second half of the 19th century to introduce into psychology the research paradigms that had proved so successful in natural sciences during the first half of the century (la Motte-Haber 1994). As stated earlier, the definition of the mind in the dictionary does not take position on the debate whether the mind is spiritual or material. We have mentioned the speculative nature of the debate, and this is precisely what the founders of scientific psychology wanted to escape from: following the example of natural sciences, they wanted to escape from speculation and metaphysics, and to found their discipline on the solid ground of experiments. In the wake of the materialist view that was dominating the natural sciences of the time, it was only logical that they took for granted that the mind is material in nature.

i. Reflexology and Behaviorism

Truly speaking, reflexology, Behaviorism and psychophysics were developed on different intellectual backgrounds. Nevertheless, we follow the path traced by la Motte-Haber (1994) and present them together, because they all study the same object and tried to reduce psychological reactions to physical excitations.

The basic assumption common to these approaches is best illustrated by Pavlov's famous dog: after a proper training, the dog's stomach produced gastric acid each time it saw food presented to it. Thus, the dog functioned like a mechanical machine – a black box in more modern scientific terms – which produced a measurable output to some unknown perceptual input, called sensation. In such a system, the inputs to the senses, for example to audition, create sensations that are then processed to yield perceptions.

According to such an assumption, it should become possible to invent a machine – or a computer algorithm – that simulates the human being and give the same results. This approach has achieved some successes, as attest the codecs used in audio transmission nowadays, which are based on psychoacoustic principles and achieve a near-to-perfect bit-rate reduction in the transmission – thus enabling music transmission through Internet, for example. However, such a machine or algorithm is not always easy to develop, for example for food testing or cosmetics, and most often one has to resort to subjective testing: a panel of human subjects, selected for reliability and precision in their judgement, is asked to evaluate a given product subjectively (Bech and Zacharov 2006). In fact, the panel acts as a machine, delivering a measure as its output.

Several techniques have been developed. Commonly used is the semantic differential, introduced by Ogden and Richards (1923) to "reintroduce meaning in psychophysics".

ii. Streams and auditory scene analysis: Bregman

Usually, real sounds, that is, sound from the real world, are not created isolated, but are part of a sound sequence perceived as a whole. Apparently, the first one to realize this property of auditory perception was Bregman (1990) who called auditory streams the perceptual units.

According to Bregman, sounds from the world impinge on the outer ears and are led to the inner ears where they are transformed in a pattern of neural excitations that is very much like a spectrogram. However, sounds from different streams are mixed together in the ears, leading to composite spectrograms that must be deciphered by the brain in order to recognize what belongs to each stream. How the brain achieves this recognition is still an unresolved question.

Bregman's vision of the processes involved by the stream recognition, which he calls auditory scene analysis, is very much impregnated by the psychophysical paradigm. Indeed, it is a bottom-up theory: all information is available in the original signals – the bottom level – and the mind applies some algorithms to the signals at different levels up the processing chain in order to sort out the different streams and recognize them. Bregman even compares this process with language parsing that uses a set of rules to cut a continuous stream of sounds into words. The similarity between auditory scene analysis and linguistics has not escaped his attention, and he invocates Chomsky's generative grammar that tends to explain how meaning is loaded onto a sentence by a large number of rules that form the deep structure of a given language. In a similar fashion, perception amounts to detect the deep structure of the sensory input and build up a description of the regularities – or universal properties – in the world.

A common property of the rules for auditory streaming is their ecological validity. For Bregman, it means that they tend to give the *right* answers about how the auditory stream has probably originated in the external word.

b. Gibson and the ecological approach

In reaction with psychophysics, and under the influence of Gestalt psychology, Gibson (1979) radically rejects the stimulus/response formula and the theory that sensation is necessary for perception. In fact, he casts doubt on the reality of sensation, and explains perception through a radical innovation – though he acknowledges debt to the gestaltists, and specially to Koffka and Lewin: the concept of affordance.

The affordance of an object of the world is what it offers to the perceiver. As stressed by Gibson himself, "it implies that the 'values' and 'meanings' of things in the environment can be directly perceived." But this meaning remains external to the perceiver. The last point is extremely important for Gibson, who takes position in the debate of the nature of mind by rejecting any from of dualism, either mind-matter dualism or mind-body dualism: the main value of psychophysics, he argues in his introduction, is that it "helped to get rid of the doctrine of the soul in psychology". This *a priori* explains the whole endeavour of Gibson to develop a bottom-up theory of meaning; all other theory, he argues with great insight, "come down to this: we can perceive the world only if we already know what there is to be perceived."

Gibson's theory of affordance is built upon the extracting of invariants from a stimulus flux, what he calls information pickup. This is an activity of a perceptual system, and the information thus extracted cannot be communicated. This is because Gibson reacts to the linguistics theories he is aware of, based on classical objective categories that are defined by

their properties. Perception cannot be based on them, because meaningful perception is direct and immediate: there is no time for checking properties! Therefore, his theory of perception reacts against language, as exemplified in his denial that the stream of experience can be divided between present and past: the dichotomy comes from language and the grammatical category of "tense".

c. Language as the central human feature

We have argued that psychophysics transform the human being in a machine that can measure sensations. Experience shows that humans are not very good at it, and jury panels for sensory analysis must be chosen and trained carefully if accurate measurements are to be obtained (Bech and Zacharov 2006). On the other hand, the specificity of human being is to communicate by mean of language. Hence the idea of relying on verbal descriptions when subjects have to communicate their perception.

i. Language is context dependent: Mason et al.

In their assessment of verbal elicitations techniques against nonverbal ones, Mason et al. (2001) have carefully reviewed the major streams of research on language in the Anglo-Saxon world. Referring to Ogden and Richards (1923), they reckon that language can either be used symbolically or emotionally. Focusing on the symbolic use, they argue that the link between words and objects of the world truly is empirical and arbitrary. Therefore, "words should not be treated as adequate pictures of things; they are merely arbitrary signs for certain ideas", as expressed by Loke in 1689. Consistently with this view of language, anomalies occur in verbal communication.

A further argument of Mason et al. against verbal descriptions is the inaccuracy of quantitative perceptual estimates. What they mean is that language is inadequate to separate the physical world into an infinite number of positions on some perceived dimensions. In other words, language is inadequate to measure perception. In fact, there is nothing surprising about that: language has never been designed to measure the world, but to communicate about it. And it is quite successful at it, as proved by the millions of years of evolution that have lead mankind to its present predominant position on earth (Harari 1914).

The conclusion of Mason et al. is that communication, and in particular the use of verbal language, is open to interpretation. Quoting an impressive list of publications on communication and psychology, they argue that the full meaning of a word does not appear until it is placed in context, with the word's meaning changing according to how it is used and even with the situation. This is because their conception of linguistics reduces the use of language to naming objects, or to describing them by a set of adjectives, often imposed upon the subjects by the experimenter. In this respect, their conception of language is very similar to Bregman's conception: they therefore also address the question of truth, that is, of the correct interpretation of an event. This conception, that language is there to describe physical objects and events really present in the world that we human inhabit – as Bregman (1990) puts it – is in opposition with Saussure's general linguistics.

ii. Saussure: language is based on oppositions

Whereas Bregman, Gibson, and Mason et al. are interested in regularities, invariants and universal properties, Saussure (1916) states at the beginning of his posthumous *Cours de linguistique générale* that "language is based on oppositions". This statement has given birth to one of the most fruitful branch of human research of the last century: structuralism.

Since language is based on oppositions, meaning cannot link a word to an object of the world in a unique way, as Mason et al. were hoping. Indeed, meaning needs the two terms of an opposition to reveal itself, and is therefore context dependent: another meaning arises if one of the terms is changed. Greimas (1970) expresses the same idea more strongly: "Meaning springs out of the relation between two terms in an opposition". For him, this is even what perception is about: "We perceives differences, and the world take sense in front of us and for us".

Language cannot, therefore, be reduced to a list of labels corresponding to objects; nor to a list of properties attached to objects. Indeed, artists have known for a long time the comic effect of lists of words, as attested by Rabelais in his "Gargantua" and "Pantagruel". Verbal communication cannot be reduced to an analysis of the words used, but includes the relationships between these words such as grammatical categories. As will be seen later in Section 4, much meaning can be derived from these relationships.

d. Categorisation

Central to the way the world makes sense to us is categorization. Indeed, sorting out object is the basis of the scientific approach (Latour 1993). But our understanding of categories has considerably evolved in recent years, due to the introduction of the experimental method in cognitive sciences.

i. Aristotle, Kant and the speculative approach

The classical theory of categories is based on the presence of properties that are shared by all members of the category. More precisely, the Webster dictionary defines a *category* as "a classificatory division in any field of knowledge", and further refers to its metaphysical meaning according to Aristotle and Kant. Thus, in Aristotelian philosophy, a category is "any of the fundamental modes of existence, such as substance, quality and quantity, as determined by analysis of the different kinds of predication"; whereas in Kantian philosophy, it is "any of the fundamental principles of understanding, as the principle of causation". More generally, metaphysics defines a category as "any classification of terms that is ultimate and not susceptible to further analysis".

In the second half of the 20th century, evidences, most of them of experimental nature, have gradually weakened the classical definition of categories. They showed that most categories used by human being are not based on common properties, but rather on concepts such as similarities and dissimilarities. Such concepts are also basic to the definition of languages (Hjemslev 1943).

ii. Rosch, Lakoff, and the experimental realism

According to Lakoff (1987), Rosch was the first to provide a unified view of the experimental evidences that, in everyday life, categories are not based on common properties. For her, categories experimentally constructed by human beings are based on the notion of prototype. For each category, such as *birds* or *trees*, there exist elements that better represent the category than others: *robin* for *birds*; or *oak* for *trees*. Many experiments prove it: for example, when asking a group of subjects to list the elements of a given category, some elements are more often listed than others. Further, she extended the finding that there exists a *basic level* at which most of our knowledge is organized: it is characterized, among others, by short names, first acquisition by children, fast identification, and similarly perceived shapes. Rosch (1987) attributes this organization to two principles: cognitive economy, and perceived world structure. "The perceived world is not an unstructured total set of equiprobable co-

occurring attributes", and for example, "wings co-occur with feathers more than with fur". This is why Lakoff calls this theory for *experimental realism*.

The "prototype theory" and its principles call for three remarks. The first one concerns the principle of cognitive economy, that Hjemslev in his *Prolegomena* also considers as one of the principles on which the theory of language rests. The second remark concerns the construction of categories around similarities: this makes it possible to build categories with "free sorting tasks", where subject must group together objects according to their similarities, and separate objects that are dissimilar. It is strongly reminiscent of Saussure's statement: "language is based on oppositions". The third remark concerns the insistence on perception in Rosch's work, which confirms the relationship that Greimas (1970) introduced between perception and the meaning of the wold.

Lakoff develops further Rosch's theory to address such concepts as *meaning*, *truth* and *knowledge*. He states that "Basic-level concepts are meaningful to us because they are characterized by the way we perceive the overall shape of things […] and by the way we interact with things with our bodies". In other words, "they are directly meaningful because they put us in touch with preconceptual structures in our bodily experience of functioning in the world. It is because *the body is in the mind*" (Lakoff's Italics). This pre-existence of the meaning is reminiscent of Gibson's position, just as the rejection of the mind-body dualism. Lakoff remains within the psychophysical tradition of the material mind. As for truth, it becomes relative, a measure of how well a statement "fits the preconceptual structure of experience", and knowledge is "closely related to basic-level experience". In other words, Lakoff shares our central hypothesis that mental representations, in other words knowledge, are intimately related to meaning, as stated in the Introduction.

e. Greimas and structural semantics

Greimas (1970) has developed Saussure's hypothesis that language is based on opposition, and derived from it a synthesis between categorization and language theories that explains how "meaning springs out of the relation between two terms in an opposition".

i. Elementary structure of meaning

The basic brick in Greimas's semantic theory is the semiotic square, or elementary structure of meaning (Figure 1). It is constructed around an *opposition* between two contrary signs S_1 and S_2 on the upper line; and is completed by introducing a new opposition between *Non* S_1 and *Non* S_2 on the lower line. Further relationships are:

- *contradictions* between two contradictory signs on diagonal lines
- *implications* between two complementary signs on vertical lines, but orientated from bottom to top.

S_1 is arbitrarily considered positive and S_2 arbitrarily considered negative, $S = (S_1 + S_2)$ is the complex axis, and *Non* $S = (neither\ S_1\ nor\ S_2)$ is the neutral axis. The construction of a semiotic square proceeds from the upper opposition to the construction of *Non* S_1, then to the construction of *Non* S_2, in this order.

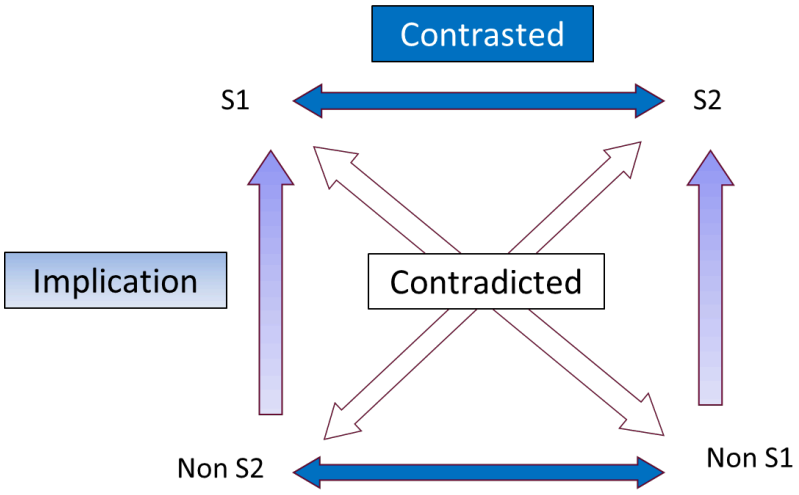

Figure 1: the semiotic square (from Taupin 2017).

ii. Actantial model

The second brick in Greimas's semantic theory is the actantial model (Figure 2). It was developed from Propp (1928)'s *Morphology of the tale*. It stages six *actants* distributed on three oppositions, each defining a specific axis:

- The *quest* (or *desire*) axis opposes the *subject* (or hero) to the *object* (of the quest);
- The *transmission* axis opposes the *sender*, who initiated the quest, to the *receiver*, whom the quest is realized for.
- The *power* axis opposes the *helper*, who helps the subject to obtain the object, to the *opponent.*

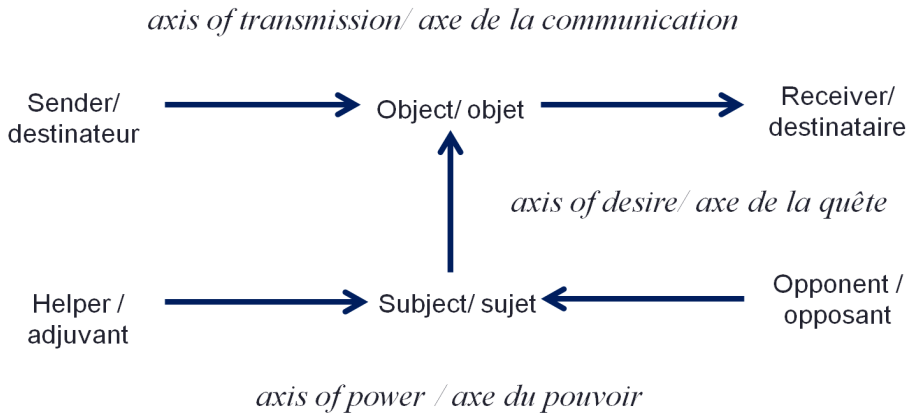

Figure 2: the actantial model (from Taupin 2017).

The sender is a superior authority that fixes the value of the object. This value is transmitted to the hero, who becomes both receiver and subject, and goes on the quest. The last two actants either help the subject to, or prevent the subject from getting the object. During the quest, the subject must acquire qualities/skills through the *qualifying* test. Then follows the *decisive* test, where the subject acquires the object, and the *glorifying* test, where the sender rewards or punishes the subject. The three tests are integral parts of the quest.

It should be noted that actants are not the characters of a story, but correspond to structural roles played in turn by the characters. For example, Fontanille (2004) considers affordance as

a *potentiality* offered by an actant: it needs a test, usually the qualifying test, to become actualized.

3. Methodology

The methodology that was specifically developed for our research on sound perception is therefore based on three concepts: categorization, ecological validity, and the role of the instructions given to the test subjects.

a. Categorization

Due to the intimate link between knowledge and categories, categorization is the central element of our methodology. A series of techniques associated to categorization in the literature, from free sorting to structural analysis, were adapted to sound perception. They all make use of the fact that human beings group objects at the basic level, and that language also function at the basic level.

If meaning does reflect the perceived structure of the world through basic-level concepts, as explained in Sec. 2.d, then listeners perceive the sound in the world at the basic level, and should be able to describe it with few words. Thus, asking test persons to sort out different sound sequences according to some given similarity leads to their mental representations, that is, to the way they organize their knowledge; then they are asked to describe each group with their own words. As precise labels are often missing for describing sounds (Dubois 2000), it is necessary to compare the groupings made by several listeners and their verbal descriptions in order to attain some generality. In fact, experience shows that the mean groupings stabilize with 20 or more subjects.

Another method is based on content analysis, modified in order to take into account Saussure's statement that language does not reduce to a list of nouns, nor to a list of nominal phrases. It also consists of verbs, adjectives, and pronouns, not to speak of modalities, all of which nuance the meaning that language conveys. Proper linguistic analysis must make use of all these aspects if sound quality and its implications for the listeners are to be evaluated (David 1997, Dubois 2009). A variant applies to drawings and pictures, by listing the represented objects and their spatial organization.

More recently, we have applied Greimas's analysis to narratives obtained from test persons who were describing their collages about imaginary urban environments. In most cases, the full actantial model was retrieved, including the quest and the three tests (Taupin 2017).

b. Ecological validity

In some experiences, the subjects were interviewed in real environments. But in most cases, soundscapes were recorded and replayed in a specifically designed listening room. Indeed, free sorting is not possible in real environments, as one cannot superpose different soundscapes, and therefore requires the artificial environment of a listening room.

Great care was given to the design of the room, which was as damped as possible, and to the design of the recording and playback systems. What was aimed at was not the accurate reproduction of the sound field as measured outside in the world, but accurate reproduction of the perception and meaning of the soundscapes, so that the subjects describe the sound scenes with the same words as in the real world, and react to the sound scenes as in the real world.

Following Gibson, we call *ecological validity* such an accurate reproduction of the world (Maffiolo 1999, Vogel 1999).

Intensive recording tests carried out by Maffiolo and Vogel led to using a stereophonic recording system similar to the ORTF stereo microphone system, except that the microphones were spaced more widely apart (0.9m in general). This system allows accurate identification of the sound sources, and to smooth reproduction of moving sources such as cars passing by. However, it does not reproduce background noise accurately (Guastavino et al. 2005), and 1st order Ambisonics recording, played back on 12 loudspeakers distributed evenly in space, was later used in complement.

The choice of stereophonic recording was made both for practical and cognitive reasons. First of all, stereophonic playback is straightforward and does not need sophisticated decoding as for artificial head. But most of all, stereophony can be considered as basic-level, in the sense of Rosch, since all listeners are used to it and "naturally" understand the sound field it reproduces. This is not the case for artificial head recordings, which very often create front-back confusion, and were therefore discarded.

c. The role of instructions

No attempt was made to record the associated visual scenes. More generally, the question arises how to compensate for the missing context.

Sound scene is not an object per se, but takes place in the middle of a series of events – in a narrative – which helps giving it its meaning. The missing part of the narrative must therefore be replaced, and that is just what the instructions to the listeners do. As a consequence, their wording must be designed with care, and must sound similar to real world experience if the reactions of the subjects are to be meaningful – that is, similar to real life reactions. We therefore insist on accurate transcription of the instructions in the description of listening tests.

A similar question arises when one wants to obtain narratives. Taupin (2017) opted for the technique of projective collages that frees the subjects from the constraints of language and increases their creativity.

4. Examples

We now present a few selected examples among the different tests that were carried out. They are not intended to exhaustively present all the results obtained, but rather to illustrate the methodology and the underlying concepts.

a. Free categories

i. *Cluster analysis*

30 subjects were asked to group 16 sound sequences according to loudness similarity. From the grouping, distances were computed, based on the general principle that short distances between two sequences correspond to their frequent grouping, and long distances to their rare grouping. From these distances, a tree is computed with an algorithm based on Tversky's analysis (Poitevineau et al. 2002), or more classical factor analysis is performed. The two analysis basically gives the same results, but we prefer the tree representation since it fits on one plane by construction. Details of the analysis are given in Maffiolo (1999).

According to Tversky, distances on the tree are measured by adding together the lengths of the branches that link 2 different leaves. Leaves are the outer extremities of the branches and correspond to the different sound sequences. Where branches meet at their inner extremities correspond to classes: they represent the mean grouping of sequences by the subjects.

In Figure 3, the numbers in the circles or squares refer to the leaves. The underlined numbers next to the leaves gives the mean loudness levels of the sound sequences, measured in dBA. It should be noticed that the groupings do not always correspond to similar levels: for example, the loudest sequences, 10 and 13, are not grouped together; nor are sequences 11 and 14, despite very similar loudness. In fact, the most salient feature in Figure 3 is the separation of sequences in squares – top of the tree – from sequences in circles – bottom of the tree: they correspond respectively to "event sequences", where something happens that can be named and described, and "amorphous sequences", where nothing happens. Thus, even when asked to focus on loudness, subjects cannot help blending signification to their judgements, leading to a sharp discrimination between the two types of sequences. The salience of signification was further confirmed by repeating the test with sound sequences equalized in level, leading to much the same groupings (Maffiolo 1999).

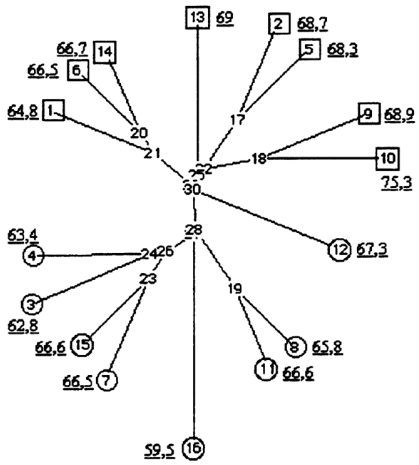

Figure 3: additive tree for loudness similarity; figures indicate loudness level in dBA, square indicate event sequences and circles amorphous sequences (from Maffiolo 1999).

Factor analysis (Figure 4) confirms the discrimination, with amorphous sequences on the negative side of Factor 1 and event sequences on the positive side – with the exception of amorphous sequence 12, which also appears on the wrong side of the tree in Figure 4. Notice, as stated before, the visual superiority of the tree as compared to factor analysis, since it discriminates the groups – or clusters – in two dimensions only whereas three dimensions are necessary to discriminate all the clusters in factor analysis (e.g. Cluster 3-4 from Cluster 7-15).

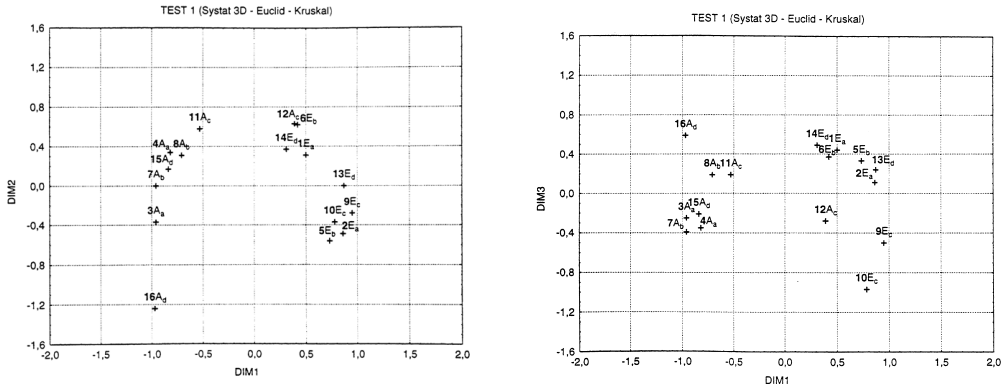

Figure 4: factor analysis of Figure 3; amorphous sequences are on the left, and event sequences on the right (from Maffiolo 1999).

ii. Verbalisation

The verbalisations that subjects associate with classes give access to their mental representations. Therefore, when they were finished with the grouping task, subjects were asked to qualify each group with their own words. Thus, no constraint on the vocabulary was imposed on them.

Figure 5 present some results of the verbalisation task. 3 classes are qualified, using the most common descriptors associated with the elements of the classes. We have graphically distinguished between: physical properties, written in Italics; and sound events, sources and activities, written in normal characters. As shown in Figure 5, physical properties are mostly associated with amorphous sequences – numbers in circles – and sound events, sources and activities with event sequences – numbers in squares. A more rigorous analysis of all the verbalisations associated with loudness similarity confirms this finding: 22.1% of all verbalisations concerning amorphous sequences relate to physical properties, whereas 15.3% relate to sound events, sources and activities; the proportion is almost reverse for event sequences, with 22.9% of verbalisations related to sound events, sources and activities, and only 15.3% to physical properties.

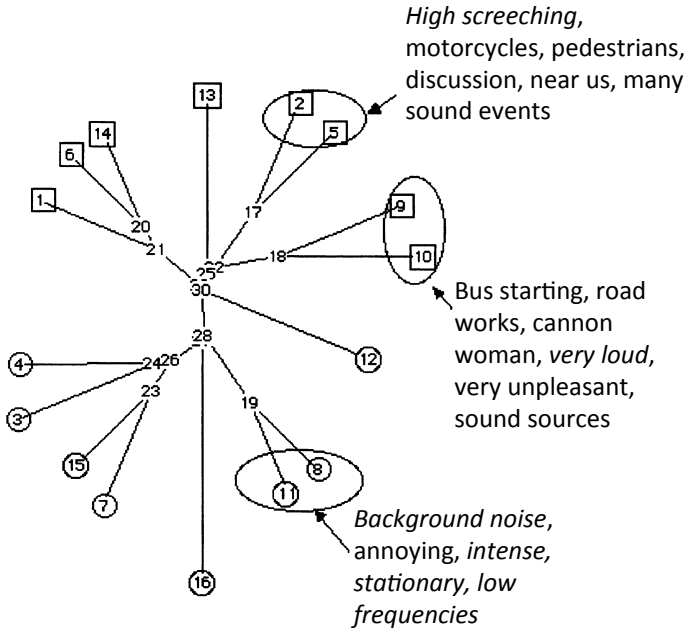

Figure 5: verbalisations associated to the main groups (from Maffiolo 1999).

In conclusion, free categorisation and its associated verbalisation deliver information on how knowledge about sound sequences is organized in the mind: the organisation respects the meaning of the sequences. A further lesson from free categorisation is that loudness is not organized in the mind along a dimension, but is rather as property of the sequences.

b. Semantic categories

An alternative to free categorisation is the use of open questionnaires.

i. *Analysing open questionnaires*

In several commercial trains run by the French Railways (SNCF), open questionnaires were distributed to a few hundred passengers. Beside the usual questions on their age, journey, etc., the questionnaire asked questions about comfort in general, then focused on acoustical comfort. Common to all these questions was the fact that passengers were asked to answer in their own words. Details of the survey are given in Mzali (2002).

The first surprise was that passengers were eager to reply. Nearly all of the 300 questionnaires distributed were answered, leading to some thousands of verbalisations that had to be analysed. The first task was to retype all responses in worksheet format, which took a few weeks. When this was done, 3 persons read the answer and independently constructed the grid of categories for the analysis. For example, the noises heard inside the carriages were filtered in the following categories: announcements, mobile phones, other people, newspapers, doors, rolling noise. Thus the categories are not imposed *a priori* on the subjects, as is the case for close questionnaires, but derived *a posteriori* from the responses of the subjects.

The analysis rests on simple statistics. For each response, the counters of the relevant categories are incremented by one if the response mentions an element of the category. Then, the counters are translated in percentages of the number of responses. In some cases, more specific linguistic analysis is carried out, that takes into account linguistic features such as person marks, modal verbs, etc. An example is provided below, but interested readers are referred to David (1997).

At this point, it is necessary to insist again on the extreme importance of the wording of the questionnaires. Indeed, questions often ask about specific situations that are not always experiences by the subjects while they reply. Thus, wording must set the subjects in the right context. Wording is therefore specific of a given language and not easily translated into another.

As an example, Table 1 presents part of the semantic analysis of the 23 first responses to the question: “what can you say of the noises related to the running of the train (low pitch, high pitch, brilliant, enveloping)? Give a description.” Only *objective descriptions* (DO) is presented, amongst which the category *judgement* is displayed in Table 2. Notice that the words selected for the lowest level of the category, such as “hypnotizing” or “overwhelming” (*abrutissant*), are extracted from the subjects’ responses. A closer analysis of these words shows that they can be grouped into negative and neutral judgements, as displayed in Table 2, leading to the taxonomy of Figure 6 for the judgement of noises related to the running of trains. This taxonomy strongly reminds of the folk taxonomies analysed by Greimas (1970). Also notice that it mostly uses the basic level, that is, single words.

Table1: semantic analysis of question "what can you say of the noises related to the running of the train (low pitch, high pitch, brilliant, enveloping)? Give a description." (from Mzali 2002).

sujet	Comment vous paraissent les bruits liés à la marche du train (graves, aigus, brillants, enveloppants	DO	Jugement	Sources
101	Graves surtout quand ils sont liés à des vibrations. Le bruit de fond est hypnotisant.	1	1	
102	Les bruits sont en effet constants, enveloppants, variés selon les virages ou selon l'air ambiant certa	1		
103	Aigus. Sifflement au niveau des oreilles.	1		
105	C'est usant, abrutissant.		1	
106	Par exemple dans les tunnels: on sent que les oreilles se bouchent. Il y a une différence entre une perso		1	1
108	Graves et enveloppants.	1		
109	Assez intenses et plutôt aigus.	1		
110	Graves et sourds.	1		
111	Enveloppants.	1		
112	Enveloppants, récurrents et fatiguants.	1		
113	Ils sont graves et enveloppants.	1		
114	Enveloppants.	1		
115	Souvent enveloppants, souvent bruyant légèrement en bas.	1		
116	Enveloppants.	1		
118	Sous le tunnel aigus.	1		1
119	Bruits graves et enveloppants avec un petit sifflement qui au bout de quelques temps vous donne n	1	1	
120	Graves en bruits de fond, aigus précisément. Prenants. Bouchant les oreilles.	1		
121	Grave -> bourdonnement. Aigu -> sorte de chuintement.	1		
122	Ils sont plutôt graves. Un seul sifflement (des roulements) est aigu mais assourdit. je me sens entou	1		
123	Ronronnement. Augmentation avec la vitesse.	1		1
	Total	55	15	8

Table 2: results for category "judgement" (from Mzali 2002).

Positif	Négatif	Neutre		Abrutissant	Etouffant	Hypnotisant	Malaise	Oreilles		Abstraction	Pas forcément désagréable
	1					1					
	1							1			
	1			1							
	2				1			1			
	1			1							
	1						1				
	2			1				1			
		1									1
0	19	7	0	6	1	4	3	5	0	3	2

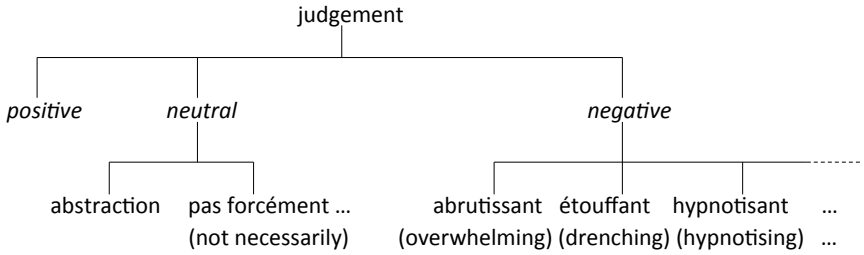

Figure 6: taxonomy for the judgement of noises related to the running of trains (from Mzali 2002).

ii. The semantics of "pleasantness"

In an attempt to better understand the meaning of pleasantness, one question of the same survey (Mzali 2002) asked the subjects to list in their own words the noises they noticed during their journey, and distribute them among 4 classes that were proposed to them: pleasant, unpleasant, annoying, and indifferent. From the responses listed by the subjects, 4 categories were extracted, using the same technique as in the preceding section. The distribution of the responses is presented in Figure 7, where the original French labels for the classes are also given. We shall see shortly the importance of referring to the French labels, which illustrates that wording is specific to a given language.

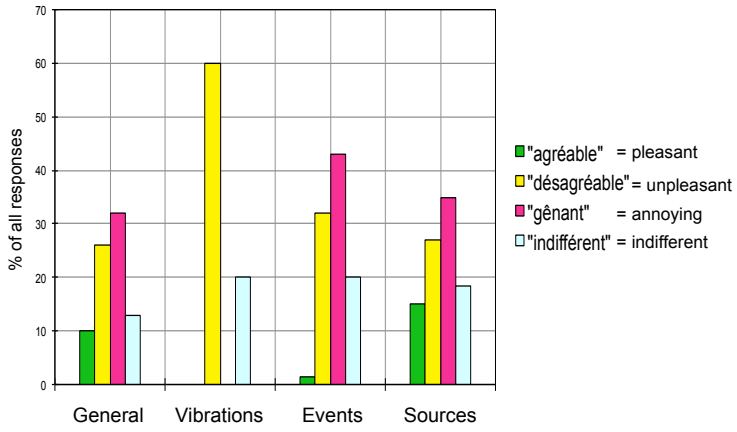

Figure 7: semantics of "pleasantness" (from Mzali 2002).

The 4 categories extracted are: general impression; vibrations and movements; events, that is, tunnels, junctions, train crossing, etc.; and sources. The percentage of responses corresponds to the percentage of subjects that gave responses belonging to each of the categories – the total does not add up to 100 – and the responses are further differentiated according to the 4 classes of noises.

Figure 7 reveals that vibrations are "unpleasant", whereas events and sources are more "annoying" than "unpleasant". A specific linguistic analysis further reveals that "annoying" (French "gênant") is linked to the other train users, with phrases such as "people talking loud", "chats" and "other travellers" listed for sources; and "unpleasant" (French "désagréable") is linked to the functioning of the train, with phrases such as "automatic doors" or "door opening (compressed air)". In fact, *doors* have an ambivalent status: they become "annoying" when activated by other train users, with phrases such as "door opening when people pass by". This semantics of "unpleasantness", which was confirmed by another study (Dubois et al. 1998), can be deduced from the linguistic material used to described the classes: "annoying" (French "gênant") is a gerund, a verbal form that implies an action,

usually made by someone; but “unpleasant” (French “désagréable”) is an adjective constructed on a verb (deverbal adjective), only implying an effect on the test person.

c. Prototypical categories

In accordance with the prototype theory of categorization, prototypes are the most often listed elements by a group of subjects asked to list the elements of a given category. Following the same idea, it should be possible to find out the prototypes of alarms by asking many subjects to name them as they recognize them in a sound sequence.

i. Prototypes of alarms

30 subjects listened to sound sequences where alarm signals were superposed. Three types of contexts were used: traffic noise; noise recorded in a park; and no background at all. Subjects were asked to stop the sequence as soon as they could hear an alarm signal, then to name it. Details are given in Vogel (1999).

Incidentally, constructing the sound sequences was not trivial. Signals cannot be inserted at random in the background noise, otherwise the sequences sound artificial and the signal is easily detected, as informal listening proved it. They had to be inserted at an appropriate place in the sequence, which were all event sequences (Sec. 4.a), in order to respect the meaning of the sequence. In other words, event sequences “tell” something to the listeners. This irruption of narratives in soundscape (Greimas 1970) was not further investigated.

The hypothesis underlying the test is that subjects more often quote prototypes of alarms because they are more readily available in memory (Sec. 2.d). Besides, they are designated by one word only (basic level). The results of the test are presented in Figure 8 for the three contexts. Occurrences are given as absolute values: how many times subjects have used each label. One first notice that subjects have mostly used sources to label the alarms, confirming the previous analyses; and that labels consisting of one word only are more frequent in context (traffic and parks), confirming the hypotheses – one word is more available than several, especially when the mind is busy analysing the context.

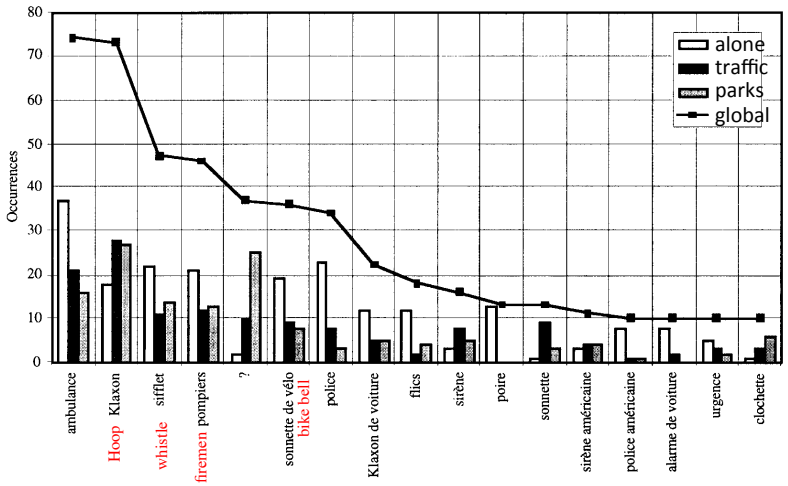

Figure 8: most frequent labels after listening to alarm signals (from Vogel 1999)

As in Sec. 4.a, labels were sorted out in two classes: physical properties; and interpreted sources. Figure 9 presents the distribution of the two classes according to context: mean values across all subjects are plotted together with their standard deviations. Even though the

standard deviation increases in contexts, the trend remains clear: sources are less frequently used in contexts, and physical properties more frequently. Nevertheless, sources dominate, in accordance with the fact that contexts were event sequences.

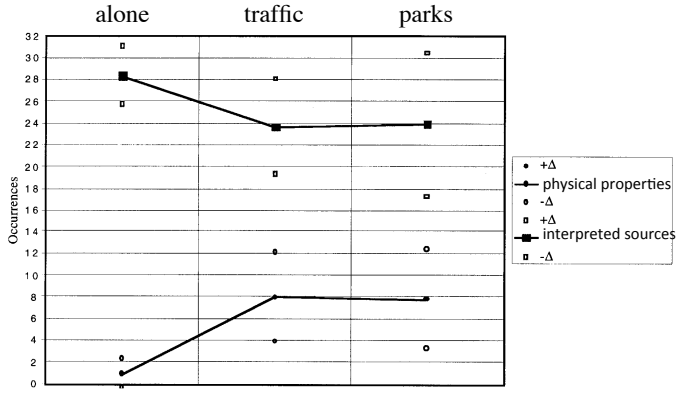

Figure 9: influence of context on labelling strategy (from Vogel 1999).

As in Sec. 4.a, physical properties in Figure 9 represent acoustical descriptions of the signals in term of pitch, loudness, etc. But it also includes imitations of the signals, such as "wah-wah". Inevitably, the question of whether an imitation is a physical property or an interpreted source arises: by considering them as a physical property, we have followed the linguistic tradition that analyse phonetic transcriptions, such as "rap-rap" and "honk-honk", at the acoustical level. However, assuming that imitations are interpreted sources – an assumption that would better fit the fact that they are more quickly available in memory – only marginally changes the distribution, confirming the validity of the analysis.

Last but not least, for each label, a prototype can be associated as the alarm signal most often designated by the label. This is demonstrated in Figure 10 for the labels "ambulance" and "SAMU" – an emergency service run by public hospitals in France. It can be seen that signal 3, the new electronic signal for ambulances in France, is prototype for "ambulance" since a majority of subjects associate them together. But the identification dramatically drops in contexts, although it remains the most often associated signal. On the other hand, the former mechanical signal for ambulance is not identified in contexts, where signals such as the former police signal, the fire brigade, and hoops are often taken for "ambulances", especially in traffic noise. In fact, this confusion is basic in traffic, since subjects know that they must give way to ambulances, police and firemen: the precise identification is therefore superfluous.

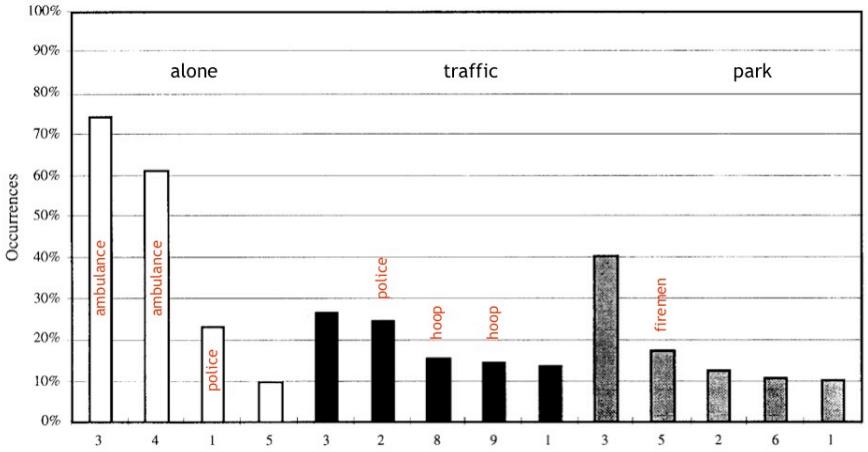

Figure 10: prototypes associated with labels "ambulance" and "S.A.M.U." (from Vogel 1999).

d. Graphic categories

i. Drawing sound

30 subjects were asked to draw the sonorous Paris ("dessiner le Paris sonore"). Analysis of the drawings by Maffiolo et al. (1997) revealed 4 categories, which are represented in Figure 11. 13% of the subjects drew abstract schemata (top left in Figure 11), which are idiosyncratic inasmuch as they only bear meaning for one person – the person who drew them. 20% drew maps of Paris (bottom left), a stereotype that corresponds to a learned representation shared by all members of a given group. 23% drew organized sources (top right in Figure 11), often in a specific location as in the example, but also in generic locations. And 50% drew unorganized sources (bottom right), side by side and without location. The total exceeds 100% since some subjects used several strategies.

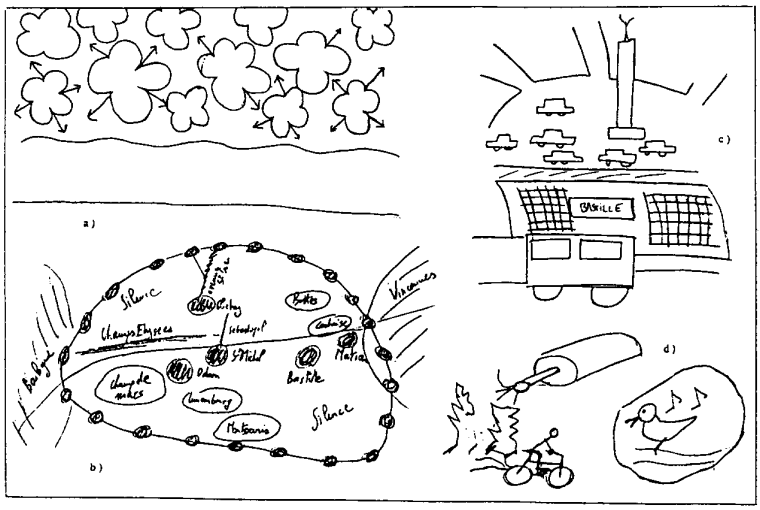

Figure 11: drawing the sonorous Paris (from Maffiolo et al. 1997).

The analysis reveals that a majority of subjects drew sources, a finding which is in agreement with the Sec. 4.a. A deeper analysis is however difficult to carry out, except in the case of organized sources in a specific location: the drawing specifies the point of view of the subject. Indeed, in the example on top right of Figure 10, it is obvious that the subject is standing on the platform of the metro station that is located below Place de la Bastille in Paris.

ii. An artist's point of view

The experiment with graphic categories can be extrapolated to analyse artists' representations of the world. An example is given in Figure 12 which is an artist's view of the research done in our laboratory on urban soundscapes: an artist organizes sound sources in a generic location, using the title (bottom left of Figure 12) to explain what it is about – that is, the general meaning of the picture. Indeed, once we know that the picture represents the sounds of the city ("Bruits de la ville") and that LAM, our research team, mainly study music instruments, the story told by the picture becomes obvious: people at LAM record urban soundscape to replay it later! We shall not develop further the analysis, which involves narrative analysis in order to describe the picture. But central in the picture is the score on which the two researchers on the right write out the quest for the sounds of the city.

Figure 12: an artist's view of the sounds of the city (J.M. Galmiche)

The same analysis has been applied to other pictures, such as used in pamphlets, and has revealed the artists' point of view.

e. Actantial categories

So far, we were not able to obtain narrative nor to apply the actantial model. There needs a trigger to obtain narrative, as for example Figure 12. Taupin (2017) developed this technique on a larger scale, using projective collages.

40 students from Tongji University in Shanghai were first offered a warm-up session consisting in free word associations and commenting pictures of cities unknown to them. It aimed at opening their mind and freeing their feelings about exploring urban scenery. They were then divided in groups of one or two persons, and each group had a pile of Chinese lifestyle, sport and news magazines, the same for each group, from which they could cut whatever seemed appropriate to them. The instructions were to realize a collage depicting the ideal imaginary city to drive in, using drawings or pictures from the magazines pasted on a white paperboard. There were no constraints to the content in the picture. When the collages were ready, they had to write some comments on their board, then present it to the other participants. The oral presentations were recorded and transcribed, then word-for-word translated into French for analysis purposes.

Figure 13 presents an example of the collages thus obtained, and of the corresponding oral presentation. Surprisingly, they all consisted in narratives that can be analysed according to the actantial model. Most of the narratives, such as the one corresponding to Figure 13, present a complete actantial structure, with the three tests of the quest. Very surprizing was that the helper usually consists of the traditional Chinese elements (*wǔxíng*). The corresponding actantial model is given in Figure 14. This confirms that narrative structures are invariant across cultures, but stresses the importance of traditional elements for wellbeing.

Figure 13: "My healthy life", one of the collages obtained (Taupin 2017).

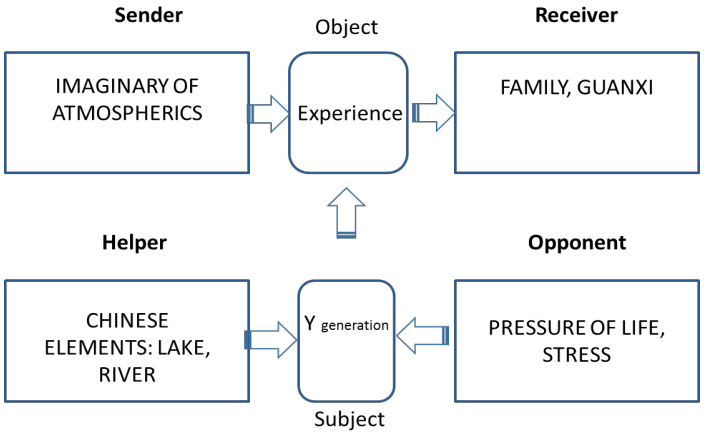

Figure 14: the actantial structure of "My healthy life" (from Taupin 2017).

The technique is currently under development in Korea and in France, with focus on imaginary soundscapes (Jeon and Polack, 2018). The same narrative structure has been found, with a similar emphasis on the helper role of the elements, but with a weaker test structure.

5. Discussion

i. Focusing on the human subject

Cognitive psychology focuses on the human subject, as operating the link between perception and meaning (Dubois, 2000).

Indeed, the human subject sits in the centre of the world outside-there, where she/he is living and where she/he is a member of a group. In the world exist sound signals; and in the group, sound belongs to a collective representation. Thus the human being, living in the world, perceives the signals of the world; however, she/he perceives *relevant* signals only, that is, signals that are relevant to the collective representation of his group mediated through a common language. This is because, as part of a group, the human being talks and communicates with the group in a *meaningful* manner, that is, in a manner that corresponds to the collective representation of the group – and to the basic-level of categorization. Thus, central in our theory of perception is the fact that perception is related to the collective representations of the group which the subject belong to: the key to understanding perception resides in meaningful communication between the human beings belonging to the same group

and using the same set of representations, as fixed by the language (the same set of words). Therefore, linguistics is the key to understanding perception.

ii. Mental representations and verbal descriptions

Mental representations were used by Bregman (1990) in a manner that he does not fully define. It implies the possibility to calculate appropriate plans and actions on it. It also implies the possibility of mental description. In fact, a stream is a mental representation of a sound, or rather of several sounds belonging to the same event.

Central in the mental representation of Bregman is the verbal description of an acoustic event: it clusters words around the auditory units. In the examples given by Bregman, the auditory units are reduced to a sound and the verbal descriptions mostly correspond to physical descriptions of the sound. This is in agreement with our concept of mental representation, but only with half of it: the semantics of "sound" as opposed to "noises"; and the verbalisation of "amorphous sequences" as opposed to "event sequences". Nevertheless, when confronted to events belonging to the same category, subjects naturally resort to physical description to compare them (Vogel 1999).

Bregman's concept of mental representations also includes mental schemas: each schema incorporates information about one particular regularity of our environment. However, schemas are learned and often employ attention, as is attested by expressions such as "listening for". For example, when we are listening carefully for our name being called among many others in a list, we are employing a schema for our name. More generally, Bregman believes that schemas play a central role in the understanding of language, a situations that is strongly reminiscent of Greimas's *semes* (originally called *sémènes* in Greimas 1970). However, schemas are activated, just as neural fibres are, whereas *semes* are parsed unto a sentence, using a top-down approach that proceeds from general to particular meaning: in other words, we cannot understand a sentence if we do not know before hand what it is about, a situation which we sometimes experience when we are addressed without notice in a foreign language.

Bregman's "mental representations", therefore, do not reduce to the concept of "collective representation" which we used in Sect. 5.i and which was introduced by Durkheim (1898). According to Durkheim, collective representations reside in the mind where they acquire both reality and necessity, although they can be pure fictions. In fact, according to Durkheim (1998), the mind is constituted of the present and past representations. In this sense, collective representations are mental representations, they are part of the memory, and therefore represent the collective knowledge of a group. Moreover, for Durkheim, representations imply similarities and differences, which are the basis of Rosch's basic-level categorisation (Sect. 2.d.i) and of Greimas's structural semantics (under the name of *opposition*, Sect. 2.e.i). Durkheim's definition of representation, more precisely of collective representation, is therefore equivalent to our own definition of a mental representation.

iii. Mental images, affordance and meaning

The psychophysical view on perception makes use of the concept of mental image. A mental image is a projection of the world outside-there on the mind, similar to the image of the world created on the retina of the eye by the lens. The assumption is that the image is transmitted by the neurons all the way to the brain. The ecological approach of Gibson (1979) was constructed as a reaction against the concept of mental image since it strongly opposes the idea that visual perception has to do with an image created on the retina by the lens.

We have argued that Gibson was also reacting to the linguistics theory of his time he was aware of. Indeed, it is amazing that such an acute mind as Gibson has constructed a whole theory of information pickup on the concept of "invariant". Had he be more trained on linguistics, he would have realized that the word "invariant" is a verbal construct, the negation of "variant" (*Non variant* with Greimas's notations). Thus, from a linguistic point of view, "variant", that is, "differences", are more fundamental than "invariant". Unknowingly, Gibson supports Greimas's semiotic approach, which we endorse. According to Greimas, who follows the structural tradition inaugurated by Saussure (1916), meaning is based on oppositions: Greimas's "meaning springs out of the relation between two terms in an opposition" echoes Saussure's "language is based on oppositions". Thus, meaning is present in the mind of the subjects, and only springs out when they perceive differences. This top-down approach is indeed very different from the bottom-up approach of Gibson, for whom affordance is a property of the objects in the world that is perceived with the object by the subjects.

In possession or a more elaborate theory, one cannot help asking Gibson naively where the affordance is hidden in the object. Gibson has, indeed, carefully avoided the question. In our opinion, Fontanille (2004) gave the ultimate answer, linking the ecological approach to structural semantics: affordance is a *potentiality* offered by an actant (Sect. 2.e.ii).

iv. "Language is not a nomenclature"

A key concept in Saussure's linguistics, the fact that language cannot be reduced to a list of labels has escaped the attention of many psychologists who do not take Saussure's linguistics seriously. This is particularly the case in the Anglo-Saxon world, which follows Ogden and Richards 1923's interpretation of the semantic triangle (Figure 15). Though attested since Aristotle in the European philosophical tradition, where the link between symbols and objects is taken for conventional and mediated through the concept (Rastier, 2008), Ogden and Richards argue that the convention has the value of *truth* in a given language. Thus, the symbol and the object it represents are equivalent, leading to the concept of "veridical label": words *are* what they symbolize. Thus, the teaching of Saussure, that is, the difference between signifier and signified (*signifiant*/*signifié*) is denied. This is, for example, the position of Bregman who writes that the regularities in the world tend to give the *right* answers about how a visual image has probably originated in the external world (our italics). This is *not* our position: we believe, and we hope to have illustrated it in Sec. 4.b, that language is far more than a list of words, and that the meaning of the world can be "read" in the thickness of language, that is, in the difference between signifier and signified.

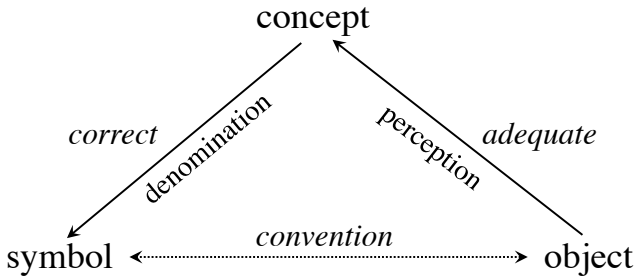

Figure 15: the semantic triangle (after Rastier 2008).

Lakoff (1987) and Mason et al. (2001) also raise the question of truth. Lakoff explains it through the adequacy of the basic level to the perceived world; Mason et al. give arguments

against it. They also give arguments against the possibility of naming objects with precision. As for Greimas, truth only gets meaning when opposed to a contrary sign, such as *lie* or *falsity*.

6. Conclusion

Throughout this paper, we hope to have convinced the reader that, beyond the traditional approach of psychophysics that holds language for inadequate to quantify perception, there is room for a more cognitive approach that makes fully use of some of the most recent achievements of linguistics and cognitive sciences. The main message form this paper is therefore *the usefulness of verbalisations* in experimental psychology, provided that language is not reduced to a set of labels but that its full power, including all its morphological categories such as nouns, verbs and adjectives, but also tenses and modalities, are taken into account in order to get access to the positioning of the test subject with respect to her/his perception and its qualification. Indeed, when language is taken seriously, *verbalisations give access to the mental representations* of the listeners, that is, to the organisation of knowledge about the sound of the world. This is always the case with direct perception of the world, as language categories correspond to the structure of the world as perceived by human being – the so-called basic-level. As for reproduced soundscapes, the recording and reproduction system must respect this perceived structure of the world, that is, must respect *ecological validity*. In other words, *meaning is linked to the structure of the world* as described by common-sense categories, which are basic level. Thus, central to any theory of perception is basic-level categorization, based on similarities and differences from which meaning springs out. Paraphrasing Lakoff, we are tempted to conclude that *the mind is in the language*.

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